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A Monetary Policy Model Without Money for India

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Abstract

A New Keynesian model estimated for India yields valuable insights. Aggregate demand reacts to interest rate changes with a lag of at least three quarters, with inflation taking seven quarters to respond. Inflation is inertial and persistent when it sets in, irrespective of the source. Exchange rate pass-through to domestic inflation is low. Inflation turns out to be the dominant focus of monetary policy, accompanied by a strong commitment to the stabilization of output. Recent policy actions have raised the effective policy rate, but the estimated neutral policy rate suggests some further tightening to normalize the policy stance.

JEL Classification Numbers: E31; E32; E52; E58; F41

Keywords: Exchange Rate Pass-through, India, IS Curve, Monetary Policy, Monetary Transmission, Neutral Interest Rate, New Keynesian Model, Phillips Curve

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"The best advice about money is not to talk about it... […] it exists not by nature but by law. And it is in our power to change it and make it useless"

Aristotle, 330 B.C.

I. Introduction

Regime changes represent important milestones in the history of monetary policy, shaping it and, in turn, shaped by it. Quite naturally, they have fascinated economists. These events have been studied for the manner in which they reflect the changing state and structure of the economy and its surrounding environment; the way in which economic agents react, and in particular, their expectations about crucial economic variables such as inflation and output; policy transmission and the choice of instruments. Often these tectonic movements have uncovered policy mistakes and threats to monetary policy credibility have usually forced and/or brought forward their occurrence. Nevertheless, regime shifts have more often than not been delayed and academic advances have both led and lagged practitioners in ushering in change.

The monetary policy framework in India has undergone fundamental modifications. Surprisingly for an economy that has been inward-looking and relatively closed for the greater part of its independent history, these shifts have mirrored and closely followed the train of global developments. Viewed in a historical perspective, three broad phases of transformation are discernible. First, the period up to the 1970s, with the Keynesian paradigm the ruling orthodoxy worldwide, was marked by subordination to fiscal policy - monetary policy did not matter. As in other developing economies emerging from a colonial past, the logical operational corollary of this regime in India was a structuralist tradition of credit rationing and exchange controls. The pursuit of low unemployment (read as faster growth in developing countries) allowed inflation to drift upwards until it became unconscionable.

The recognition brought on by influential work in the 1960s that monetary policy has powerful effects on real variables in the short run, the shift to floating exchange rates in advanced economies (managed floats in the case of India and many developing economies) and loss of formal constraints on money creation, oil price hikes and stagflation on the back of productivity growth slowdown in the 1970s brought about the end of an era. Monetarists assembled international evidence on the association between long-run sustained inflation and excessive money growth. This was bolstered by econometric proof of the stability of the demand for money and the persuasive argument that a central bank could exercise sufficient control over money through its monopoly over currency and reserves. In India, systematic evidence was turned in on stability in money demand and the money multiplier, and a predictable chain of causation running from changes in money supply to prices and output. This ushered in the second phase of monetary policy setting. Beginning in the mid-1980s, monetary targeting with feedback became the *raison d'être* of the conduct of monetary policy in India. Again, viewed with the hindsight of history, it was part of a worldwide revolution. Although Germany (1975), Switzerland (1978) and the USA (the early 1980s) were amongst the first advanced economies to adopt monetary targets in the operating framework of monetary policy, many developing countries also adopted various formulations of the money rule.

Yet, winds of change were blowing across the world again. Recession in the early 1980s focused attention on the sacrifice of output/employment that demand managed inflation control entailed. Doubts about the credibility and time consistency of monetary policy surfaced. Moreover, money demand functions, especially in the major advanced economies, started to exhibit instability. Globalization, capital mobile on a massive scale, and the explosion of financial innovations rapidly threatened the edifice of monetary targeting regimes. Accordingly, in the 1980s, several countries either modified the operating framework of monetary policy to a monetary-cum-output targeting approach or abandoned monetary targeting altogether. From 1989, inflation targeting regimes enshrining variants of the interest rate regimen had been gaining currency and several emerging economies also moved to target inflation in an explicit, formal manner. During this period, ground was being broken again in the academia. Ideas that prices are mark-ups over costs, that there is a natural rate of unemployment, that inflation is influenced by output relative to its potential, and that prices and wages are sticky were getting increasingly established. The door was opened to the analysis of interest rates in the context of practical policy making. Short-term interest rates based on an underlying continuity of influence over the long-term rate and interest rate rules moved into centre-stage of the debate. In 1994, another revolution occurred – the Federal Reserve shed monetary mystique and began to announce the federal funds target, followed by 'forward guidance' on its expected path.

India was not immune to these forces. Radical changes occurred in the institutional setting for monetary policy in the 1990s. Notable among them were the phased emergence out of fiscal dominance, a market-based exchange rate regime, the progressive rollback of exchange control, and financial sector reforms resulting in the deregulation of interest rates and the activation of various segments of the financial market continuum. In the late 1990s, the third regime change was set in motion - interest rates progressively became the main instrument of monetary policy, supported by indirect instruments such as open market operations and reserve requirements. The centerpiece in the operating framework of monetary policy became the Liquidity Adjustment Facility (LAF). Repo and reverse repo rates essentially began to provide a corridor for market interest rates to evolve.

The story of regime changes in monetary policy is also one of mutually reinforcing advances in theory and practice. At the risk of broad generalization, it can be said that analytical endorsement has usually ensured the success of a regime change. A clear theoretical perspective using the tools of modern macroeconomics to analyze optimal policy settings enables central banks to develop a conscious and articulate account of what they are doing. This is necessary in order for them to know how to act systematically to serve their objectives that are removed from their direct control. To be able to communicate their policy framework and rationale to the public has become vital just so that they are better understood.

In India, the establishment of monetary targeting was broadly supported by analytics and evidence (Rangarajan, 1988; 1998**;** 2002**;** 2010). The building blocks of the more recent regime were laid in that era, essentially in response to sweeping environmental changes described earlier. This paper is an effort to explore theoretical foundations for the current monetary policy framework in India and empirically assess monetary transmission channels in the period 1996-2009. It draws upon the working consensus that has been achieved since the late 1990s on the core principles of monetary policy. Alternatively termed as the New Neoclassical Synthesis or the New Keynesian model, it has emerged as one of the most influential and prolific areas of research in macroeconomics (Gali, 2008a). In one sentence, inflation and output respond to aggregate demand, aggregate demand to interest rates, and interest rates are set by monetary policy, in turn, in response to expected movements in inflation and output. Importantly, money has no explicit role – a model without 'em'. Within the new Keynesian tradition, however, this paper is agnostic. The fact that money does not make an explicit appearance does not imply any belief that money does not matter. Far from it: money is central but unseen.

The rest of the paper is organized into five sections. The next section (Section II) reviews select pivotal contributions to the literature that have a bearing on the specific characteristics of the model developed in this paper. This is followed by Section III dealing with the evolution of the monetary policy framework in India since the early 1990s. Section IV discusses the facets of the theoretical framework in which the model is nested with a view to adapting it to suit Indian conditions. Data, estimation and simulation results are discussed in Section V, and then the paper comes to a close with concluding observations.

II. The State of the Debate – Survival of the Fittest

Since the 1990s, there has been a marked introspection among central banks about the way in which they conduct monetary policy.

Increasingly, they have been willing to abandon secrecy and be more explicit to the public about their actions and the considerations upon which they are based. In some cases, this has been reflected in commitment to straightforward objectives – inflation targeting, for example – but more generally, they have been more forthcoming in their reports and analyses about their goals and why they chose them, the logic guiding their policies and the manner in which they intend to achieve their stated objectives. Practical application conditioned by (i) a core set of agreed macroeconomic principles about the impact of monetary policy and (ii) a clear political-economic demand for an increased emphasis on policy rules has emerged since the late 1980s and the early 1990s (Taylor, 1998). An illustration of (i) is that while there is no long-run trade-off between output and inflation, there is a short-run trade off that concerns monetary policy. A reflection of (ii) is the wider recognition that people's expectations matter and the policy rule must be consistent, simple, and systematic and clearly communicated to be able to gauge these expectations.

Developments in theory have not lagged behind either. Over the last two decades, a new consensus seems to have emerged in favor of a monetary policy that is disciplined by clear principles of systematic conduct for institutions that are aware of the consequences of their actions and take responsibility for them, choosing their policies with careful attention to what they want to accomplish. The first rules about monetary policy have, however, been traced to those that tied its supply to a commodity – most recently bullion (Woodford, 2003). Perhaps the earliest example of a prescription for monetary policy in terms of an interest rate rule is found in times when the leading industrial nations remained committed to the gold standard: *"If prices rise, the rate of interest is to be raised; and if prices fall, the rate of interest is to be lowered; and the rate of interest is henceforth to be maintained at its new level until a further movement of prices calls for a further change in one direction or the other"* (Wicksell, 1898). In the 1970s and 1980s, a practical application of a monetary policy rule was the money rule in which money supply was to grow proportionally with respect to output to ensure price stability – a variant of the 'k' percent rule (Friedman, 1960). Modern day central banks may have greatly downgraded the role of monetary aggregates in the actual conduct of monetary policy, but they have continued to draw upon the legacy of the preceding regimes – by retaining the notion of specific policy rules as central to the monetary policy framework. That these rules are now formulated in terms of interest rates, largely following Taylor (1993), reflects an effort to depict the real world as best as possible, instead of working through intermediates to cover up for the limited knowledge of the manner in which the real economy works. This approach did reshape the conduct of monetary policy analysis with the empirical insight that in practice actual monetary policy decisions could be usefully approximated by a simple interest rate rule that responded to movements in inflation and output. In itself, it is neutral on the issue of the usefulness of monetary aggregates and does not preclude it.

The Taylor rule is the best-known example of a proposed rule for setting interest rates. According to it, the US Federal Funds operating target is set as a linear function of measures of the current inflation rate and the current gap between real and potential output. The original numerical specification contains a constant indicating an implicit inflation target of 2 percent per annum and an estimate of the long-run real federal funds rate of 2 percent per annum, so that a long-run average inflation rate at the target requires a long-run average Federal Funds rate of 4 percent. The coefficients 1.5 and 0.5 were attached to the inflation gap term and the output gap term, respectively, to approximately characterize the U.S. policy between 1987 and 1992, and that was found to result in desirable outcomes in terms of inflation and output stability. Emphasis was placed upon the importance of responding to inflation above the target rate by raising the nominal interest-rate operating target by *more than the amount* by which inflation exceeds the target. Estimates of empirical central bank reaction functions have found that a dynamic specification fits the data better (Judd and Rudebusch, 1998). Simple modifications of the Friedmanesque 'k' percent money rule have also been proposed (McCallum, 1988, 1993). This rule specifies the growth rate of the monetary base rather than the value of the policy interest rate. The base growth rule can be expressed as follows: $\Delta b_t = \Delta x^* - \Delta v_t + 0.5(\Delta x^* - \Delta x_{t-1})$, where Δb_t is the rate of growth of the monetary base; Δv_t is the rate of growth of base velocity; Δxt is the rate of growth of nominal GDP and Δx^* is the target rate of growth of nominal GDP. In this sense, although central banks may not adhere to a rule, it may be a rule that provides the closest description of actual monetary policy (Paez-Farrell, 2009).

With this discussion in the fore, we turn to the main principles underlying the new Keynesian model which has come to be regarded as a standard tool for the analysis of monetary policy (Goodhart and Hofmann, 2005a), the most popular model for the analysis of monetary transmission (Goodhart and Hofmann, 2005b) and even 'a general tendency' in research in this area conducted by both central bankers and academics (McCallum, 2001). In our stylized portrait here, we draw heavily on Woodford (2003) whose work in this area is widely regarded as a seminal contribution (Bean, 2007)[2]. As opposed to new Classical models (Lucas, 1972) and the real business cycle models (Kydland and Prescott, 1982; Long and Plosser, 1983), the new Keynesian model posits that systematic monetary policy can

[2] While Woodford (2003) has come to be regarded as 'iconic' (Goodhart 2007), Gali (2008b) can also be considered to be of rich textbook value for the comprehensive treatment and analysis of the new Keynesian model. Gali and Gertler (2007) also give a quick introduction to the new Keynesian framework.

make a substantial difference in the way that an economy responds to real disturbances. Expectations turn out to be crucial. Successful monetary policy is all about shaping market expectations of the way in which interest rates, inflation, and income are likely to evolve. Reading expectations formation correctly is what makes monetary policy work as much as agents need to read correctly how monetary policy works. In a nutshell, what new Keynesians want to change is the 'how' of monetary policy.

Clarida et al. (1999) arguably provide the most lucid exposition of the main aggregate relationships that define the new Keynesian model. The first one relates aggregate demand *(*proxied by deviations of output from long-term trend) to the *ex ante* real interest rate - an IS curve 'grounded in dynamic general equilibrium'. Other variables such as the real exchange rate (Svensson, 2000), real base money (Nelson, 2002), property prices (Hofmann, 2001) and the like have also been found to have a significant influence on aggregate demand. A richer specification of the IS curve that includes the short-term real interest rate and property prices produces significant and satisfactory explanations for the behavior of aggregate demand for the G 7 countries (Goodhart and Hofmann (2005a). The augmented IS function may, however, be representing a reduced form rather than a structural relationship. This underscores the need for more rigorous establishment of the theoretical underpinnings of an extended IS curve.

The second major relationship is the positive response of inflation to the output gap – a Phillips curve with the assumption of inter-temporally optimal price setting by forward-looking monopolistically competitive firms (Calvo, 1983). These nominal rigidities play an important role in the model since they bring in the short-run inflation-output trade-off and provide the conduit for monetary policy to vary the nominal interest rate so as to change the real interest rate and thereby to affect the course of the economy. The introduction of the Phillips curve can be regarded as an innovation over the standard IS-LM framework which had two equations and three unknowns and could be solved only by assuming either the price level or the output level as fixed. The Phillips curve, by pinning down the degree of stickiness in prices in the short-run, allows for both short-run movements in output relative to potential and for monetary policy to operate in its stabilization role, while providing a transition to the classic long-run equilibrium of full price flexibility (Meyer, 2001). Thus, even if the central bank were not to care about inflation in itself, it will find its stabilization desirable as an indirect way to close the output gap.

The final building block that completes the model is a link between the nominal short-term interest rate or the policy instrument and the rest of the economy embodied in the two baseline relationships described earlier. This derives from a central bank objective function in which Clarida *et al.* (1999)

follow Woodford (1998) in adopting a quadratic approximation of a utility-based welfare function that minimizes the squared deviations of output and inflation from potential and target, respectively. Their approach is agnostic in deference to the unsettled debate in the literature (De Long, 1997; Blinder, 1997; Clarida and Gertler, 1997; Bernanke and Mishkin, 1997), which questions the validity of this approach on several aspects – for instance, the lack of consideration for inflation variability and the uncertainty generated by it for lifetime financial planning; or, the differential impact of economic phenomena on different groups in society which is important from the point of view of welfare analysis. As Clarida *et al.* (1999) argue, their main interest lies in optimal policy rules that set a time path for the interest rate instrument that maximizes the objective function, subject to linear behavioral constraints. Imposing binding commitments – rules as opposed to discretion – is easier said than done and, therefore, solutions may be sought in institutional mechanisms such as appointing a conservative central banker who assigns a high weight to inflation relative to society at large (Rogoff, 1985), or signing an optimal contract with central bankers (Walsh, 1995) or securing the independence of the central bank by law.

The advent and widespread usage of the new Keynesian model has by no means received a full and broad unanimity in the profession at large (see Meltzer, 1999; Nelson, 2000). A central bank's control over the interest rate ultimately stems from its ability to control base money and this is unlikely to change in the foreseeable future (Goodhart, 2000). McCallum (2001) showed that theoretically a model without money could be mis-specified[3]. Central banks have to be concerned with setting the steady state rate of inflation, not just minimizing the variability of inflation around its steady state value. For this purpose, explicit attention to the long-run relationship between money growth and inflation may be valuable. It has been argued that new Keynesian models do not actually explain the rate of inflation without reference to money. They only explain departures of inflation from its trend, and this trend has to be determined somewhere else – specifically by the long-run rate of money supply (Nelson, 2003). Therefore, it may be useful to analyze the behavior of monetary aggregates in evaluating the consistency of a policy that pursues low inflation.

Others have taken opposing positions that essentially focus on the explicit role of money in monetary policy analysis. For instance, it has been

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[3] Using the same theoretical model employed by McCallum, Leahy (2001) demonstrates that the former's criticism is valid only when transactions costs are large and so money matters; but by McCallum's own admission, this effect can be expected to be large only in extreme situations such as when the payments system is under stress. Ordinarily, as McCallum agrees, along with Svensson (2001) it is likely be so small that it can be disregarded.

shown that models estimated with a monitoring range for money growth serve as an insurance policy against undesirable multiple equilibria (Christiano and Rostagno, 2001). Furthermore, it has been argued that consensus models lack the transmission mechanism embedded in a spectrum of yields that matters both for the determination of aggregate demand and for money demand in terms of Friedman’s original specification, and this mis-specification could be undermining the true role of money (Nelson, 2003). For instance, open market operations that are undertaken to change the policy/target rate also produce changes in money growth. It has also been warned that there can be real dangers to relegating money to ‘in the wings off-stage’ role, especially of fostering the notion that monetary policy can offset each and every shock in the economy since monetary policy is being depicted in terms of real rather than monetary variables (King, 2002).

How do new Keynesians respond? According to an influential view in this strand, the absence of any role for money is only apparent and on the surface. It is conceivable to append an LM function to the three-equation consensus model to identify the supply of money by the central bank. This would, however, be completely unnecessary from the point of view of the model since the latter is able to specify determinate paths for output, inflation and interest rates without reference to a money demand function or the measurement of money supply. This is, however, not in any way inconsistent with a stable long-run relationship between money and inflation which is implicit. Money supply becomes a less interesting endogenous variable (Meyer, 2001). Even those in the profession who reject Taylor rules as a useful description of monetary policy have nevertheless supported the movement away from the use of monetary aggregates in monetary policy analysis (*e.g.*, Svensson, 2003). In this view, the high long-run correlation between money growth and inflation is misunderstood – since it is a correlation between two endogenous variables, it says nothing about the direction of causality. Moreover, even a stable money demand function does not preclude the optimality of monetary policy arrangements which proceed without any reliance on data on the money stock (Rudebusch and Svensson, 2002). A more forceful argument is that a model that determines the equilibrium path of inflation without reference to money supply does not in any way violate money neutrality. The consensus model relates real variables only to relative prices – inflation rate relative to trend and inflation rate relative to the nominal interest rate. Trend inflation corresponds to the central bank’s target rate incorporated into the policy rule and can be determined without reference to money by specifying a loss function for the central bank rather than a policy rule (Woodford, 2006). It is not essential to monitor money growth to realize that an undesirable inflation trend is developing; for this, the measurement of inflation itself will suffice. The mere fact that a long tradition in the literature has established a fairly robust long-run relationship between money growth and inflation does not imply that monetary statistics must be the most important sources of information about price stability or of the soundness of monetary policy. A deeper study of the dynamics of wage- and price-setting and the role of expectations in such setting is perhaps more crucial (Woodford, 2003).

To be fair, this response has been met by some skepticism. Others in the profession, including those who would be counted in the post-Keynesian tradition, have not taken kindly to the 'downgrading of the role of monetary aggregates'. It has been contended that the consensus model is essentially a 'fair weather model' that may work only in periods of stable economic developments (Goodhart, 2007). For instance, in the face of deflation, the model may have very little practical usefulness because of the zero nominal bound on the interest rate. On the other hand, the behavior of monetary aggregates would continue to provide some guide on the underlying economy and quantitative easing, as in the case of Japan during the 1990s and more recently in several advanced economies in the current crisis, may continue to allow monetary policy remain active and effective. Arguably, a similar outcome can be expected in the opposite case of high and volatile inflation when expectations come unhinged. Furthermore, monetary policy operates on the premise that different assets are not perfect substitutes of each other. Defaults become possible and risk premia come into play. The consensus model is perhaps making the faulty assumption or simplification that everyone is equally credit worthy – the transversality condition by virtue of which the consensus model becomes a non-monetary model. The true measure of inflation may be lurking among these asset prices and the demand for assets may be a function of shocks to the supply of money (Goodhart, 2007).

How can the new Keynesian framework be improved? One area in which there needs to be a deeper understanding is the impediment posed by the zero nominal bound on the interest rate – initially thought to be a distant theoretical possibility associated with 'liquidity trap' conditions but which turned out to be a reality during 2009 over much of the advanced world following the global financial crisis. Mainstream new Keynesians would hold that this is not the case. As long as various financial assets are not perfect substitutes, monetary policy can operate even after policy rates are driven to zero if it can affect the spreads between the policy rate and the prices of other financial assets (Meyer, 2001). Furthermore, it is in this precise context that new Keynesians argue for maintaining a positive average rate of inflation. Together with the presence of nominal wage rigidities, this will prevent real wages going too low in a deflation and also keep the nominal interest rate above zero. This is consistent with the strategy followed by many central banks around the world (Gali, 2008a). Another challenge, as shown in Blanchard and Gali (2007), is that of coming up with meaningful sources of policy trade-offs or dealing with 'divine coincidence' (the absence of a trade-off between stabilization of inflation and stabilization of the welfare-relevant output gap), through the introduction of real imperfections such as slow adjustment of real wages which create an endogenous time-varying wedge between efficient and natural levels of output. Introducing asset prices/wealth into the consensus model appears to be a promising area of future research, although this will mean a veritable battle royale with the main stream orthodoxy that seems to have weathered the glancing blow from the recent crisis - that monetary policy should not concern itself with asset prices. Another issue from the point of view of this paper is that the manner in which monetary and credit aggregates evolve provides useful information on how the economy is coping with income/liquidity constraints, risk and uncertainty. Irrespective of the explicit non-appearance of money in the model that is estimated here, policy makers are better off monitoring monetary and credit aggregates as a very useful cross-check. As long as the monetary policy stance is mainly conveyed through the setting of interest rates, money is omnipresent endogenously. The messages that money emits may be garbled by short-run demand shocks, but distinguishing the news from the noise is the art of monetary policy.

III. The Indian Experience

The paper began with regime shifts. In India, dating them is difficult because they have always been overlapping.[4] At the cost of over-simplification, the regime employing interest rates as the main instrument of monetary policy transmission can be located in 1997 when the Bank Rate was reactivated after a hiatus of seven years. Enabling conditions were created in the preceding five years by financial sector reforms, drawing upon recommendations of the Committee on Financial System (RBI, 1991) that placed emphasis on the development and deepening of various segments of the financial markets, including the progressive deregulation of bank lending and deposit rates, and in a significant way, facilitated the shift in the manner in which monetary policy came to be conducted.

The analytics underpinning the monetary policy framework underwent a silent transformation in the later part of the 1990s. In its monetary policy statement of April 1998, the RBI announced that it would switch to a multiple indicator approach "to widen the range of variables that could be taken into account for monetary policy purposes rather than rely solely on a single instrument variable such as growth in broad money (M3)". Movements in

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[4] See Reddy (1999) for a comprehensive review of the evolution of the operating framework of monetary policy in India. .

money market interest rates, exchange rates, foreign exchange reserves, credit to Government and commercial sector and the fiscal position of the Government were closely monitored and utilized to guide policy actions. The era of monetary targeting was drawing to a close and the paradigm in Indian monetary policy was shifting. Analytical explorations by an internal Working Group (RBI, 1998b) showed an upward drift in the money multiplier and an increase in its volatility. It also found that while the demand for money exhibited parametric stability, it lacked predictive stability – “monetary policy exclusively based on the demand function for money could lack precision” (pp. 62). Furthermore, the output response to monetary policy impulses delivered through interest rates was found to be stronger and more persistent than through a quantity channel such as credit. The impact of interest rates on inflation was also found to be more pronounced than that of the exchange rate. In 1999-2000, the stance of monetary policy was conveyed through reductions in the (reverse) repo rate and the Bank Rate, and India was on the path to a new monetary policy framework. At that stage, it was felt that movements in the Bank Rate should not be too frequent. The reverse repo rates soon began to provide a floor for the overnight call money market rates. While repo auctions were employed in the event of tightness in liquidity conditions to assuage market stress, it was the Bank Rate, to which all other rates on accommodations by the RBI were linked, that remained, till 2002, the main signaling rate for conveying the stance of policy, and the effective ceiling for money market rates.

Turning to the instrumentation, an Interim Liquidity Adjustment Facility (ILAF) operated through repos and lending against collateral of Government of India securities was introduced in April 1999. The ILAF was a mechanism by which liquidity was injected at various interest rates, but absorbed at the fixed repo rate. In the following year, a full-fledged LAF was put in place in stages. The intellectual rationale for the regime shift was provided by a Committee on Banking Sector Reforms (RBI, 1998a) which recommended that in order to facilitate an efficient integration of financial markets, the RBI should institute a LAF operated by way of repos and providing a reasonable corridor for market play. The Bank Rate progressively gave way to the repo rate as the upper bound of the policy interest rate corridor, although it continues to be announced. From November 2004, the LAF began to be operated with only overnight repo/reverse repo auctions and longer-term auctions were discontinued, although the RBI retained the option to conduct them at its judgment. With the establishment of real time gross settlement, a screen-based dealing platform and a clearing corporation, intra-day LAF auctions have also been employed with reasonable success. Over the ensuing period, the LAF has evolved into the principal operating procedure of monetary policy. In view of persistent and large capital inflows, the need to sterilize forex market interventions, the finite supply of government securities with the RBI to conduct OMOs and restrictions on the RBI issuing its own securities, a Market Stabilization Scheme (MSS) was introduced in 2004. Under the MSS, government securities/treasury bills are issued by the RBI to mop up liquidity of more durable nature arising from capital flows (Mohan, 2009). The cash reserve ratio (CRR) has all through been seen as an important instrument in the RBI's arsenal for regulating liquidity in the economy. Technically, the operating target of monetary policy continues to be bank reserves; however, the predominant reliance on the LAF for signaling the policy stance by modulating bank reserves has meant that the focus is increasingly on the interest rate as the effective target for monetary policy. The RBI has stated in its policy announcements that the conduct of monetary policy is guided by objectives of price stability, growth and financial stability with relative weights depending upon evolving domestic and global macroeconomic and financial conditions. Price stability is an important but not the exclusive goal of monetary policy in India.

Arguably, the first systematic effort to seek analytical foundations for the new regime in terms of the new Keynesian synthesis can be traced to RBI (2002). While the statistical results therein turned out to be reasonably robust, the empirical exercise was based on annual data with purely backward-looking specifications in an OLS framework. In essence, this paper is an effort to extend and enrich that first initiative with fuller dimensions and also to round it off into a complete model rather than a summation of parts.

Recent efforts towards evaluation of monetary policy in India have mainly been confined to interest rate and base money type rules. Mohanty and Klau (2004) estimated an open economy Taylor rule for 13 emerging economies. For India, the relationship between the short-term interest rate and the inflation rate was found to be relatively weak while the interest rate was negatively correlated with the exchange rate - a currency depreciation is associated with an increase in the interest rate and *vice versa*. The output gap turned out to be a statistically significant determinant of short-term interest rates in India. Interestingly, in all sample countries except for Chile, current period real exchange rate changes had uniformly negative signs in the reaction function, suggesting that central banks "lean against the wind" by raising rates when the exchange rate depreciates. Virmani (2004) also found evidence indicating that both an open economy backward-looking Taylor rule and a similarly specified McCallum rule captures the evolution of the short-term interest rate in India reasonably well. Inoue and Hamori (2009) also obtained similar findings. Employing dynamic OLS, they found that while the coefficient on the output gap is statistically significant and with the correct sign, the same is not true for the coefficient on the inflation term and this result does not change under an open economy Taylor rule. Accordingly, they concluded that an inflation targeting framework is inappropriate for India, an inference that is also arrived at by Singh (2006) and Jha (2008). A comprehensive analysis of monetary policy rules across different specifications in both backward- and forward-looking versions is undertaken in Singh (2010). Using annual data, monetary policy's reaction to inflation is found to be stronger than to the output gap for the period 1988-2009. The long-run coefficients on the inflation gap and output gap are estimated to be 1.05-1.78 and 0.71-1.10, respectively, across alternative models.

Yet another strand of empirical effort has sought to estimate the Phillips curve in standard and augmented backward-looking specifications in the context of the objective of estimating the sacrifice ratio for India (Kapur and Patra, 2000) and in the context of modeling inflation expectations (Patra and Ray, 2010). Phillips curves and IS curves for India have also been estimated in RBI (2004). The monetary transmission mechanism has been analyzed in a VAR framework [Ray *et al.* (1998), Al-Mashat (2003), and RBI (2004)]. Illustratively, RBI (2004) estimated a VAR using the index of industrial production, wholesale price index, Bank Rate, broad money and exchange rate and found transmission lags to be shorter than suggested in the literature at about 6 months, but no attempt was made to provide confidence intervals around those estimates. Monetary tightening was associated with a reduction in both output and prices, and with exchange rate appreciation. Thus, with the exclusion of RBI (2002), the focus has been on one or other of the three building blocks of the new Keynesian model in backward-looking specifications. Nevertheless, insights provided into both the operating framework of monetary policy in India and issues in actual estimation are extremely useful for the specification involved in this paper.

IV. The Organizing Framework

The foregoing exploration of a still evolving debate, globally and in India on a much limited scale, provides the perfect launching pad for setting out the theoretical framework for estimating the new Keynesian model for India. As the evolution of ideas has shown, the best results are obtained when the model that is moored in purely theoretical underpinnings is enriched by country-specific considerations and the actual process of formation of key elements such as expectations in the environment under consideration. Therefore, the process of developing the building blocks of the new Keynesian model in India needs to be informed by an understanding of local conditions.

The Model

The intuitive appeal of the new Keynesian model is its simplicity in characterizing the monetary policy design. As explained earlier, it reduces the economy into a two-equation system comprising an aggregate supply or Phillips curve and an aggregate demand or IS curve. It has the empirical appeal of the IS/LM system in general equilibrium with at least two improvements: the Phillips curve and the IS curve are based on microeconomic foundations and factor in forward-looking economic behavior; and a policy reaction function that depicts more accurately than competing models the operating procedure of modern central banks.

Aggregate Supply

The aggregate supply or Phillips curve evolves from Calvo pricing as stated in Section II, *i.e.,* each firm has a fixed probability of being able to reset its price in any given period optimally on the basis of expected future marginal costs, independently of the time elapsed since its most recent price adjustment. This captures the spirit of staggered price setting, but facilitates aggregation by making the timing of the firm's price adjustment independent of its history (Clarida *et al.* 1999). Such a formulation leads to a purely forward-looking Phillips curve: inflation depends *inter alia* upon its own leads or expected future inflation ($E_t\ \Pi_{t+1}$) rather than on expected current inflation ($E_{t-1}\ \Pi_t$) as in the traditional expectations-augmented standard Phillips curve.

The forward-looking Phillips curve does not get much empirical support. Lagged inflation remains an important determinant of inflation, and in fact, a purely backward-looking Phillips curve seems to be preferred by the data (Rudebusch and Svensson, 1999). An alternative and more popular approach is to specify hybrid relationships (Smets and Wouters, 2003; Linde, 2005; Goodhart and Hofmann, 2005a, 2005b). This is accomplished by modifying the Calvo framework to assume that amongst the firms able to adjust prices in a given period, only a fraction set prices optimally (*i.e.*, on the basis of expected future marginal costs). The remaining fraction use a simple rule of thumb: they set price equal to the average of newly adjusted prices of the last period plus an adjustment for expected inflation, based on lagged inflation. The hybrid Phillips curve (equation 1) – with both forward- and backward-looking inflation components - nests the pure forward-looking Calvo model as a special case (Gali *et al*., 2005).

$$\Pi_t = a0 + a1{*}mc_t + a2{*}E_t\ \Pi_{t+1} + a3{*}\Pi_{t-1} + \epsilon_t \qquad (1),$$

where Π is the inflation rate, mc is real marginal cost (deviation from steady state), and Et denotes expectations at time t. While the theoretical formulation relates inflation to real marginal costs which are unobservable, most empirical exercises proxy real marginal costs by the output gap defined as the deviations of output from its trend[5].

In empirical analysis, extended specifications of the Philips curve including other variables – unit labor costs (Gali and Gertler, 1999; Gali *et al.*, 2005); supply shocks (Mehra, 2004); primary commodity prices (Goodhart and Hofmann, 2005b) - may appear *ad hoc* with reference to the basic theoretical model, but have been found to have better explanatory power and the correct signs. Furthermore, for emerging market economies such as India, global commodity inflation and exchange rate movements display significant short-term volatility and are amongst the important determinants of short-term inflation (Batini *et al.,* 2005). The significance of the exchange rate in the evolution of domestic inflation tends to be greater in the case of emerging market economies than in developed economies (Ho and McCauley, 2003; Ito and Sato, 2006). Accordingly, issues relating to exchange rate pass-through into domestic inflation have become important in policy and academic discussions. We, therefore, augment the baseline Phillips curve specified at (1) with these two variables as follows:

$$\Pi_t = a0 + a1*mc_t + a2*E_t\,\Pi_{t+1} + a3*\Pi_{t-1} + a4*\,\Pi^*_t + a5*\Delta ey_t + v_t \quad (2),$$

with Π^* representing global commodity prices, Δey being the variation (year-on-year) in the nominal exchange rate of the rupee against the US dollar and other variables are as indicated earlier.

Aggregate Demand

The New Keynesian aggregate demand or IS curve assumes inter-temporally optimizing households and is obtained by log linearising the consumption Euler equation under a market clearing condition. Unlike the traditional IS curve, current output (defined as deviations from trend) depends on expected future output as well as the real interest rate. As individuals prefer to smooth consumption in response to future higher incomes, expectations of higher future output induces them to consume more

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[5] In their estimates of the hybrid Phillips curve, Gali *et al*. (2005) find that the forward-looking behavior is dominant: for the US, the coefficient on expected inflation is around 0.66, double of that on lagged inflation (0.33). Batini *et al*. (2005) also report similar results. According to Mehra (2004) and Goodhart and Hofmann (2005), however, the dominance of forward-looking behavior is due to omission of supply shocks and other determinants of current inflation in the estimated models. Once the hybrid Phillips curve is augmented with supply shocks, the forward-looking behavior is no longer dominant. The coefficient on lagged inflation exceeds that on expected inflation and, moreover, contrary to Gali *et al*. (2005), the output gap variable also turns significant.

in the current period. Current output is inversely related to the real interest rate as per standard theory and the interest elasticity of output represents the inter-temporal elasticity of substitution between consumption and saving. Iterating the equation forward, it can be shown that the output gap depends not only on the current real interest rate but also on its expected future path. In other words, to the extent that monetary policy has control over the real interest rate due to nominal rigidities, expected as well as current policy actions affect aggregate demand (Clarida *et al*., 1999).

While the new Keynesian IS curve in its strict theoretical version is purely forward-looking, backward-looking and hybrid specifications have been found to match the lagged response of output to monetary policy better in empirical applications (Rudebusch, 2002; Rudebusch and Svensson, 1999; Peerman and Smets, 1999). As backward-looking expectations in the new Keynesian IS curve are technically inconsistent with theory, it becomes necessary to assume habit persistence in consumption behavior of households: household utility also depends on lagged consumption (Fuhrer, 2000). Taking into account these considerations yields a hybrid IS curve of the form:

$$y_t = b0 + b1*(i_t - E_t \Pi_{t+1}) + b2*E_t y_{t+1} + b3*y_{t-1} + g_t \qquad (3)$$

where y is the output gap, Π is the inflation rate, i is the nominal interest rate and g reflects demand shocks.

The empirical evidence relating to the hybrid IS curve is mixed. Estimating backward-looking IS curves for industrialized countries does not seem to obtain a significant negative relationship between the real interest rate and the output gap (Nelson, 2002; Goodhart and Hofmann, 2005 a; b). It has been argued that this insignificance of the interest rate is due to an omitted variable problem as other key determinants of aggregate demand are left out. Interest rate effects on output are indirectly transmitted through these variables (Goodhart and Hofmann, 2005a). Studies that have incorporated such other variables and obtained significant negative coefficients on the real interest rate are documented in Section II. These findings support the estimation of extended specifications of the hybrid IS curve. Accordingly, equation (3) is augmented with variables that embody significant demand-side effects in the evolving Indian context: deviations of agricultural income from trend (nearly two-thirds of India's population draw their livelihood from agriculture, and which continues to be subject to vagaries of monsoon and accordingly, variations in agricultural activity can significantly affect aggregate demand) and key asset prices. The augmented IS curve takes the following form:

$$y_t = b0 + b1*(i_t - E_t \Pi_{t+1}) + b2*E_t y_{t+1} + b3*y_{t-1} + b4*YAGR + b5*x_t + b6*REER_t + b6*NFC_t + b7*BSES_t + g_t \qquad (4)$$

where YAGR is real agricultural output, x is real world exports[6], REER is the real effective exchange rate, all expressed in terms of deviations from trend. NFC is non-food bank credit and BSES is equity prices (Bombay Stock Exchange (BSE) SENSEX), both expressed as year-on-year rates of change. The other variables are as indicated earlier.

Monetary Policy Reaction Function

The model is closed by a monetary policy reaction function in which the monetary authority wields the nominal interest rate to secure the objectives of minimizing volatility in output and inflation. This results in a specification similar to the well-known Taylor rule. A forward-looking specification is recommended in theory in which the interest rate is adjusted to future inflation and output deviations from target/potential – the target variables depend not only on the current policy stance but also on expectations about future policy. From practical considerations, a general specification with both backward- and forward-looking terms and incorporating the well-documented interest rate smoothing by central banks (inertia in policy response) is preferred in the empirical literature (Clarida *et al*., 2000; Paez-Farrell, 2009). Accordingly, our specification of the policy reaction function takes the form

$$i_t = c0 + c1^* E_{t-j}\, \Pi_{t+k} + E_{t-j}\, y_{t+m} + c3^* i_{t-1} + v_t \qquad (5)$$

where i is the nominal policy/short-term interest rate, y is the output gap, Π is the inflation gap (in terms of deviation from the objective level set by the central bank for monetary policy purposes), and 'j' represents the possible information lag to which the central bank is subject. If k=m=0, then (3) reduces to the original Taylor rule with the central bank responding to current inflation. If k and m are both positive, we get a forward-looking version of the Taylor rule; the outcome is a backward-looking version if k and m are negative. An analysis of the optimal choice of the lead structure in the policy rule in alternative models does not find a significant benefit from responding to expectations out further than one year for inflation or beyond the current quarter for the output gap (Taylor and Williams, 2010). As in the case of the Phillips curve and the IS curve, we follow the literature in augmenting equation (3) by open economy considerations. Exchange rate smoothing is found to be an important consideration in the policy reaction function of most emerging economies, including India (as in Mohanty and Klau, 2004). Furthermore, in the context of growing degree of trade and

[6] Data on world GDP are available only from the first quarter of 2000 onwards in the IMF's World Economic Outlook and moreover, only growth rates are available. Hence, real world exports are used as a proxy for external demand.

financial integration, large capital flows and potential business cycle synchronization, it would be useful to explore the influence of key international interest rates on domestic monetary policy. Accordingly, equation (5) can be extended to the following form:

$$i_t = c0 + c1^* E_{t-j}\, \Pi_{t+k} + c2^* E_{t-j}\, y_{t+m} + c3^* i_{t-1} + c4^* \Delta eq_t + C5^* i^*_t + v_t \qquad (6)$$

where i* is the Federal Funds rate, Δeq is the variation (quarter-on-quarter, annualized) in the nominal exchange rate of the rupee against the US dollar and other variables are as explained earlier.

An important issue in the estimation of policy rules is the use of the output gap, a variable which is not observed. Moreover, in view of frequent and often sizable revisions, there can be large divergences between real time data on which authorities make their policy judgments and the final revised data that are used in empirical work. Accordingly, it may be optimal to replace the output gap variable with its first difference (Taylor and Williams, 2010). We explore such a formulation and report results in Annex II.

It is important to articulate a key anticipation in the actual estimation of the reaction function, reiterating the point made in Section II and emphasized by Kerr and King (1996), Bernanke and Woodford (1997) and Clarida *et al.* (1997). The coefficient on the inflation gap is expected to be at or above unity, failing which the policy rule can itself become a source of instability in the model leading to indeterminacy of the equilibrium . With this coefficient below unity, a rise in inflation leads to a decline in the real interest rate which stimulates a rise in aggregate demand which, in turn, induces a rise in inflation, thus confirming self-fulfilling revisions in expectations. When the coefficient is above unity, short-term real interest rates do not adjust to accommodate sunspot shifts in inflationary expectations. Macroeconomic fluctuations occur only in the presence of shocks to fundamentals and not from the policy rule itself. The policy rule, however, does affect how the economy responds to fundamental shocks.

V. Estimation Results

The three-equation new Keynesian described in Section III [equations (2), (4) and (6)] model is estimated on quarterly data for the period April 1996 to September 2009, the choice of period being determined by the availability of quarterly data on real GDP for India[7]. In order to test the robustness of the results, we also estimate the model for the period prior to the collapse of the

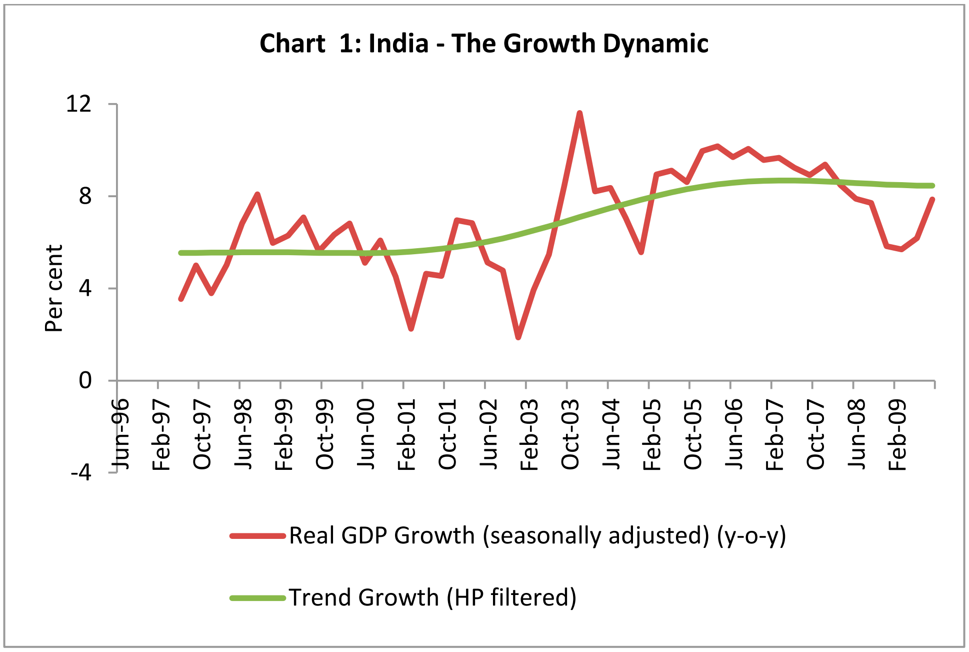
[7] Beginning the quarter October-December 2009, the Central Statistical Organisation (CSO) of the Government of India has released a new series of national accounts statistics with 1999-2000 as the base, but only starting from April-June 2004.

Lehman Brothers (*i.e.*, up to the quarter April-June 2008) and also for a truncated period April-June 2002 to April-June 2008, which coincides with substantial changes in the operating framework of monetary policy following the introduction of the LAF in early 2000 and up to the Lehman collapse. The results for the two truncated samples, which are given in Annex II, generally match the estimates for the full period, attesting to the stability of the estimated model over time.

Variables and Data

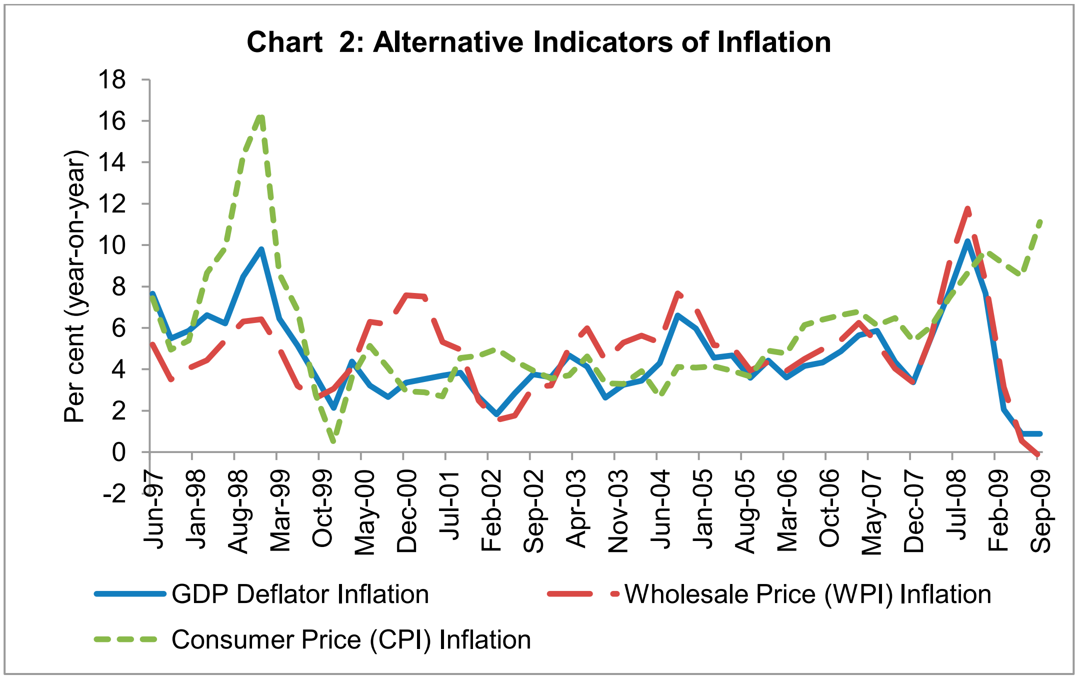
In view of the quarterly data and for the series which enter in gap form, the underlying data series are seasonally adjusted using the X-11 algorithm of the US Department of Commerce. Inflation and other measures, which are measured on a year-on-year (y-o-y) basis, have negligible seasonality and are not de-seasonalized. Also, the policy rate and exchange rate series are not de-seasonalized.

Most studies on India dealing with high frequency (quarterly/monthly) data have used industrial production as a proxy for economic activity, which is not entirely appropriate since industrial production accounts for only a fifth of GDP. This paper uses quarterly GDP as the activity variable. The output gap is measured by the difference between real GDP (seasonally adjusted) and its trend obtained by the HP filter (Chart 1). The output gap turned positive in late 2005, exceeded one per cent for five consecutive quarters beginning January-March 2007 and reached its cyclical peak of 1.6 per cent in the quarter ended December 2007 – the period characterized as one of "overheating" by the Reserve Bank in its monetary policy statements around that time - for the first time in the Indian context. The output gap turned negative in late 2008 under the impact of the global financial crisis, but appears to have narrowed by late 2009. Trend growth of the Indian economy is estimated at around 8.5 per cent for the period 2006-09.

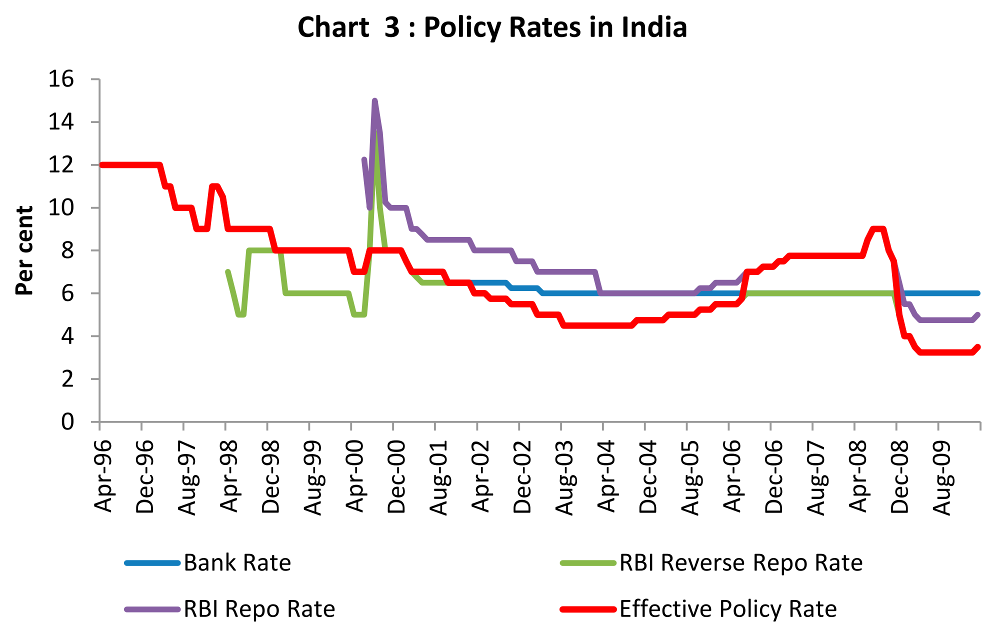


Headline inflation in India is measured by variations in the wholesale price index (WPI)[8]. While monetary policy projections by the RBI are formulated in terms of WPI inflation, other indicators of inflation – consumer price inflation and GDP deflator – are also monitored closely as a part of its multiple indicator approach. The WPI inflation measure does not capture the prices of services - the predominant component of GDP. Moreover, WPI inflation movements are often dominated by food and fuel prices, which impart significant volatility and, being often driven by supply shocks, are least amenable to monetary policy actions. The various measures of inflation in India tend to converge over the medium- and long-term, but reveal substantial differences in the short-run (Chart 2). For the purpose of estimation, we prefer GDP deflator as the measure of inflation, but we also report results using inflation measured by WPI as a robustness check.

[8] Till November 2009, the WPI was available on a weekly frequency with a lag of a fortnight. Since then, it is available on a monthly frequency, although data on two sub-groups of the index - primary articles and fuel - continue to be available on a weekly frequency.



As regards the appropriate policy interest rate, the choice is complicated by regime shifts and consequent changes in operating procedures. Over the period of study, the Bank Rate was the effective policy rate until February 2002, giving way thereafter to LAF repo (liquidity injection) and reverse repo (liquidity absorption) rates. In the subsequent period, the policy rate has switched between repo and reverse repo rates, depending upon overall macroeconomic conditions. During episodes of relatively benign inflation and abundant liquidity (March 2002-June 2006 and again during December 2008-September 2009), the reverse repo rate became the effective policy rate. On the other hand, during episodes of inflationary pressures and/or tight liquidity (July 2006-November 2008), the repo rate was the effective policy rate (Chart 3). The effective policy rate, thus defined, is used as the policy rate. The LAF corridor framework provides flexibility to change gears quickly from reverse repo mode to repo mode and vice versa in the event of larger than anticipated changes in intermediate and goal variables.



Note: Effective policy rate is as explained in the text.

All data are taken from published sources. Data on world exports, unit value index for exports, and the index of world non-fuel commodity prices are from the IMF's International Financial Statistics. Data on the US federal funds rate target are from the Fred database of the Federal Reserve Bank of St. Louis (http://research.stlouisfed.org/fred2/). All data on the Indian economy - quarterly real GDP, its component (GDP from agriculture), the various measures of inflation, the policy rates, the nominal exchange rate of the Indian rupee against the US dollar and the real effective exchange rate (REER index covering 36 partner countries) are taken from the RBI's "Handbook of Statistics on Indian Economy 2008-09" supplemented by information from the RBI's Monthly Bulletin and data put out on the website of the Central Statistical Organisation (CSO) of the Government of India (http://www.mospi.gov.in/mospi_press_releases.htm).

Following Clarida *et al.* (1998, 2000) and Goodhart and Hofmann (2005), we estimate the equations using Generalised Method of Moments (GMM) in view of leads of the explanatory variables being used and potential endogeneity of the variables[9]. For the purely backward-looking specifications, ordinary least squares (OLS) estimates are also reported.

[9] All estimations have been done in WinRATS (version 7.30) with standard errors corrected with Newey-West/Bartlett window and 2 lags in all cases (4 lags in specifications in columns 10-11 in Table 3).

Several alternative formulations were attempted but only the preferred equations are reported here.

IS Curve

Starting with the baseline backward-looking IS curve, the real interest rate has the expected lagged negative impact on the output gap. An increase of 100 basis points in the real policy interest rate leads to a narrowing of the output gap by almost 10 basis points with a lag of three quarters, reflective of the monetary transmission lags[10]. The long-run coefficient is more than double at 24 basis points (Table 1, column 2). The coefficient on agricultural GDP gap is positive and significant, indicating that fluctuations in agricultural activity relative to trend continue to produce powerful demand shocks in the Indian economy, notwithstanding the rising prominence of the services sector. The diagnostic tests indicate that there is no serial correlation in the residuals and this is true for most of the equations estimated in the paper.

While these results suggest that it takes three quarters for the change in the real interest rate to impact demand, some caveats need to be noted in order to depict the real life situation. Whereas interest rates in the money and bond market segments are reasonably flexible and enable the smooth transmission of policy impulses fairly rapidly, the credit market is characterized by asymmetries and bank deposit and lending rates exhibit stickiness for a variety of institutional factors such as administered interest rates for small savings and provident funds on the deposit side, interest rate ceilings and statutory preemptions for loans to agriculture and export sectors on the lending side (Subbarao, 2010). The banking system continues to be dominated by public sector banks (almost 70 per cent share in assets at present) which also infuses uncertainty and market imperfections, and adds to rigidities in the transmission mechanism (Mohan and Patra, 2009). Furthermore, persistent excess liquidity conditions engendered by capital inflows have tended to slow transmission of the policy rate to bank deposit and lending rates. Consequently, lags of the real interest rate remain significant even beyond three quarters – at least, up to eight quarters in the baseline backward looking specification of the IS curve, even as other variables continue to be statistically significant (Table 1, column 3)[11].

[10] Goodhart and Hofmann (2005b) report a coefficient of only (-) 0.02 on the real interest rate for the US and the euro area.

[11] On lags on the real interest rate, our results are consistent with Goodhart and Hofmann (2005b) as well as Rudebusch and Svensson (1999) in which the real interest rate variable in the IS curve is defined as a four quarters average, and not contemporaneously.

Column 4 of Table 1 reports the results of augmenting the baseline specification to incorporate the effects of external demand[12]. The world export gap (representing external demand conditions) is statistically significant: an increase of 100 basis points in the real world export gap is associated with a contemporaneous increase of 12 basis points in the output gap in India in the short-run, with a long-run impact of 17 basis points. Real appreciation of the exchange rate has the expected contracting impact on economic activity: an appreciation of 100 basis points in the real exchange rate gap leads to a narrowing of the output gap by 6 basis points with a lag of two quarters. In the augmented specification, the coefficient on the real interest rate is now somewhat higher in the short-run than in the baseline specification. The coefficients on the real interest rate and the real exchange rate sum to 0.20 (0.28 in the long-run) in line with the cross-country evidence of 0.10-0.25 for a quarterly model (Berg *et al.,* 2006). The results are qualitatively similar for the backward-looking specification when estimated through OLS; however, the real interest rate variable enters significantly only at the fifth lag (Table 1, column 10).

We turn next to the purely forward-looking version of the IS curve and estimate both the baseline and the augmented specifications (columns 5 and 6). The results for the baseline specification (column 5) are broadly the same as the backward-looking version. The only difference is that the real interest rate is significant only at the sixth lag. There is, however, no support for the augmented forward-looking specification: the real interest is not significant (column 6).

[12] We also augmented the equation to examine the impact of stock prices, money supply, bank credit and the cash reserve ratio (CRR) on aggregate demand. However, none of these variables was found to enter the IS curve significantly.

Table 1: Estimates of IS Curve

Variable	Alternative Specifications										
1	2	3	4	5	6	7	8	9	10	11	12
	Dependent Variable: YGAPSA (Sample Period: 1997:2-2009:3)										
	Using GDP deflator									**Using WPI**	
Constant	0.32	0.37	0.37	0.25	0.08	0.12	0.11	0.05	0.16	0.04	-0.03
	(3.3)	(4.8)	(5.6)	(2.4)	(1.0)	(1.4)	(1.8)	(0.6)	(1.3)	(0.4)	(0.6)
RPR{-3}	-0.10		-0.14								
	(2.8)		(5.2)								
RPR{-5}						-0.06		-0.03	-0.08		
						(1.8)		(0.8)	(1.9)		
RPR{-6}				-0.13			-0.06				
				(3.4)			(2.2)				
RPR{-7}					-0.05						
					(1.1)						
RPR{-8}		-0.16									
		(4.4)									
RPRWPI{-5}										-0.01	-0.01
										(0.2)	(0.3)
YGAPSA{-1}	0.59	0.40	0.28			0.39	0.39	0.24	0.26	0.27	0.30
	(8.0)	(7.5)	(4.2)			(8.5)	(8.5)	(3.6)	(2.6)	(2.8)	(5.9)
YGAPSA{+1}				0.55	0.35	0.44	0.43	0.33			0.49
				(9.0)	(6.3)	(8.0)	(9.1)	(4.5)			(6.1)
YGAPAGRSA}	0.13	0.23	0.21	0.24	0.27	0.12	0.11	0.20	0.25	0.25	0.12
	(3.0)	(7.2)	(5.7)	(6.2)	(7.7)	(2.8)	(2.8)	(3.9)	(8.9)	(4.7)	(2.7)
WEXPRGAPSA}			0.12		0.09			0.06	0.09	0.09	0.04
			(8.0)		(7.5)			(4.2)	(3.3)	(5.5)	(2.3)
REER36GAPSA{-2}			-0.06		-0.02			-0.02	-0.08	-0.08	-0.00
			(3.0)		(0.8)			(1.2)	(2.9)	(3.7)	(0.2)
SEE	0.70	0.64	0.62	0.66	0.54	0.56	0.56	0.50	0.53	0.64	0.58
R-bar squared	0.64	0.73	0.72	0.71	0.81	0.79	0.79	0.83	0.80	0.70	0.76
Q-statistic	0.94	0.86	0.21	0.79	0.94	0.01	0.01	0.14	0.75	0.55	0.01
J-specification	9.7	9.1	9.5	10.6	7.4	10.0	9.0	5.6	--	10.9	6.7
Significance level of J	0.71	0.77	0.57	0.64	0.77	0.62	0.70	0.85	--	0.45	0.75

Notes:

1. Estimation is by Generalised Method of Moments (GMM) methodology for the sample period 1997:2 to 2009:3 using quarterly data and two lags each of the following instruments: RPR, YGAPSA, YGAPAGRSA, WEXPRGAPSA, REER36GAPSA, DLNFC, DLBSESA, and CRR. For columns 11-12, the instrument RPR is replaced by RPRWPI. Column 10 is estimated by OLS. Variables names are in Annex 1.
2. Figures in parenthesis are t-statistics. Q-statistic gives significance level of Box-Pierce-Ljung Q-statistic for residual autocorrelation for 4 lags. J-specification and its significance is test for over-identifying restrictions.
3. SEE: Standard error of estimate.

Columns 7 and 8 present the results of the baseline hybrid specifications *i.e.*, including both lagged and expected output gaps. The empirical results support this formulation. The coefficients on both the lagged and one-quarter ahead expected output gap are positive and significant; moreover, the coefficient on the expected output gap is somewhat higher than the lagged output gap. On the other hand, the coefficient on the real interest rate turns out to be significant only at the fifth and sixth lags. However, the Q-statistic suggests serial residual correlation. When the hybrid specification is augmented to control for external demand variables, the coefficient on the real interest rate, as in the purely forward-looking version, turns insignificant (Table 1, column 9).

With WPI inflation, the coefficient on the real interest rate is no longer significant although correctly signed (Table 1, columns 11-12). This could perhaps be reflecting the greater variability in quarter to quarter headline WPI inflation. Other variables are broadly unchanged vis-à-vis those based on the GDP deflator.

Overall, the backward-looking augmented specification (Table 1, column 4) seems to provide the best fit and this is our preferred specification for use in model simulation later on. This equation also produces satisfactory results in terms of in-sample dynamic forecasting. The Theil inequality measure (TIM) is relatively low, indicative of better fit. The decomposition of TIM shows that bias and variance are quite low – almost close to zero. Most of TIM can be attributed to co-variance proportion, which measures unsystematic error (Table 2)[13].

Table 2: Forecasting Performance

S. No.	Statistic	IS curve (Table 1, col. 4)	Phillips curve (Table 3, col. 4)	Policy rule (Table 4, col. 2)	Policy rule (Table 4, col. 3)
1	2	3	4	5	6
1	Mean error	-0.06	-0.07	0.40	0.23
2	Mean absolute error	0.49	1.15	1.08	0.91
3	Root mean square error (RMSE)	0.65	1.45	1.37	1.10
4	RMSE (%)	--	35.5	20.9	17.5
5	Theil inequality measure	0.29	0.15	0.10	0.08
	a. Bias	0.01	0.00	0.08	0.04
	b. Variance	0.03	0.13	0.22	0.11
	c. Co-variance	0.96	0.87	0.70	0.85

Note: The various statistics are for dynamic in-sample forecasts of individual equations.

[13] For any value of TIM, the ideal distribution of inequality is: bias and variance should be both close to zero and co-variance should be close to 1 (Pindyck and Rubinfeld,1998).

Phillips Curve

The limited evidence in the Indian context finds support for a backward-looking specification of the Phillips curve (RBI, 2002; RBI, 2004; Kapur and Patra (2000); Patra and Ray (2010)]. Accordingly, we begin with the pure backward-looking specification as the baseline. Our estimation results indicate that a widening of the output gap by 100 basis points results in a rise of inflation by 32 basis points with a lag of four quarters (the long-run impact is almost three times higher at around 94 basis points) (column 2, Table 3). Inflation displays a considerable degree of inertia as indicated by the large size of the lagged coefficient (0.66). This suggests that shocks to inflation can be persistent. Global commodity prices (non-fuel) have the expected positive impact on domestic inflation. While the coefficient on global inflation (0.06 in the short-run and 0.18 in the long-run) may appear small, it needs to be assessed in relation to the sheer size of the changes witnessed in international commodity prices in recent years. For instance, in the quarter April-June 2008, the IMF's commodity price index (non-fuel) registered an increase of 15 per cent (y-o-y); the estimated coefficient of 0.06 suggests that this global commodity price surge would have added almost one percentage point to domestic inflation in the same quarter, with the long-run impact being almost three percentage points. In the quarter ended June 2008, domestic inflation (GDP deflator) was 7.7 per cent, up from 5.9 per cent a year earlier. A year later in April-June 2009, the IMF's commodity price index collapsed by 33 per cent (y-o-y) and the estimated same-quarter impact on domestic inflation would have been a reduction of almost 2.0 percentage points (domestic inflation at that point was only 0.9 per cent). Thus, the significant volatility exhibited by global commodity prices has been an important driver of domestic inflation in the recent period. The OLS estimates for the backward-looking specification are almost similar to the GMM estimates (column 8, Table 3). In view of the sharp acceleration in primary articles inflation from 1.2 per cent in the quarter ended December 1997 to 15.3 per cent a year later, we include a dummy (DUM1998Q3Q4) for the quarters July-September 1998 and October-December 1998.

The estimated equations imply a sacrifice ratio in the range of 1-2, close to the estimates in Kapur and Patra (2000) and RBI (2002). This suggests that monetary policy induced disinflation of one percentage point from its trend/long-run average is associated with a reduction of 1-2 per cent in output (see Kapur and Patra, *op cit.*).

Is the inflation process in India forward-looking? Empirical evidence supports the proposition. In our purely forward-looking specification (Table 3, column 3), the coefficient on the output gap is significant and broadly unchanged relative to the backward-looking specification. The coefficient on lead inflation (0.63) attests to the strength of expectations in influencing current inflation. We turn next to the hybrid Phillips curve specification (Table 3, column 5). The coefficients on both the lagged (0.59) and the quarter-ahead inflation (0.42) are statistically significant[14]. The coefficient on output gap remains significant, albeit lower at 0.20 *vis-a-vis* 0.32 in the baseline. The null hypothesis that the sum of coefficients of the lagged and the quarter-ahead expected inflation is unity cannot be rejected, validating the vertical nature of the long-run Phillips curve and, therefore, the absence of any exploitable trade-off in the long-run in the Indian context.

Exchange Rate Pass-through

The growing openness of the Indian economy, and the increasing co-movement of global and domestic prices alongside a greater flexibility in movements of the exchange rate has generated animated interest in India in exchange rate pass-through into domestic inflation. At one end of the spectrum, there is an advocacy for using the exchange rate as an instrument for inflation management (Shah, 2008; IMF, 2010). On the other hand, there is the view expressed by the authorities: "Our exchange rate policy is not guided by a fixed or pre-announced target or band. Our policy has been to intervene in the market to manage excessive volatility and disruptions to the macroeconomic situation" (Subbarao, 2010). We assess this debate by augmenting the baseline and hybrid specifications with the nominal exchange rate measured by year-on-year variation of the Indian rupee *vis-a-vis* the US dollar.

In the backward-looking specification, the exchange rate variable is statistically significant (column 4, Table 3), although the coefficient on the output gap is lower at 0.20 from 0.32 in the baseline. The dynamics show that that the cumulative pass-through increases from 0.05 on impact to 0.08 after one quarter, 0.11 after two quarters, 0.12 after three quarters, 0.13 after four quarters and reaches close to its long-run value of 0.15 after seven quarters. These results suggest that a 10 per cent appreciation (depreciation) of the Indian rupee (*vis-a-vis* the US dollar) would reduce (increase) inflation by 0.5 percentage points in the same quarter, by 1.3 percentage points after a year and by 1.5 percentage points after seven quarters. The results appear to be broadly confirmed by the coefficients obtained in the hybrid specification, although the Q-statistics point to serial correlation in residuals (Table 3, column 7). In the OLS estimation of the backward-looking version, the exchange rate variable is only weakly significant (Table 3, column 9). Overall, on a careful assessment of various specifications and their diagnostics, the backward-looking specification augmented with the

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[14] This is consistent with the cross-country evidence that finds the coefficient on expected inflation to be significantly below 0.50 (Berg *et al*., 2006). For the US, Gali *et al*. (2005) estimate the coefficients on expected inflation to be higher at 0.65, but as discussed earlier, this could be reflecting omission of supply shocks (Mehra, 2004).

exchange rate and global inflation (Table 3, column 4) is our preferred specification when we simulate the full model.

Using WPI in lieu of the GDP deflator (Table 3, columns 10-11) does not materially alter the results in the backward-looking specification. The exchange rate pass-through is slightly higher: 0.06 in the same quarter and 0.21 in the long-run. The hybrid version, however, does not provide a good fit: the coefficient on the output gap is insignificant.

The exchange rate pass-through obtained from the augmented backward looking Phillips curve specification (column 4, Table 3) appears to be consistent with other estimates - 0.06-0.10 (Khundrakpam, 2008; Choudhri and Hakura, 2001) and 0.17-0.23 (RBI, 2004), although the methodologies and time periods are different. The exchange rate pass-through for India is close to that of low inflation countries (0.16)[15]. A low coefficient on pass-through suggests that monetary policy is credible - economic agents anticipate that, in the event of substantial exchange rate movements, the central bank would take necessary steps to contain inflation around the target (Taylor, 2000).

[15] A cross-country comparison indicates that the long-run pass-through coefficient for low inflation countries (inflation of less than 10 per cent) is estimated at 0.16, whereas for moderate inflation countries (inflation rate of 10-30 per cent) and for high inflation countries (inflation rate of above 30 per cent), the coefficient is 0.35 and 0.56, respectively (Choudhri and Hakura, 2001). For the six major advanced economies (non-US G-7), the long-run pass-through coefficient is in the range of 0.09 (France, Japan) to 0.36 (Germany), while the average across the six countries is 0.19 (Choudhri *et al.,* 2005). For Korea and euro area, the long-run pass-through coefficient is 0.13 each, whereas for the US and Japan is lower at 0.02 and 0.04, respectively; on the other hand, for China (0.77), Hong Kong (0.37) and Chile (0.35) are found to be higher (Ca'Zorzi *et al*., 2007).

Table 3: Estimates of Phillips Curve

Variable	Alternative Specifications									
1	2	3	4	5	6	7	8 (OLS)	9 (OLS)	10	11
	Dependent Variable: INFGDP								**Dependent Variable: INFWPI**	
	Sample Period: 1997:2-2009:3									
Constant	1.19	1.60	1.02	-0.14	-0.22	-0.36	1.05	0.98	0.90	-1.08
	(7.4)	(8.1)	(7.1)	(0.7)	(1.0)	(2.1)	(3.3)	(3.1)	(7.7)	(5.1)
YGAPSA{-4}	0.32	0.35	0.20	0.19	0.14	0.10	0.24	0.19	0.28	0.05
	(4.9)	(5.2)	(3.4)	(4.8)	(2.8)	(2.0)	(2.2)	(1.7)	(3.1)	(1.1)
INFGDP{-1}	0.66		0.67	0.59	0.59	0.60	0.69	0.67		
	(17.3)		(20.3)	(16.0)	(14.9)	(14.8)	(8.9)	(10.0)		
INFGDP{+1}		0.63		0.42	0.41	0.44				
		(16.4)		(8.9)	(7.4)	(10.0)				
INFWPI{-1}									0.72	0.64
									(28.1)	(23.2)
INFWPI{+1}										0.54
										(10.6)
INFGLOBAL	0.06		0.08	0.03	0.04	0.04	0.06	0.08	0.10	0.03
	(11.0)		(6.4)	(5.1)	(3.0)	(3.0)	(4.5)	(4.2)	(7.6)	(2.2)
DUM1998Q3Q4	3.97	3.00	3.32	1.18	0.81		4.23	3.89	2.08	0.57
	(8.1)	(4.6)	(6.0)	(1.5)	(1.0)		(9.4)	(7.6)	(5.2)	(1.8)
DLEXCHA			0.05		0.04	0.04		0.05	0.06	0.03
			(2.4)		(1.6)	(1.9)		(1.6)	(2.4)	(1.6)
SEE	1.09	1.30	1.07	0.92	0.92	0.96	1.07	1.05	1.14	0.83
R-bar squared	0.71	0.57	0.72	0.78	0.78	0.76	0.72	0.73	0.71	0.85
Q-statistic	0.32	0.05	0.37	0.01	0.00	0.00	0.32	0.43	0.07	0.00
J-specification	11.4	11.7	11.2	11.9	12.1	11.9			8.5	8.2
Significance level of J	0.78	0.82	0.74	0.69	0.60	0.69			0.90	0.88
Memo:										
Chi-squared (1) *				0.00	0.00	0.95				13.3
Significance level *				0.95	0.98	0.33				0.00
Sacrifice ratio	1.1	--	1.7	--	--	--	1.3	1.7	1.0	--
Exchange rate pass-through (long-run coeff.)	--	--	0.15	--	--	--	--	0.15	0.21	--

*: Test for the hypothesis that the coefficients on lagged and expected inflation sum to unity.

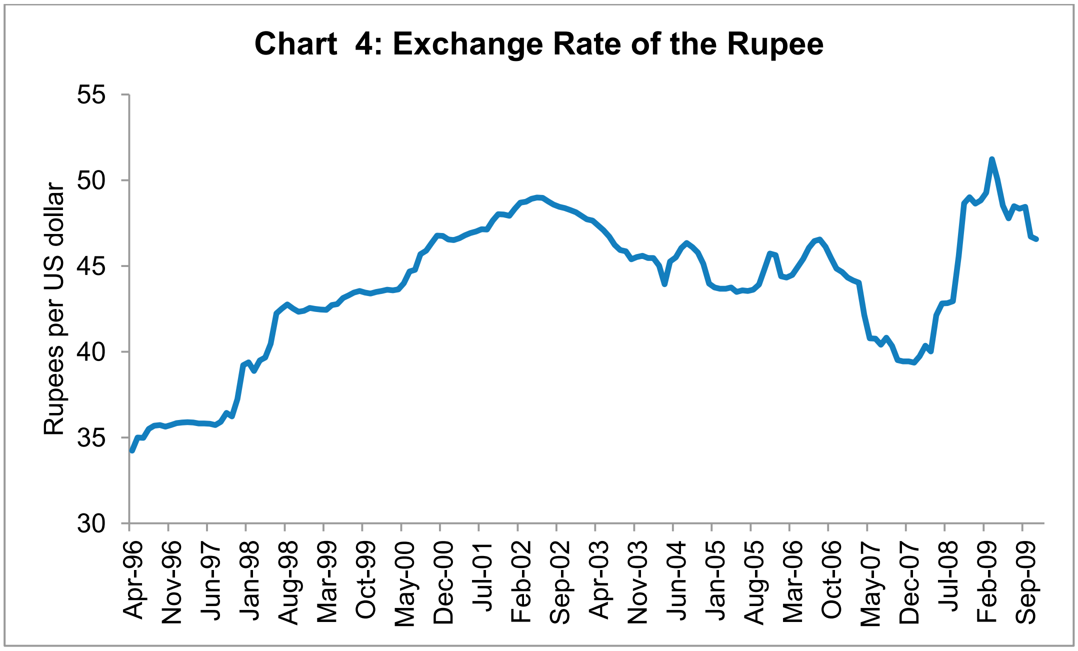
Notes:

1. Estimation is by GMM methodology for the sample period 1997:2 to 2009:3 using quarterly data and two lags each of the following instruments: YGAPSA, YGAPAGRSA, INFGDP, INFCPI, INFWPI, INFGLOBAL, INFPC, INFPOL, DLEXCHA and DLM3. Columns 8 and 9 are estimated by OLS. Variable names are in Annex 1.
2. Figures in parenthesis are t-statistics.. Q-statistic gives significance level of Box-Pierce-Ljung Q-statistic for residual autocorrelation for 4 lags. J-specification and its significance is a test for over-identifying restrictions.
3. Sacrifice ratio is (1-coefficient on lagged inflation)/(coefficient on output gap).
4. SEE: Standard error of estimate

Turning back to the debate on exchange rate pass through and inflation management, it is worthwhile to take note of a few India specific features. First, in the Indian context, periods of higher inflation are often caused by supply shocks emanating from agricultural commodities like pulses, oilseeds and wheat/rice where imports are often not a viable solution, given the scale of imports needed to satisfy demand for a country as large as India. Moreover, in case of items such as pulses, imports are not an option due to non-availability of close substitutes. Consequently, the exchange rate would turn out to be a relatively feeble and even futile instrument in view of this inflation history and the sheer magnitude and frequency of the supply shocks to which the Indian economy is prone. Second, as the IS curve estimates show, real appreciation has a significant negative impact on aggregate demand and this impact works its way through adverse impact on net exports and the tradable sector. While the current account deficit in India has been modest, the merchandise trade deficit is rather high (close to 10 per cent of GDP). Large external deficits, as the cross-country experience clearly shows, can be a source of future vulnerability. Finally, the policy preference, which appears to be broadly supported by the literature, is for progressively increasing the flexibility of the exchange rate so as to derive its natural equilibrating properties in the context of balance of payments adjustment rather than artificially manipulating it to secure short-sighted domestic objectives that are by no means assured. Illustratively, the Indian rupee appreciated by 18 per cent *vis-a-vis* the US dollar between August 2006 and January 2008. This appreciation was more than reversed over the next 14 months as the rupee depreciated by 23 per cent between January 2008 and March 2009 (Chart 4). In the face of substantial two-way movements of the exchange rate, a policy aimed at an opportunistic use of exchange rate appreciation to contain inflation will not yield durable results. On the debate, therefore, while the jury may be out, the estimation results and the circumstantial evidence in India as well as in other large continental economies in which external trade is relatively small portion of GDP, indicate that the argument for using the exchange rate as an inflation management tool appears to be short-sighted and weighed down by adverse implications.

Monetary Policy Reaction Function

In the context of the monetary policy reaction function, the clear preference in the literature is for a forward looking rule, reflecting the recognition of 'long and variable lags' in monetary transmission. The place of the pure backward looking specification analogous to the IS and Phillips curves set out earlier is taken by one that employs contemporaneous arguments in the tradition of Taylor (1993). Accordingly, we begin with the estimates of the forward-looking specification with inflation measured by deviation of the GDP deflator from the RBI's indicative inflation threshold of around 5 per cent.



Experimentation with various leads produces the best results for a formulation with two-quarter ahead inflation and output gap, with both variables significant and with the expected positive signs. A one percentage increase each in expected inflation and the output gap provokes a symmetric response in the form of an increase in the policy rate by 29 and 25 basis points, respectively (Table 4). The lagged policy coefficient is 0.79, indicating a high degree of interest rate smoothing in India, which is consistent with the observed response of monetary policy, both domestically and globally. The long-run coefficient on inflation is estimated at 1.4, consistent with the Taylor principle (*i.e.*, the coefficient should be greater than unity) – a requirement for a stable reaction function, as pointed out in Sections II and IV. The long-run coefficient on the output gap turns out to be 1.2, indicating the strong commitment of the RBI relative to other central banks to output stabilization within its multiple objectives[16].

[16] For the six major advanced economies, Clarida, Gertler and Gali (1998) found the long-run coefficient on output gap ranging between 0.08 (Japan) and 0.88 (France) - the simple average for these six countries was 0.36. For the euro area, Blattner and Margaritov (2010) report an average coefficient of 0.94 on output growth. Mohanty and Klau (2004) in their study of 13 EMEs estimate the long-run coefficient on output gap in a wide range of 0.43 (India) to 3.5 (Brazil). The simple average across the sample countries was 1.21.

Table 4: Estimates of Monetary Policy Reaction Function (Forward-looking)

Variable	Alternative Specifications							
1	2	3	4	5	6	7	8	9
	Dependent Variable: EFFECTIVE Sample Period: 1997:2-2009:3							
	Inflation Measured by GDP Deflator				**Inflation Measured by WPI**			
Constant	1.41	1.50	1.21	1.57	0.54	0.70	0.58	0.87
	(4.4)	(4.7)	(4.6)	(5.6)	(1.8)	(2.1)	(2.3)	(2.8)
INFGDPDEV{+2}	0.29	0.25	0.20	0.21				
	(3.5)	(2.9)	(4.4)	(3.5)				
INFWPIDEV{+2}					0.30	0.30	0.24	0.25
					(3.8)	(3.2)	(2.8)	(2.6)
YGAPSA{+2}	0.25	0.24	0.02	0.06	0.25	0.22	0.16	0.17
	(2.7)	(2.9)	(0.3)	(0.7)	(2.7)	(2.7)	(1.8)	(2.0)
EFFECTIVE{-1}	0.79	0.77	0.71	0.66	0.90	0.88	0.85	0.82
	(16.7)	(16.6)	(17.3)	(11.8)	(21.5)	(17.8)	(15.5)	(13.1)
DLEXCH4{-1}		0.02		0.01		0.02		0.01
		(1.9)		(1.7)		(1.5)		(1.4)
FEDFUND			0.21				0.08	
			(4.2)				(1.6)	
FEDFUND{-1}				0.20				0.07
				(2.8)				(1.4)
SEE	0.82	0.82	0.68	0.72	0.81	0.82	0.74	0.76
R-bar squared	0.76	0.77	0.84	0.82	0.77	0.77	0.81	0.80
Q-statistic	0.83	0.73	0.45	0.37	0.91	0.87	0.84	0.72
J-specification	8.6	4.2	9.7	4.8	5.4	4.6	5.8	4.5
Significance level of J	0.38	0.76	0.21	0.57	0.72	0.71	0.57	0.61
Memo:								
Long-run coefficient on inflation	1.4	1.1	0.7	0.6	3.0	2.5	1.6	1.4
Long-run coefficient on output gap	1.2	1.0	--	--	2.5	1.8	1.1	0.9
Long-run coefficient on exchange rate	--	0.09	--	--	--	--	--	--
Neutral policy rate	6.7	6.5	--	--	5.4	5.8	--	--

Notes:
1. Estimation is by Generalised Method of Moments (GMM) methodology for the sample period 1997:2 to 2009:3 using quarterly data and one lag each of the following instruments: EFFECTIVE, YGAPSA, WEXPRGAPSA, INFGDPDEV, INFCPIDEV, INFWPIDEV, INFGLOBAL, DLEXCH4, DLM3, DLNFC and FEDFUND. Variable names are in Annex 1.
2. Figures in parenthesis are t-statistics. Q-statistic gives significance level of Box-Pierce-Ljung Q-statistic for residual autocorrelation for 4 lags. J-specification and its significance is a test for over-identifying restrictions
3. SEE: Standard error of estimate.

Consistent with the open economy specifications of the IS and Phillips curves, the forward looking policy reaction function is augmented by the US federal funds rate as well as by changes in the rupee/US dollar exchange rate. Both variables turn out be significant with the expected signs. A 10 per cent depreciation (q-o-q, annualized) of the rupee *vis-a-vis* the US dollar, *ceteris paribus*, is associated with a modest increase of 2 basis points in the policy rate a quarter later, with the long-run impact being less than 10 basis points (Table 4, column 3). The Indian rupee has exhibited significant two-way movements over the past decade. Since the early 2000s, there is no evidence of any systematic policy rate responses to exchange rate movements. The Reserve Bank's main instrument to smooth excessive exchange rate volatility has been active capital account management along with interventions in the foreign exchange market (Mohan and Kapur, 2009). Turning to the US Federal Funds rate, an increase of 100 basis points in the Fed Funds rate is associated with an increase of 21 basis points in the policy rate with a one quarter lag (Table 5, column 4). The introduction of the Fed funds rate, however, generates instability in the reaction function - the long-run coefficient on inflation falls below unity, while the coefficient on the output gap turns insignificant.

On the basis of a comparison of various specifications and diagnostics (including forecasting criteria in Table 2), we prefer the specification augmented with exchange rate (Table 4, column 3) for the full model simulation.

Forward-looking Monetary Policy Rule with WPI Inflation

When WPI inflation is used, the policy response is more robust to inflation and the output gap across all specifications. In the baseline specification, the long-run coefficient on inflation turns out to be as high as 3.0 (Table 4, column 6) and remains above unity in most specifications. There are, however, some notable differences *vis-a-vis* the policy reaction function that uses the GDP deflator. First, both the exchange rate and the US Federal Funds rate now turn insignificant. Second, the degree of interest rate smoothing appears to be higher. At the risk of broad generalization and purely from an estimator's perspective, these results do not recommend the incorporation of an international policy interest rate such as the Fed funds rate in the policy reaction function for India.

Neutral Policy Rate

An important issue that is often raised in the context of a monetary policy framework wielding the interest rate as its main instrument is: what is the neutral policy rate? Empirically, it corresponds to that policy rate at which the output gap is zero and inflation is at target/threshold. The estimated equations implicitly suggest that the neutral policy rate is around 5.5-6.5 per cent – around 6.5 per cent when the GDP deflator is used and around 5.5-6.0 per cent with the WPI (Tables 4 and 5). These estimates of the neutral rate should be treated as indicative and within wide confidence intervals, warranting corroboration by alternative methodologies, and should not be seen as point estimates. Furthermore, the assessment of the neutral rate is conditional upon the view on the rate of potential output growth which, in the Indian context, is widely regarded to be on a rising trajectory over the medium-term as more of latent productive capacity in the economy gets actualized. Given the uncertainties, the neutral rate curve is thick and reflective of a range of scenarios (Gokarn, 2010)**.**

Monetary Policy Rule with Contemporaneous Variables

Taylor (1993) preferred the use of current period inflation and output gaps rather than their expected future values in view of uncertainty surrounding future projections. Estimation of a policy reaction function formulation with contemporaneous arguments for the baseline specification (column 2, Table 5) shows that the coefficients on both inflation (GDP deflator) and output gap remain positive and significant, but the long-run coefficient on inflation turns out to be less than unity, whereas that on the output gap remains above unity. In the augmented specification, the exchange rate variable now turns out to be insignificant. As regards the US Federal Funds rate, the variable continues to be statistically significant (Table 5, columns 3-5). The results are almost identical when WPI is used as the measure of inflation (Table 6, columns 6-9).

How do our estimates compare with other work in this area? Anand *et al.* (2010) estimate a DSGE model for India and find, first, that the weight on exchange rate is almost three times that on inflation in the estimated policy rule - "the RBI places more emphasis on stabilizing the rate of depreciation than on reducing inflation volatility". Second, they find that output stabilization does not play a significant part in the conduct of monetary policy – neither in the estimated policy rule nor in the optimal rule. These findings are not corroborated by our estimation results, abstracting from choice of methodology. First, our estimates show that the weight on inflation is more than 12 times that on the exchange rate in the forward-looking version when inflation is measured by the GDP deflator (Table 4, column 3). Furthermore, in the forward-looking version with inflation measured by the WPI as well as in the contemporaneous formulation for both the GDP deflator and the WPI, the exchange rate is not significant. Second, the coefficient on the output gap is significant in most of our specifications. Thus, output stabilization is an important determinant of the monetary policy response in India. Finally, the long-run coefficient on inflation is significantly above unity in our forward-looking specifications.

Table 5: Estimates of Monetary Policy Reaction Function (Contemporaneous)

Variable	Alternative Specifications							
1	2	3	4	5	6	7	8	9
	Dependent Variable: EFFECTIVE Sample Period: 1997:2-2009:3							
	Inflation Measured by GDP Deflator				**Inflation Measured by WPI**			
Constant	1.27	1.43	1.39	1.60	1.01	1.14	1.01	1.16
	(4.7)	(3.6)	(5.0)	(4.9)	(4.8)	(3.2)	(4.3)	(4.2)
INFGDPDEV	0.10	0.12	0.11	0.13				
	(2.3)	(2.2)	(3.1)	(3.1)				
INFWPIDEV					0.08	0.09	0.06	0.05
					(2.8)	(2.7)	(2.2)	(1.7)
YGAPSA	0.29	0.29	0.16	0.12	0.28	0.28	0.21	0.14
	(3.7)	(3.7)	(2.3)	(1.6)	(3.6)	(3.2)	(2.2)	(1.5)
EFFECTIVE{-1}	0.80	0.78	0.69	0.65	0.83	0.81	0.76	0.73
	(19.3)	(13.8)	(13.2)	(10.0)	(23.9)	(14.9)	(17.7)	(13.6)
DLEXCH4{-1}		0.00		0.00		0.00		0.00
		(0.4)		(0.4)		(0.4)		(0.4)
FEDFUND			0.18				0.13	
			(3.4)				(2.6)	
FEDFUND{-1}				0.20				0.16
				(2.9)				(2.3)
SEE	0.68	0.70	0.60	0.62	0.71	0.72	0.65	0.67
R-bar squared	0.86	0.85	0.89	0.88	0.85	0.84	0.87	0.86
Q-statistic	1.00	0.99	0.92	0.88	1.00	1.00	0.92	0.95
J-specification	6.3	5.4	8.3	5.5	5.6	5.0	7.6	6.7
Significance level of J	0.62	0.61	0.31	0.48	0.69	0.66	0.37	0.35
Memo:								
Long-run coefficient on inflation	0.5	0.5	0.4	0.4	0.5	0.5	0.3	0.2
Long-run coefficient on output gap	1.5	1.3	0.5	--	1.6	1.5	0.9	--
Long-run coefficient on exchange rate	--	--	--	--	--	--	--	--
Neutral policy rate	6.4	6.5	--	--	5.9	6.0	--	--

Notes:
See Table 4.

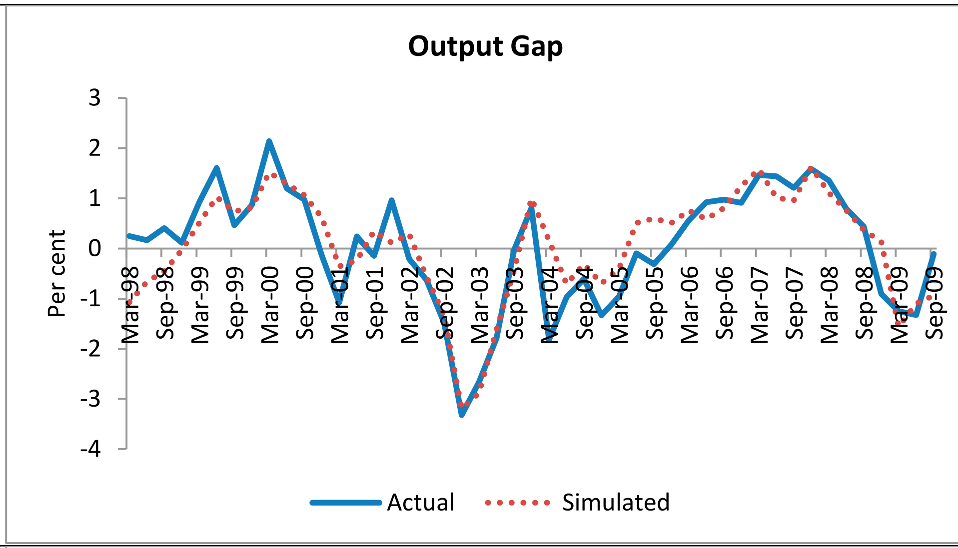
Mohanty and Klau (2004) also find that the long-run coefficient on the exchange rate (0.60) is higher than that on inflation (0.43). First, apart from differences in sample periods, Mohanty and Klau (2004) use the real exchange rate in the policy rule, whereas we use the nominal exchange rate in keeping with the announced intention of containing nominal exchange rate volatility. Second, while we use the policy interest rate in the reaction function in the tradition of Taylor, market interest rates are used by Mohanty and Klau and Anand *et al.* - daily inter-bank interest rate in Mohanty and Klau (2004) and 3-month treasury bill rate in Anand *et al.* (2010). Market interest rates do respond to policy rate signals, but they are episodically impacted by autonomous volatility due to liquidity conditions, market-related shocks, news and announcement effects that can be persistent, inducing deviations away from the policy rates that are lasting (Bhattacharya *et al.*, 2009). Moreover, during March-August 2007, a ceiling of Rs.30 billion was imposed on daily absorption through reverse repo under the LAF. This had the impact of dragging overnight money market interest rates to near zero even as policy rates were unchanged during this period. Third, Mohanty and Klau (2004) use industrial production as a proxy for output, while we use GDP which is the most comprehensive measure of output. Finally, we find that a forward-looking model better explains monetary policy behavior *vis-à-vis* contemporaneous specifications, whereas Anand *et al* and Mohanty and Klau report only contemporaneous versions.

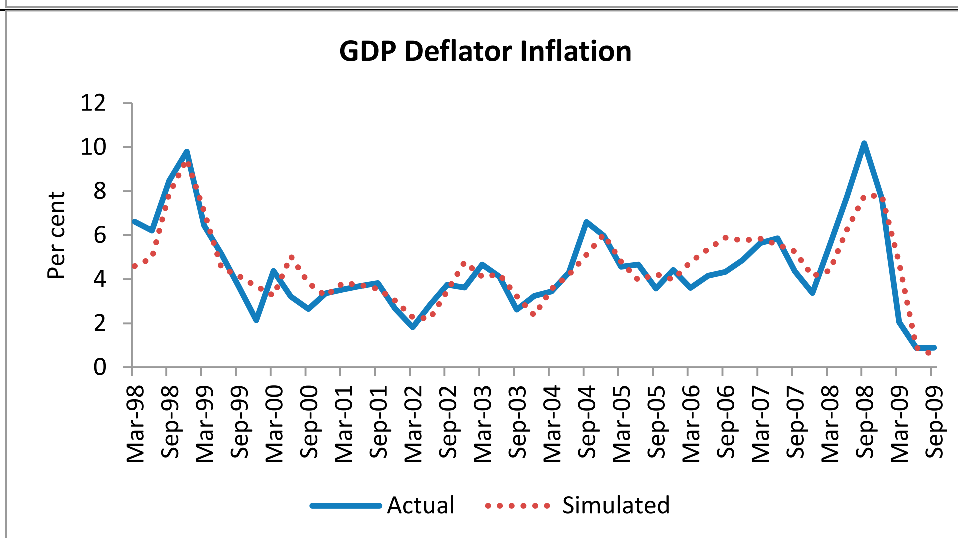
Model Simulations

Collecting these results, we proceed to simulating the full model using our preferred specifications *i.e*., the backward looking IS curve augmented with open economy terms (Table 1, column 4), the backward looking extended Phillips curve (Table 3, column 4) and the forward looking baseline augmented policy reaction function (Table 4, column 3)**.** The simulations show that the model tracks the actual data reasonably well, including most of the turning points (Chart 5), with three notable exceptions. The model over-predicts the output gap during the period 2004-05 which, given the lags, is mirrored in higher inflation in 2006.This episode needs to be seen in the context of the underlying growth dynamics of that period. The Indian economy had gone through a slowdown during the period 2000-02, with real GDP slackening from nearly a decade of 6 percent plus growth to an average of 4.7 percent. In 2003-04, there was a strong rebound to 8.5 percent, but it was interrupted in 2004-05 as drought conditions brought about a sharp fall in the growth of agricultural output to near zero, beginning from the last quarter of 2003-04. In the following years i.e., 2005-08, momentum was regained and growth averaged 9.5 percent. Thus, the year 2004-05 in which real GDP growth was a healthy 7.5 percent, turned out to be an outlier in a shift in the growth trajectory that was being charted by the Indian economy before the global crisis struck. Compensatingly, however, the model appears to have predicted inflation reasonably well and consequently, there was a very moderate over-prediction of the policy rate in the relevant quarters. The second episode is in 2008 (Q1 to Q3), with the model under-predicting inflation, which is reflected in the under-prediction of the policy rate in early 2009. This is attributable to the sharp increase in international crude oil prices and the concomitant increase in domestic fuel prices (including the administered component of fuel items). Fuel group inflation in the WPI rose sharply from 2.9 per cent (y-o-y) in December 2007 to 17.2 per cent in August 2008 – for India as for the rest of the world, the third oil shock! Finally, the model is unable to capture the shift to unconventional and unprecedented monetary policy post-Lehman Brothers as a part of which policy rates were cut to all-time lows. But this must be true of policy interest rate reaction functions the world over, especially in advanced economies where the zero nominal bound was encountered and the rest is history still being made.

We also assess model dynamics in response to shocks to endogenous variables (inflation, output gap and policy rate) as well as some exogenous variables (global commodity inflation, world exports, nominal and real exchange rates). An increase in expected inflation attracts a pre-emptive monetary policy response, which leads to higher real interest rates immediately, contraction in aggregate demand and closing of the output gap. Over time, inflation comes down in response to higher interest rates, but the reversion of interest rates back to the baseline is protracted - it takes almost 2-3 years for all the three variables to return to the baseline. Similar dynamics are in play in response to an aggregate demand (output gap) shock. The monetary transmission lags are evident from a shock to the policy interest rate. Output starts contracting after three quarters and reaches its trough after one more quarter before gradually returning to its baseline. Inflation responds after seven quarters of the shock and the maximum impact is felt after 10 quarters (Chart 6). Clearly, monetary policy has a persistent impact on real activity and inflation in the short-run, even as there is no long-run impact.

Chart 5: Model Simulation





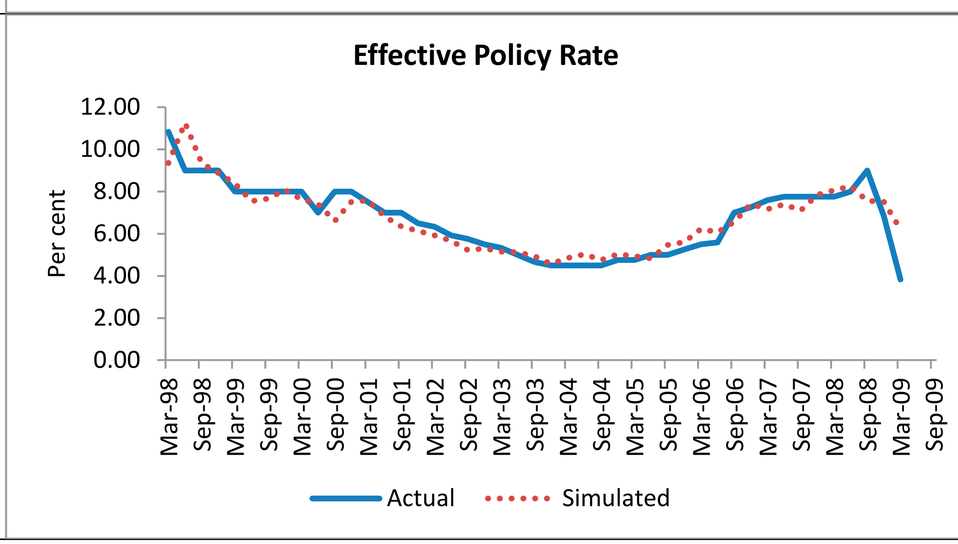
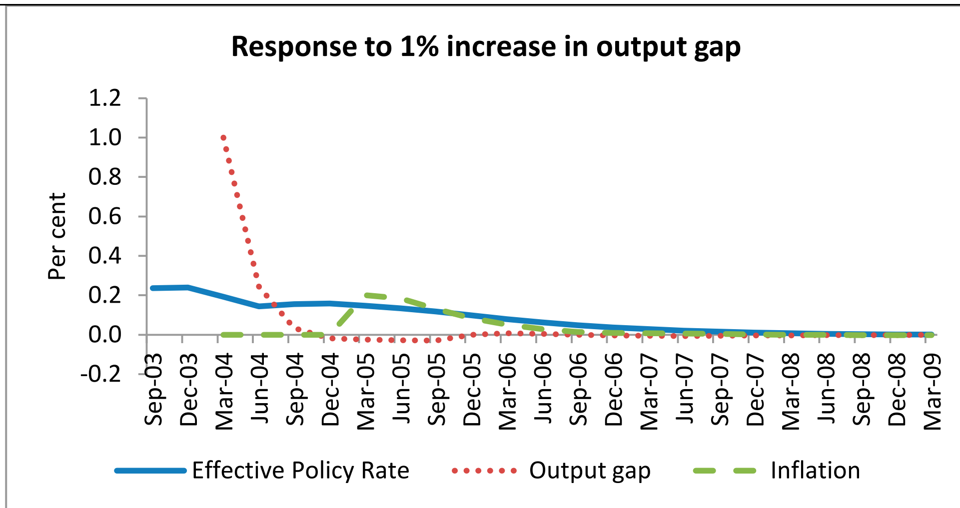
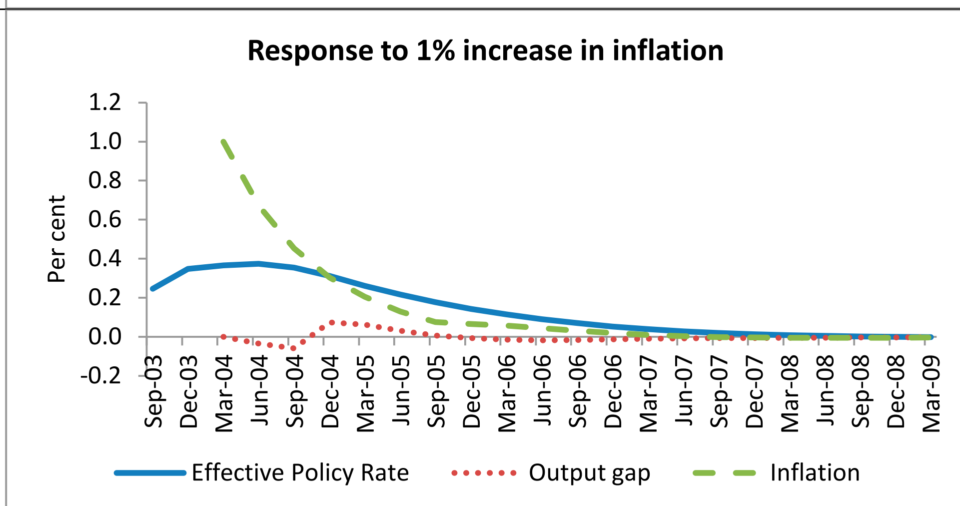
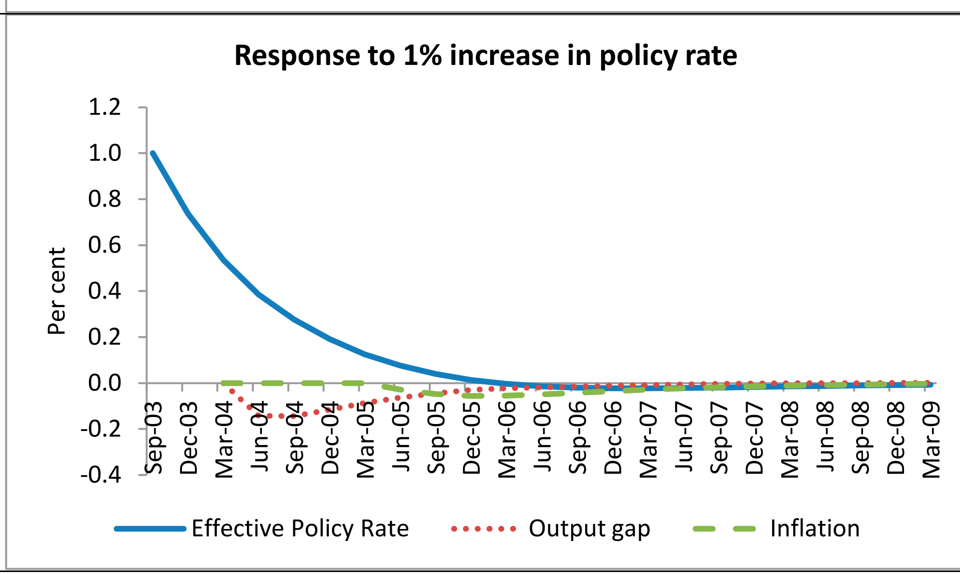


Chart 6 : Responses to Shocks to Endogenous Variables: Deviation from the Baseline

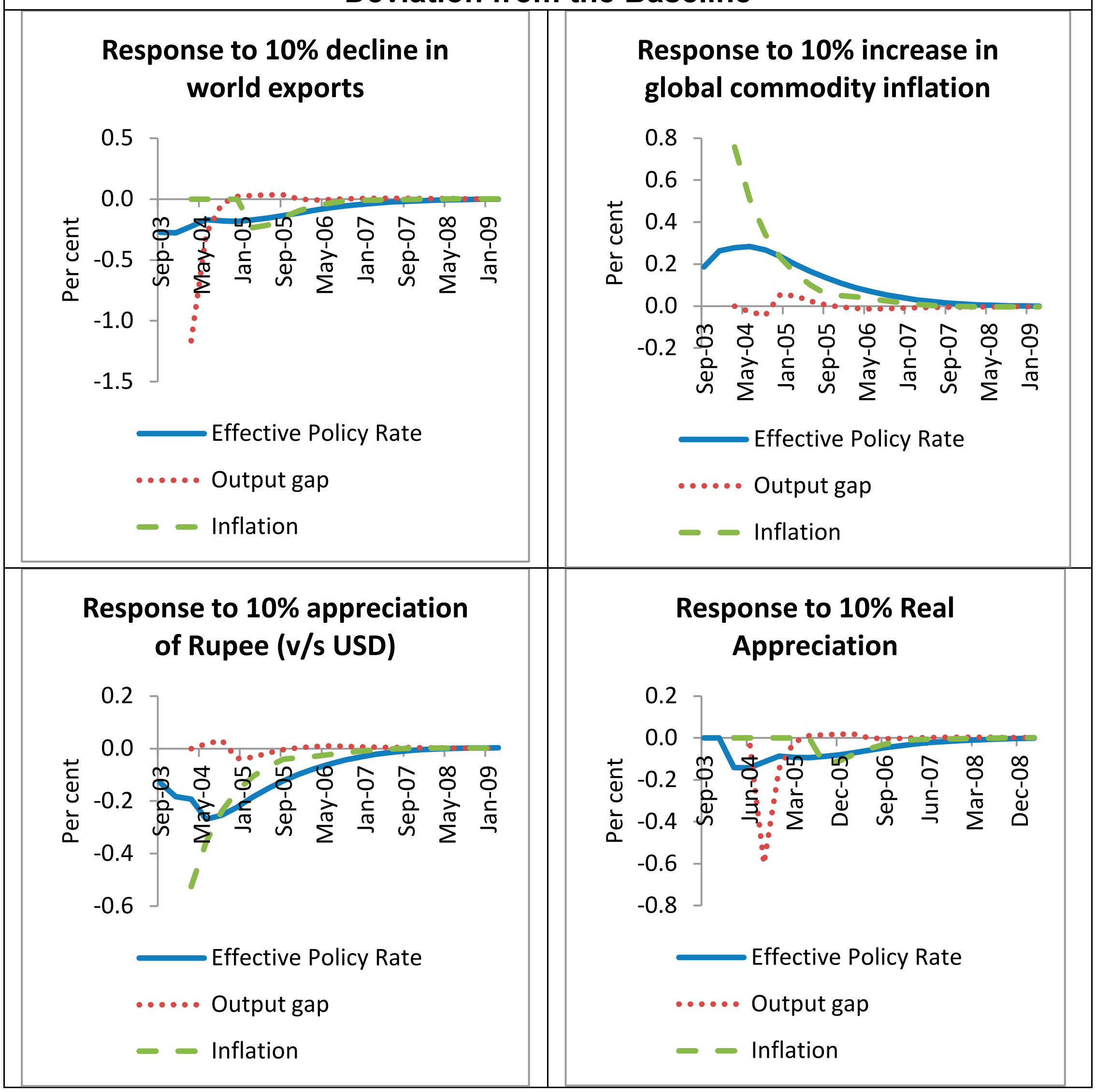






As regards the exogenous shocks, appreciation of the nominal exchange rate lowers inflation and the effect is protracted. Lower inflation induces monetary easing, which boosts demand temporarily. In contrast, a real appreciation shock dampens aggregate demand and, with a lag, reduces inflation. Monetary policy eases pre-emptively, given the forward-looking nature of the reaction function (Chart 7). In practice, the two shocks will work together. Any nominal appreciation will immediately translate into real appreciation, given rigidity in prices. The dampening effect of real appreciation on aggregate demand will be mirrored in external deficits with potential consequences for external sector sustainability and financial stability.

Chart 7 : Responses to Shocks to Exogenous Variables: Deviation from the Baseline



To sum up, the estimates of the IS curve, the Phillips curve and the monetary policy reaction function are consistent with the cross-country evidence. Sensitivity analysis suggests that the estimates are generally robust. Monetary policy reacts in a forward-looking manner to expected inflation and output dynamics. This also highlights the need for monetary policy to be pre-emptive for effective macroeconomic stabilization.

VI. Conclusion

This paper was a voyage of exploration and discovery. What began as a search for establishing analytical underpinnings for the monetary policy framework currently in place in India encountered some of the fundamental, almost metaphysical, questions that confront the profession regarding the conduct of monetary policy as an instrument of macroeconomic stabilization. At the end of this crossing, these questions may remain unanswered in fullness, as in all metaphysics, but definitely not unaddressed.

The paper bears out our expectations that the new Keynesian framework provides the intellectual rationale for the current monetary policy framework in India, drawing upon what has emerged as a tradition among modern central banks that fashion their operating formats around the interest rate as the main channel for conveying the stance of monetary policy to the rest of the economy. The new Keynesian model has at least three innovations – that the impact of interest rates on aggregate demand is best understood in terms of the effects on its deviations from potential output; that there is an exploitable trade-off in the short-run between these deviations and the variability of inflation, which defines why monetary and fiscal policies as stabilization tools exist at all, irrespective of great moderations and great recessions; and, that stabilization policies contribute to social welfare by responding appropriately to fluctuations of output and inflation, with a good understanding of the working of the economy in space and time determining the hierarchy of weights assigned to each. More on these themes follows with reference to the Indian context.

The new Keynesian model is popularly referred to as the new consensus in economics, but as our journey through the literature showed, there is still terrain to be charted before there is a full consensus within. The role of money in monetary analysis remains an unsettled question. Is the global financial crisis in some way related to the exorcism of money/credit from present day policy analytics or would it have happened regardless? Another spin that the crisis has thrown at us is the role of monetary policy itself when interest rates approach or are at the zero nominal bound. Is there life in monetary policy beyond the bound? Does it take a money-based form? Clearly, more work is needed but in the final analysis, the new Keynesian model appears to have exhibited Darwinian properties of natural selection, having stood the test of time. It has generated in the process several novel insights into the design and conduct of monetary policy. It is flexible and is eminently suitable for practical policy modeling and simulations. The purely theoretical model is a purely forward looking one; but one that adapts to real life combines the best of both forward looking and backward looking worlds, and is extendable to incorporate open economy considerations and country-specific features. Nevertheless, it is a highly stylized and abridged representation of the working of the economy and to that extent, the intrepid policy maker must be aware of its limitations.

The application of the new Keynesian model to Indian conditions yields valuable insights into the interaction of monetary policy with the structure and functioning of the economy. First, aggregate demand responds to interest rate changes with a lag of at least three quarters, and the presence of institutional impediments in the credit market such as administered interest rates can lead to persistence of the impact of monetary policy up to two years. Recognition of this lag should condition the setting of monetary policy in the context of situations where inflationary pressures are brought on by excess demand. Fluctuations in agricultural activity are not merely supply side phenomena; they produce demand perturbations in view of the size of the population which depends on agriculture for livelihood. Thus, adverse movements in agricultural activity should legitimately be seen as blips on the monetary policy radar, and not just as extraneous supply side disturbances outside its scope. Consistent with the growing internationalization of the economy, external influences are increasingly significant in the assessment of aggregate demand. India’s economy is at a stage when it is becoming outside-in; precursor to the next stage when it will be inside-out? Time will tell.

Second, the results of this paper confirm previous findings that inflation in India, as elsewhere, has an inertial character. Inflationary pressures are persistent when they set in and consequently, a lasting imprint is left on people’s expectations, irrespective of their source. Monetary policy needs to be wielded in an agnostic manner that nips in the bud – to use an old cliché – any inflationary impulses that are deemed to be more than transient. In the recent period, external supply shocks are producing big effects on inflation in India, but this is essentially because the size of these shocks has been unusually large in recent years. Global production structures and supply-demand balances in key internationally traded commodities matter and need to be carefully monitored on an ongoing basis so as to inform policy setting.

Third, exchange rate pass-through to domestic inflation is comparable to the group of low inflation countries, indicative of credibility in monetary authority's commitment to the achievement of low and stable inflation. In India, the contemporaneous pass-through results in inflation falling by 0.5 percentage points for a 10 percent appreciation in the rupee, cumulating to a total of 1.5 percentage points over seven quarters. In the context of large two-way movements in the exchange rate, this indicates that employing monetary policy to exploit inflation control properties of rupee appreciation is not an efficient strategy and, may even be de-stabilizing. Nor is it a desirable one in view of large trade deficits and the optimal choice is one slanted towards deriving the balance of payments equilibrating properties of the exchange rate that is flexible in both directions.

Fourth, the RBI has been acting in a calibrated fashion since January 2010, like a few other central banks/monetary authorities[17], with 100-125 basis points increases in key policy interest rates and 100 basis points increase in the CRR already behind it at the time of writing this paper. These systematic policy actions have resulted in the effective policy rate transiting from the reverse repo rate (3.25 per cent in March 2010) in the first half of 2010 to the repo rate (5.75 per cent) as of July 2010 – an effective policy rate tightening by 225 basis points. Notwithstanding these moves, there appears to be no visible transmission to bank lending rates, corroborating the lag structures observed in the estimation of the model and its components. The RBI has announced in July 2010 that it is moving from the existing quarterly policy review cycle to a six-weekly cycle. It is also seeking greater transparency in the setting of interest rates in the credit market by banks through a base rate system. At the current juncture and with the caveats indicated in the preceding section, the estimated neutral policy rate defined in terms of the GDP deflator is still around 75 basis points above the effective policy rate prevailing currently. This is the indicative amount of further policy tightening that appears to be warranted to normalize the policy stance in view of sustained inflationary pressures and the narrowing of the output gap.

Fifth, our results surprisingly indicate that the conduct of monetary policy under the current regime (with interest rates as the main instrument of policy) can be best characterized as "rule-based, but not rule-bound" or

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[17] Central banks that have raised policy rates include Australia (150 bps during September 2009-June 2010), Brazil (150 bps during April-June 2010), Canada (50 bps during June-July 2010), Israel (75 bps during December 2009-January 2010), Korea (25 bps in July 2010), Malaysia (75 bps during March-July 2010), New Zealand (50 bps in June-July 2010), Norway (75 bps during October 2009-June 2010) and Thailand (25 bps in July 2010). Singapore's Monetary Authority re-centered its exchange rate policy band from zero percent appreciation to modest and gradual appreciation (April, 2010) and the People's Bank of China has been raising reserve requirements since January 2010.

alternatively one with constrained discretion. An augmented Taylor-type rule characterizes the monetary policy reaction function better than would be expected of a central bank with a multiplicity of objectives. Inflation turns out to be the dominant focus of monetary policy, and this is accompanied with strong commitment to the stabilization of output. Quite clearly, the RBI regards deviations of output from trend as carrying the seeds of future inflation. While the exchange rate variation is found to be statistically significant in the monetary policy reaction function, the weight attached to is extremely small relative to inflation and output, than what some studies would like to have us believe. This reinforces the volatility smoothing intention set out by the RBI in its public statements. Our results also point to a high degree of interest rate smoothing by the RBI, reflecting a preference for baby steps over big bangs.

Finally, the findings of this paper support a forward-looking response of monetary policy to expected inflation and output dynamics in India. Transmission lags, which are consistent with the cross-country empirical evidence, highlight the importance of being pre-emptive for effective macroeconomic stabilization, and, thereby, credible. The Indian economy is undergoing continuous and significant structural transformation and greater integration with the world economy which, in turn, impacts the monetary transmission mechanism on an ongoing manner.

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Annex I: List of Variables

CRR = Cash reserve ratio

DLBSESA = Year-on-year variation in stock prices (measured by Bombay Stock Exchange Sensex)

DLEXCH4 = Quarter-on-quarter (annualized) variation in exchange rate of the Rupee vis-a-vis the US dollar

DLEXCHA = Year-on-year variation in exchange rate of the Rupee vis-a-vis the US dollar

DLM3 = Year-on-year variation in broad money (M3)

DLNFC = Year-on-year variation in non-food credit

EFFECTIVE = Effective policy rate (as defined in text)

FEDFUND = US Federal Funds rate target

INFCPI = Consumer price Inflation (year-on-year)

INFCPIDEV = Deviation of consumer price inflation (year-on-year) from the indicative projection of 5%

INFGDP = GDP deflator inflation (year-on-year)

INFGDPDEV = Deviation of GDP deflator inflation (year-on-year) from the indicative projection of 5%

INFGLOBAL = International commodity price inflation (year-on-year) in US $ terms (measured by IMF's non-fuel index)

INFPC = Primary commodities wholesale price inflation (year-on-year)

INFPOL = Fuel group wholesale price inflation (year-on-year)

INFWPI = Wholesale price inflation (year-on-year)

INFWPIDEV = Deviation of wholesale price inflation (year-on-year) from the indicative projection of 5%

REER36GAPSA = real exchange rate gap = 36-currency real effective exchange rate (seasonally adjusted) less its HP filtered series

RPR = Real policy rate (nominal effective policy rate less GDP deflator inflation)

RPRWPI = Real policy rate (nominal effective policy rate less WPI inflation)

WEXPRGAPSA = World real export gap (= World real exports (seasonally adjusted) less its HP filtered series

YGAPAGRSA = Agricultural output gap = Real agricultural GDP (seasonally adjusted) less its HP filtered series

YGAPSA = Output gap = Real GDP (seasonally adjusted) less its HP filtered series

Annex II: Robustness Analysis

As indicated in Section V, the various specifications of the IS curve, the Phillips curve and the monetary policy reaction function were estimated for two truncated periods (April 1997- June 2008 – the pre-Lehman Brothers period; and April 2002-June 2008 – the post-LAF and pre-Lehman period) to test for the robustness of the results.

IS Curve

The coefficients obtained for the two truncated samples are broadly similar to their corresponding estimates for the full sample specifications (Annex Tables 1 and 2). The only notable difference is that for the 2002:2-2008:2 sample, the output gap terms are not significant in the augmented specifications (Annex Table 2). The real interest rate is significant at slightly longer lags.

Annex Table 1: Estimates of IS Curve

Variable	**Alternative Specifications**					
1	**2**	**3**	**4**	**5**	**6**	**7**
	Dependent Variable: YGAPSA					
	Sample:1997:2-2008:2					
Constant	0.35	0.28	0.14	0.24	-0.05	0.04
	(3.4)	(2.6)	(2.4)	(2.7)	(0.5)	(0.5)
RPR{-3}	-0.09			-0.10		
	(2.7)			(2.7)		
RPR{-6}		-0.12	-0.06		-0.01	-0.03
		(3.4)	(2.4)		(0.3)	(1.3)
YGAPSA{-1}	0.55		0.37	0.25		0.24
	(9.0)		(8.8)	(3.7)		(4.2)
YGAPSA{+1}		0.49	0.40		0.26	0.33
		(6.7)	(9.0)		(4.3)	(6.0)
YGAPAGRSA	0.15	0.23	0.12	0.23	0.26	0.17
	(3.7)	(5.7)	(3.1)	(7.0)	(8.1)	(3.8)
WEXPRGAPSA				0.12	0.13	0.06
				(6.6)	(5.4)	(2.6)
REER36GAPSA{-2}				-0.05	-0.05	-0.02
				(2.4)	(2.1)	(1.1)
SEE	0.67	0.64	0.56	0.59	0.51	0.51
R-bar squared	0.69	0.74	0.80	0.76	0.83	0.83
Q-statistic	0.70	0.90	0.01	0.09	0.80	0.12
J-specification	9.7	11.1	7.8	8.7	9.2	7.7
Significance level of J	0.72	0.60	0.80	0.65	0.61	0.66

Notes:
See Table 1 in the text.

Annex Table 2: Estimates of IS Curve

Variable	Alternative Specifications					
1	2	3	4	5	6	7
	Dependent Variable: YGAPSA					
	Sample:2002:2-2008:2					
Constant	0.19	0.34	0.28	0.00	-0.07	-0.01
	(3.1)	(5.7)	(5.8)	(0.0)	(0.7)	(0.1)
RPR{-5}	-0.09					
	(3.5)					
RPR{-8}		-0.17	-0.12	-0.06	-0.04	-0.05
		(4.7)	(4.6)	(1.6)	(1.0)	(1.5)
YGAPSA{-1}	0.46		0.35	0.07		0.09
	(12.5)		(15.6)	(1.2)		(1.2)
YGAPSA{+1}		0.26	0.20		0.01	0.03
		(4.3)	(3.8)		(0.3)	(1.0)
YGAPAGRSA	0.22	0.27	0.18	0.24	0.25	0.23
	(11.8)	(13.5)	(8.8)	(12.7)	(10.2)	(9.6)
WEXPRGAPSA				0.18	0.21	0.18
				(5.9)	(10.5)	(5.5)
REER36GAPSA{-2}				-0.05	-0.06	-0.05
				(3.5)	(3.4)	(3.3)
SEE	0.61	0.58	0.48	0.41	0.41	0.42
R-bar squared	0.80	0.82	0.88	0.91	0.91	0.90
Q-statistic	0.79	0.12	0.27	0.60	0.43	0.56
J-specification	8.2	8.1	7.2	7.8	8.3	7.8
Significance level of J	0.83	0.83	0.84	0.73	0.69	0.65

Notes:
See Table 1 in the text.

Phillips Curve

The results obtained for both the backward-looking as well as the hybrid Phillips curve in the full sample specifications broadly hold for the two truncated periods as well (Annex Table 3). Notable differences are the following: first, the null hypothesis that the coefficients on lagged and lead inflation sum to unity can be rejected. Second, the coefficient on the exchange rate is insignificant in the hybrid specification for the period 1997:2-2008:2.

Annex Table 3: Estimates of Phillips Curve

Variable	Alternative Specifications							
1	2	3	4	5	6	7	8	9
	Dependent Variable: INFGDP							
	Sample: 1997:2-2008:2				Sample: 2002:2-2008:2			
Constant	1.44	1.12	0.45	0.36	1.96	1.90	0.65	0.38
	(9.1)	(5.1)	(2.6)	(2.0)	(11.9)	(13.9)	(3.0)	(3.7)
YGAPSA{-4}	0.23	0.15	0.14	0.11	0.27	0.28	0.12	0.10
	(4.2)	(2.5)	(3.3)	(2.1)	(7.1)	(7.6)	(3.5)	(3.3)
INFGDP{-1}	0.60	0.66	0.51	0.53	0.46	0.51	0.44	0.50
	(14.6)	(13.2)	(17.3)	(14.2)	(13.7)	(13.1)	(13.2)	(15.1)
INFGDP{+1}			0.36	0.35			0.37	0.40
			(8.4)	(6.9)			(9.8)	(16.4)
INFGLOBAL	0.04	0.05	0.01	0.02	0.06	0.05	0.02	0.02
	(5.8)	(4.8)	(2.2)	(1.9)	(13.4)	(13.5)	(4.4)	(3.3)
DUM1998Q3Q4	3.68	2.93	1.61	1.29				
	(6.7)	(4.5)	(2.4)	(1.7)				
DLEXCHA		0.04		0.02		0.03		0.04
		(2.1)		(0.9)		(2.5)		(4.0)
SEE	0.96	0.94	0.78	0.79	0.90	0.90	0.75	0.74
R-bar squared	0.67	0.68	0.78	0.77	0.45	0.45	0.61	0.63
Q-statistic	0.54	0.33	0.00	0.00	0.85	0.87	0.36	0.20
J-specification	8.7	8.9	9.8	10.1	8.4	8.2	8.4	8.1
Significance level of J	0.93	0.88	0.83	0.75	0.96	0.94	0.94	0.92
Memo:								
Chi-squared (1) *			9.7	7.2			13.3	11.9
Significance level *			0.00	0.01			0.00	0.00

Notes:
See Table 3 in the text.

Monetary Policy Rule

As noted in Section III, we employ the first difference of the output gap over the full sample period as a robustness check against potential measurement errors. Using the GDP deflator as the measure of inflation, the results are broadly the same as in the baseline specification estimated with the level of the output gap (Annex Table 4). While one-quarter ahead expected inflation is significant, the first-difference of the output gap is significant only with a lag of one quarter. The long-run coefficients on inflation and the first-difference of output gap remain above unity (column 1, Annex Table 4). Unlike the baseline, the exchange rate variable is now insignificant and also wrongly signed. The US federal funds rate, as before, remains significant and in this specification, the first-difference of the output gap loses significance.

Annex Table 4: Estimates of Monetary Policy Reaction Function (Full Sample)
(using first-difference of output gap)

Variable	Alternative Specifications			
1	2	3	4	5
	Dependent Variable: EFFECTIVE Sample Period: 1997:2-2009:3			
Constant	0.82	0.72	1.41	1.57
	(2.3)	(1.9)	(4.7)	(4.8)
INFGDPDEV{+1}	0.15	0.15	0.24	0.23
	(3.0)	(3.0)	(5.2)	(4.3)
DYGAPSA{-1}	0.18	0.16	0.09	0.07
	(2.8)	(2.6)	(1.3)	(1.0)
EFFECTIVE{-1}	0.87	0.88	0.67	0.62
	(17.2)	(17.8)	(12.4)	(10.8)
DLEXCH4{-1}		-0.01		-0.00
		(1.4)		(0.0)
FEDFUND			0.23	
			(5.9)	
FEDFUND{-1}				0.27
				(6.1)
SEE	0.70	0.69	0.60	0.60
R-bar squared	0.84	0.85	0.88	0.88
Q-statistic	0.77	0.53	0.52	0.49
J-specification	8.8	8.1	6.9	5.5
Significance level of J	0.36	0.32	0.44	0.48
Memo:				
Long-run coefficient on inflation	1.2	1.3	0.7	0.6
Long-run coefficient on output gap	1.4	1.3	--	--
Neutral policy rate	6.3	6.0	--	--

Notes:1. Estimation is by Generalised Method of Moments (GMM) methodology for the sample period 1997:2 to 2009:3 using quarterly data and one lag each of the following instruments: EFFECTIVE, DYGAPSA, DWEXPRGAPSA, INFGDPDEV, INFCPIDEV, INFWPIDEV, INFGLOBAL, DLEXCH4, DLM3, DLNFC and FEDFUND.
2. Variables are defined as follows:
DYGAPSA = first-difference of output gap = Real GDP (seasonally adjusted) less its HP filtered series
DWEXPRGAPSA = first-difference of world real export gap (= World real exports (seasonally adjusted) less its HP filtered series
For other variables and notes, please see Table 4 in the main text and Annex 1.

Turning to robustness analysis for specifications based on output gap, for the forward-looking specification (Annex Table 5), the results for the post-2002 period (2002:1-2008:2) are qualitatively similar to the full sample. The long-run coefficient on inflation remains at or above unity in the baseline as well as in the exchange rate augmented specification. In fact, the long-run coefficient jumps to 2.0 when the exchange rate is included (column 6). However, for the pre-Lehman period, there is one major difference *vis-a-vis* the full sample results: the long-run coefficient on inflation falls below unity even in the baseline specification (column 7).

Annex Table 5: Estimates of Monetary Policy Reaction Function (Forward-looking)

Variable	Alternative Specifications							
1	2	3	4	5	6	7	8	9
	Dependent Variable: EFFECTIVE							
	Sample: 1997:2-2008:2				Sample: 2002:2-2008:2			
Constant	0.95	1.09	1.04	1.43	0.39	0.25	0.49	0.58
	(4.5)	(4.4)	(4.5)	(5.8)	(3.4)	(2.5)	(3.2)	(3.4)
INFGDPDEV{+2}	0.07	0.10	0.11	0.13	0.05	0.06	0.07	0.06
	(1.8)	(2.6)	(2.2)	(2.8)	(2.2)	(2.8)	(5.1)	(3.3)
YGAPSA{+2}	0.19	0.22	0.04	0.05	0.14	0.15	0.03	0.06
	(3.4)	(4.1)	(0.7)	(0.9)	(6.0)	(11.8)	(0.9)	(2.2)
EFFECTIVE{-1}	0.85	0.84	0.75	0.67	0.95	0.97	0.84	0.85
	(27.9)	(23.2)	(17.4)	(13.6)	(45.1)	(55.6)	(21.8)	(17.8)
DLEXCH4{-1}		0.02		0.01		0.01		0.01
		(2.1)		(1.9)		(3.9)		(2.6)
FEDFUND			0.17				0.16	
			(3.7)				(4.6)	
FEDFUND{-1}				0.21				0.14
				(4.0)				(3.2)
SEE	0.54	0.55	0.51	0.51	0.30	0.28	0.26	0.25
R-bar squared	0.89	0.89	0.91	0.91	0.95	0.95	0.96	0.96
Q-statistic	0.03	0.07	0.00	0.03	0.59	0.89	0.36	0.41
(8 lags)	(0.11)			(0.10)				
J-specification	8.4	6.0	8.9	5.6	6.3	5.4	4.8	5.0
Significance level of J	0.40	0.54	0.26	0.48	0.62	0.61	0.69	0.55
Memo:								
Long-run coefficient on inflation	0.5	0.6	0.4	0.4	1.0	2.0	0.4	0.4
Long-run coefficient on output gap	1.3	1.4	--	--	2.8	5.0	--	0.4
Long-run coefficient on exchange rate	--	0.13	--	0.03	--	0.03	--	0.07

Notes:
See Table 4 in the text.

For the contemporaneous specification (Annex Table 6), the results are largely similar to the full sample specification: the coefficient on inflation is significant in some specifications, and is below unity. The inflation process in India is highly volatile, given the large weight of food articles in the consumption basket. Food price pressures almost regularly emanate from recurrent supply shocks for which fiscal and supply side measures – restrictions on exports, reduction in customs duties on imports and public distribution – are considered better suited than standard monetary policy responses. Similarly, in the context of high international oil and other commodity price fluctuations, import duties have been reduced to make imports less costly and administered domestic prices in respect of these items are adjusted in a staggered manner to mitigate the burden of the pass-through on to the relatively disadvantaged. These discrete policy interventions tend to affect the monetary policy reaction function by producing long-run coefficient on inflation falling below unity over some periods as reflected in the estimations over truncated samples.

Annex Table 6: Estimates of Monetary Policy Reaction Function (Contemporaneous)

Variable								
	Alternative Specifications							
1	2	3	4	5	6	7	8	9
	Dependent Variable: EFFECTIVE							
	Sample: 1997:2-2008:2				Sample: 2002:2-2008:2			
Constant	1.02	1.09	1.10	1.18	0.86	0.76	0.38	0.65
	(5.6)	(5.0)	(4.9)	(5.4)	(6.2)	(4.7)	(3.2)	(5.8)
INFGDPDEV	0.05	0.06	0.06	0.07	0.09	0.10	0.09	0.09
	(1.5)	(2.1)	(1.5)	(1.9)	(5.1)	(3.7)	(3.7)	(4.5)
YGAPSA	0.20	0.23	0.16	0.13	0.17	0.18	0.03	0.03
	(4.1)	(3.8)	(2.6)	(2.2)	(4.9)	(5.2)	(1.4)	(1.3)
EFFECTIVE{-1}	0.84	0.83	0.78	0.75	0.88	0.90	0.89	0.83
	(28.9)	(23.2)	(18.5)	(15.7)	(36.0)	(33.5)	(38.5)	(37.1)
DLEXCH4{-1}		0.01		0.01		0.01		0.01
		(1.6)		(1.8)		(2.7)		(2.9)
FEDFUND			0.09				0.12	
			(2.1)				(4.8)	
FEDFUND{-1}				0.13				0.16
				(2.6)				(6.1)
SEE	0.54	0.54	0.52	0.50	0.31	0.30	0.26	0.23
R-bar squared	0.89	0.89	0.90	0.91	0.94	0.95	0.96	0.97
Q-statistic	0.15	0.19	0.08	0.11	1.00	0.81	0.49	0.42
J-specification	4.8	5.2	5.8	5.8	5.4	6.5	3.6	4.7
Significance level of J	0.78	0.63	0.56	0.44	0.72	0.48	0.82	0.58
Memo:								
Long-run coefficient on inflation	--	0.4	--	0.3	0.8	1.0	0.8	0.5
Long-run coefficient on output gap	1.3	1.4	0.7	0.5	1.4	1.8	--	--
Long-run coefficient on exchange rate	--	--	--	0.04	--	0.10	--	0.06

Notes:
See Table 4 in the text.