Modeling Inflation in India: The Role of Money

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Abstract

This paper studies the role of the real money gap- the deviation of real money balance from its long-run equilibrium level- for predicting inflation in India. Using quarterly data on manufacturing inflation from 1982 to 2007, we find that the real money gap is a significant predictor of inflation in India. Our results show that this variable is a better predictor of future inflation at quarterly horizon than the deviation of broad money growth from its target for the whole sample period. We also document a break in the overall predictability of inflation in the last quarter of 1995. We find that except for the real money gap, the forecasting power of other predictors under study has declined considerably after 1995.

1 Introduction

Money growth has always played a central role in the monetary policy strategy of the Reserve Bank of India (RBI). The primary goal of monetary policy in India has been to maintain a reasonable degree of price stability along with ensuring an adequate expansion of credit to assist economic growth. Following the high volatility of prices in the 1970s, the Indian government appointed a commission led by the late Sukhamoy Chakravarty in 1982 to look into the workings of the RBI and suggest appropriate monetary policy strategies for the central bank. The RBI adopted a monetary targeting strategy following the recommendations of the Chakravarty committee report in 1983. The Chakravarty committee's recommendations were influenced by the successful adoption of monetary targeting by the central banks in

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Europe, mainly the Bundesbank. The RBI followed the explicit monetary targeting strategy until 1998. In the context of the increasing deregulation of the Indian economy, the RBI's Working Group on Money Supply (1998) observed that monetary targets could lack precision in a rapidly changing economy. As a result, the RBI adopted a multiple indicator approach after 1998-1999, whereby a set of economic variables was to be monitored along with the growth in broad money. Even though the RBI does not target money growth explicitly after 1998, it assigns a very important role to money growth in its policy formulation. While the RBI has moved away from explicit money growth targeting, it still publishes the money growth target regularly. Figure 1 shows the actual money growth and the money growth target from 1983 to 2007. It is evident from the graph that even after moving away from explicit money growth targeting in 1998, the deviation of actual money growth from its target was never persistent.

Recognizing that money growth has played a central role in the overall monetary policy formulation, the objective of this paper is to investigate the role of monetary indicators in the determination of inflation in India. We compare the predictive ability of the real money gap (defined as the gap between the current real money balance from its long-run equilibrium level) and the money growth indicator (deviation of broad money growth from its target published by the RBI). Specifically, this paper examines the following questions. Does the RBI's forecast of money growth provide information about future movements in inflation? If so, is it more informative than the real money gap? We also examine the role of output gap in predicting the future movement of inflation.

In this paper, we focus on the manufacturing component of the Wholesale Price Index (WPI) as a measure of inflation. To exclude the effect of volatile energy and food prices, monetary policy in developed countries focuses on some form of core inflation. Since a measure of core inflation is not available in India, we focus on the manufacturing component of the WPI. The other two components of the WPI- primary products, and fuel, power and light- are either affected mainly by supply shocks or administered by the government. Therefore, monetary policy has no direct control over these two components. Moreover, the relative share of the manufacturing components in the overall WPI has been increasing over time. Hence, manufacturing inflation comes closest to a measure of core inflation in the Indian case.

We follow the modeling strategy of Gerlach and Svensson (2003) and Svensson (2000) in linking the real money gap to inflation. According to them, the real money gap is a proxy for liquidity overhang or pressure in the economy, and whenever it is high, it creates inflationary pressure in the economy. Gerlach and Svensson (2003) show that the real money gap has substantial predictive power for future inflation in Euro area. They also find that the real money gap contains more information about future inflation than the output gap and the Eurosystem's money growth indicator. Since the monetary targeting strategy in India at the beginning of 1983 was based on the European experiment, it would be instructive to examine the predictive power of the real money gap for inflation in the Indian context.

Our results indicate that for data spanning 1982-2007, the real money gap is a significant predictor of one quarter ahead inflation[1]. We also find that while the money growth indicator contains useful information about future movements in inflation, this information is already contained in the real money gap. This result is similar to Gerlach and Svensson (2003), who find that the real money gap is a superior predictor for future inflation than the money growth indicator in the Euro area. Our findings also suggest that output gap has not played a significant role in determining quarterly inflation in India.

The rapid changes and deregulation in the Indian economy can have consequences for the dynamics of inflation and the predictive power of different forecasting variables. Therefore, we also test for stability in the inflation dynamics and predictive power of different regressors. We find that there has been a structural break in the dynamics of inflation in the last quarter of 1995. Our findings indicate that except for the real money gap and exchange rate, the predictive power of other regressors has declined considerably after 1995. There has been a decline in the predictive performance of the money growth indicator after 1995 as compared

[1] We use inflation and manufacturing component of inflation interchangeably. The details of the price indices in India are given in section 3.

to the pre-1996 period, and does not have marginal predictive power in a regression with real money gap as an explanatory variable. We also find that the exchange rate has become a significant predictor of inflation in the later part of the sample.

The plan of this paper is as follows: section 2 provides a brief literature review on determinants of inflation in India. Section 3 presents a brief theoretical model of money, interest and prices. Section 4 describes the data; section 5 and 6 present the estimation results of this paper; and section 7 concludes.

2 Related Literature

The literature on the determinants of inflation in India has mainly focused on the cost push factors implying that the supply shocks have played a major role in Indian inflation dynamics. It is not surprising since agriculture was the dominant sector in India, and food prices used to account for a big portion of the WPI. Buragohain (1997) finds that food prices were a major determinant of inflation in India as food constituted the largest share of family budget. Balakrishnan (1992) uses an error-correction model based on mark-up pricing rule to model manufactured prices. He finds that labor and raw material costs were a significant predictors of inflation from 1952-80. Another strand of literature has focused on the role of output gap in modeling inflation. The evidence on the importance of output gap in determination of inflation is mixed. While Chand (1996) shows that output gap plays a significant role in inflation, Coe and McDermott (1997) find that output gap model in India does not work. Most of these studies are based on annual data and dates back to the early 90's, and have mainly focused on aggregate inflation. Focusing on the forecasting performance of different variables, Callen and Chang (1999) show that broad money growth, exchange rates, and import prices are useful predictors of aggregate inflation in India.

The paper which is closest to the present work is that of Nachane and Lakshmi's (2002). They use the P-star model to estimate inflation dynamics in India. They find that a P-star model fits the Indian inflation better than structuralist model for the period 1955-1995. However, their focus is not on comparing the predictive performance of the real money gap and the money growth indicator. Their study also did not focus on the instability in inflation dynamics, as the sample period in their study ended in 1995. In addition to the comparison of the predictive performance of the real money gap and the money growth indicator, we also focus on the instability in inflation dynamics and its implications for predictive performance of different predictors.

Our paper focuses on the linkage between monetary policy and the manufacturing component of inflation. The rapid changes and the sustained deregulation in the Indian economy has led to a change in the composition of its GDP. For example, the share of agriculture in GDP has declined from 39% in 1980-81 to 31% in 1990-91, and to 20% in 2005-06. These structural changes in the Indian economy certainly has implications for monetary policy. The growing importance of the non-agricultural sector implies that the Indian economy may have become more sensitive to conventional macroeconomic policies and particularly to monetary policy. This also provides the rationale for emphasis on the manufacturing component of inflation. Since the objective of this paper is to examine the role of monetary policy in determination of inflation in India, we compare the predictive performance of two main monetary indicators- real money gap and the deviation of broad money growth from its target-in forecasting inflation.

3 Inflation and the Real Money Gap

This section follows the work of Svensson (2000) and Gerlach and Svensson (2002). The model presented in this section emphasizes the role of money in the determination of inflation and consists of an inflation equation and a money demand equation. The standard Phillips curve model of inflation determination, as shown in Roberts (1995), is

$$\pi_{t+1} = \pi^e_{t+1,t} + \alpha_y(y_t - y^*_t) + \alpha_z z_t + \varepsilon_{t+1} \tag{1}$$

where $\pi_t = 4(p_t - p_{t-1})$ is the annualized inflation rate in quarter t and p_t is the price level. All variables are in logarithms except interest rates. $\pi^e_{t+1,t}$ is the expected inflation of quarter t+1 in quarter t. y_t is output, y_t^* is potential output , $y_t - y_t^*$ is output gap, z_t is any exogenous variable that can affect inflation.

The inflation dynamics according to the P^* model is governed by the following equation[2]:

$$\pi_{t+1} = \pi_{t+1,t}^e - \alpha_p(p_t - p_t^*) + \alpha_z z_t + \varepsilon_{t+1} \tag{2}$$

where $\alpha_p > 0$. Here the output gap in the Phillips curve has been replaced by the price gap $(p_t - p_t^*)$. Here p_t^* is the long-run equilibrium price that would result with the current level of money stock, provided the output is at its potential level and velocity is at its long-run equilibrium level. The quantity equation can be written as (in log form)

$$v_t = p_t + y_t - m_t$$

where m_t is level of money stock (M3 in our case). The above equation implies that the long-run equilibrium level of price p_t^* can be written as

$$p_t^* = v_t^* - y_t^* + m_t \tag{3}$$

If we define the real money gap as $\widetilde{m}_t - \widetilde{m}_t^*$ where $\widetilde{m}_t = m_t - p_t$ is the real money balance and $\widetilde{m}_t^*$ is equilibrium real money balance when price is at its long-run equilibrium level (i.e. $\widetilde{m}_t^* = m_t - p_t^*$). We can write the real money gap as $\widetilde{m}_t - \widetilde{m}_t^* = (m_t - p_t) - (m_t - p_t^*) = -(p_t - p_t^*)$. Hence, the P^* model can be written as

$$\pi_{t+1} = \pi_{t+1,t}^e + \alpha_m(\widetilde{m}_t - \widetilde{m}_t^*) + \alpha_z z_t + \varepsilon_{t+1} \tag{4}$$

where $\alpha_m = \alpha_p > 0$. The above equation is very similar to the Phillips curve with real money gap replacing the output gap. The long-run equilibrium real money balance is estimated by the long-run equilibrium money demand equation. Svensson and Gerlach (2002) use a generic money demand function where the real money balance depends on output and interest rates.

[2] See Hallman, Porter and Small (1991) and Todters and Reimers (1994).

Some authors have argued that in an open economy, and especially in a developing country, the money demand equation needs to be augmented with the exchange rate[3].

Therefore, our money demand function has the following functional form

$$\widetilde{m}_t = m_t - p_t = \gamma + \gamma_y y_t + \gamma_r i_t + \gamma_e e_t + v_t \tag{5}$$

where i_t is the nominal interest rate and e_t is the nominal exchange rate measured in terms of rupees per dollar. The interest rate and the exchange rate are in levels. If long-run money demand is stable, then the error term in the above equation will be stationary. The long-run equilibrium level of real money balance can be estimated by a long-run cointegrating relationship shown in equation (5) above. The real money gap in inflation equation (4) can be replaced by the disequilibrium error in the money demand equation. If we define the real money gap as RMGAP, then RMGAP$=\widetilde{m} - (\widehat{\gamma} + \widehat{\gamma}_y y_t + \widehat{\gamma}_r i_t + \widehat{\gamma}_e e_t)$, where $\widehat{\beta} = (1, \widehat{\gamma}_y, \widehat{\gamma}_r, \widehat{\gamma}_e)'$ is the estimated cointegrating vector.

For estimation purposes, we need to specify how inflationary expectations are formed. We follow Fuhrer (1997) and assume simple backward looking inflationary expectations. Assuming adaptive inflationary expectations, equation (4) can be written as

$$\pi_{t+1} = \delta + \lambda \pi_t + \alpha_m RMGAP_t + \alpha_z z_t + \varepsilon_{t+1} \tag{6}$$

4 Data Description

Our sample period runs through 1982 to 2007. There is no single indicator of price movements in India. Three different price indices are published in India: the Wholesale Price Index (WPI), the Consumer Price Index (CPI), and the GDP deflator. The CPI has different subgroups: CPI for industrial workers, CPI for urban non-manual employees, and the CPI for the rural sector. The WPI is a weekly series announced every Friday, with a lag of two weeks for the provisional index and a ten-week lag for the final index. The CPI is a monthly

[3] See Bahmani-Oskooee (1996).

index and is made available with a lag of about one month. GDP deflator data are available annually.

The WPI is most comprehensive measure of prices in India, and is used widely for policy deliberations. The RBI also cites WPI movements in every policy drafts. The WPI covers 447 commodities and is heavily weighted towards manufactured products. The weight of manufactured products in the overall WPI has increased over time and the weight changes with the change in the base year. For the base year 1982, the weight on manufactured items was 57%, and this weight increased to 63.7% when the base year changed to 1994. In addition to manufactured items, the WPI also consists of primary articles, fuel, and energy. The movements in primary articles are dominated by supply shocks, and the prices of fuel and energy are administered. The central banks in developed countries focus on core inflation that excludes food and energy. To take care of the issue of supply shocks and administered price controls, we focus on the manufacturing component of the WPI.

We use the annual monetary policy report of the RBI for data on money growth targets. Since real GDP data are available only at an annual frequency, we use the index of industrial production as a measure of economic activity[4]. The output gap is the Hodrik-Prescott filtered cyclical component of industrial production[5]. The interest rates in India were administered prior to financial liberalization. This imposes a problem in the selection of an appropriate interest rate as an opportunity cost of holding money. Moosa (1992) uses the call money rate as a measure of the opportunity cost of holding money. The problem with using call money rate as an opportunity cost of holding real money balance is that it is highly volatile and is affected more by the weekly funding demands of commercial banks. Depending upon the liquidity conditions in the market, the call money rate can fluctuate as much as 300-400 percent within a day or two. To take care of the huge instability in the call money market, we use the bank rate as opportunity cost of holding real money balance. The bank rate is

[4] The government started publishing quarterly data of GDP in 1994.

[5] For robustness purposes, we also perform the analysis with detrended output gap and Christiano-Fitzgerald filtered output gap and the results are qualititavely similar. Results are available upon request.

the rate at which the RBI lends liquidity to banks[6]. The data on WPI and its components, industrial production, broad money growth, and exchange rate has been obtained from the RBI website.

5 Estimation of the Real Money Gap

To estimate the real money gap in equation (6), we need to estimate the money demand equation for the Indian economy. There is a broad literature on the estimation of the money demand equation, as it plays a major role in macroeconomic analysis. Sriram (2001) presents a comprehensive survey of the money demand estimation literature. The estimation of money demand involves non-stationary variables. Hence, the usual estimation procedure is the cointegration methodology of Engle and Granger (1987). The preliminary evidence shows that we can not reject the null of unit root of the real money balance, industrial production, the bank rate and the nominal exchange rate. We also test the number of cointegrating vectors in the money demand equation and there is strong evidence of a single cointegrating vector[7]. The theory implies that the residual v_t in equation (5) should be stationary and the real money balance, income, the interest rate and the exchange rate should share a common trend. The cointegrating vector $\beta = (1, \gamma_y, \gamma_r, \gamma_e)'$in equation (5) is estimated using Stock-Watson dynamic OLS (DOLS). DOLS adds leads and lags of the differenced explanatory variables to get consistent estimates of the coefficient β[8]. The estimated money demand equation is as follows:

$$\widetilde{m}_t^* = 4.06 + 1.19y_t - 0.035r_t + 0.003e_t \tag{7}$$

The estimate of the cointegrating vector is consistent with the range of different estimates of the cointegrating vectors as shown in Sriram (2001). The range of data set used spans the

[6] For robustness check, we also use Prime Lending Rate (PLR) as a measure of interest rate and the results are qualitatively similar.

[7] To save space, results are shown in appendix.

[8] The estimates $\beta's$ are consistent despite the fact that the explanatory variables and error terms are correlated. This follows from Stock and Watson (1987), as they show that the estimates from cointegrating parameters are superconsistent, i.e. the true parameter converges to the true values at rate T rather than at rate $\sqrt{T}$ as in ordinary least squares.

period from the first quarter of 1982 to the last quarter of 2007. The disequilibrium error RMGAP is shown in figure 2. Since the estimated coefficients are superconsistent, there is no 'generated regressor' problem in the second stage equation, when we use RMGAP as an explanatory variable in equation (6).

6 Empirical Estimation

6.1 Preliminary Analysis

The graphs for the real money gap (RMGAP), inflation, the deviation of broad money growth from its target or money growth indicator (RMDEV), and the output gap (GAP) are shown in figure 2. The first order autocorrelation for real money gap is 0.6. Since the real money gap is not persistent, our estimation results are not subject to the usual inference problem when explanatory variables are highly persistent (Nelson and Kim (1993)). One of the striking features of the inflation in India is that there has been a significant reduction in the level and volatility of inflation in the 1990s. This time period coincides with the wave of financial and economic liberalization of the Indian economy. The degree of first order autocorrelation in Indian inflation is 0.4 for the whole sample period.

We perform preliminary data analysis for the forecasting variables under consideration. The results for Granger causality tests are shown in table 1. We reject the null of no Granger causality from the real money gap and money growth indicator to inflation for all sample periods. However, we do not reject the null for output gap and exchange rate. This preliminary evidence indicates strong support for real money gap and the deviation of broad money growth from its target as predictors of inflation in India.

6.2 Predictive Power of the Real Money Gap

We apply OLS to equation (6) to estimate the predictive power of the real money gap for quarterly inflation in India[9]. Table 2 presents the results for different model specifications. In all of the regressions in table 2, we make a Newey-West correction (Newey-West (1987)) to

[9] We choose appropriate number of lags of explanatory variables using BIC criteria.

the t-statistics for generated serial correlation in the residuals. Model 2 regresses quarterly inflation on its own lag. This autoregressive model explains 16 % of the variation in the next quarter's inflation. The coefficient on the lagged dependent variable is 0.4. If the next quarter's inflation is regressed on a constant and the current quarter's real money gap, we find that the coefficient on the real money gap is significant at all levels of significance. This simple model explains 16 % of the variation in inflation. If lagged inflation is added to model 2 as an additional regressor (model 4), we find that both the explanatory variables are significant at all significance levels. This model explains 27 percent of the variations in inflation. This is a simpler version of our benchmark model (equation 6).

Model 2 and 4 indicate that the real money gap has substantial predictive power for future inflation in India. Model 5 regresses inflation on its lagged value and output gap. The results are similar to those of the Granger causality tests and we find that the output gap is not a significant predictor of future inflation in India. This is consistent with Nachane and Lakshmi (2002) and Callen and Chang (1999). It would be interesting to investigate whether money growth indicator, RMDEV, provides extra information about future price level that is not contained in real money gap and its own lag. Callen and Chang (1999) find that the deviation of broad money growth from its target is an important predictor for future inflation in India. Model 6 shows that the money growth indicator, RMDEV, does not add any marginal information for prediction of future inflation. This result is in contrast to Callen and Chang (1999), where broad money growth deviation is a significant predictor of future inflation. To further investigate the importance of the deviation of the broad money growth from its target, we substitute the real money gap in our benchmark model with the deviation of money growth (model 3). The results indicate that RMDEV explains 8 percent of the variation in future inflation. However, as shown in model 6, it does not add significant information in a model where real money gap is also an explanatory variable. In fact, the real money gap encompasses all the information contained in the broad money growth indicator for the sample period under study.

It has also been argued that the exchange rate affects the movements of inflation in India.

If the Indian rupee depreciates, then imports become more expensive and the overall price level increases. To investigate the effect of exchange rate movements on the future price level, we add rate of change of exchange rate as an explanatory variable (model 7). The results indicate that exchange rate changes contain marginal information about future movements in inflation in the presence of a real money gap. The results show that the inclusion of exchange rate changes improves the fit of the model by 3 percent.

6.3 Instability in Inflation Dynamics and Predictability

The Indian economy has witnessed significant changes in the regulation regime and has undergone structural changes in the sample period under study. There have been studies on the possible impact of economic liberalization on the Indian GDP growth rate (Rodrik and Subramanian (2004)). It is perfectly plausible that the inflation dynamics in India might have witnessed a structural break as a result of the structural changes in the economy, e.g. interest rate deregulation, and global integration. This is especially important because it has been found that in the U.S. and other developed countries, there has been a structural change in the inflation dynamics, and it has become harder to forecast inflation (Stock and Watson (2007)). The graphical evidence (figure 2) supports the hypothesis of a structural break in the inflation dynamics, as there seems to be a significant reduction in the level and volatility of inflation in India in the later part of the sample.

To test for a structural break in the inflation dynamics, we perform Andrews' breakpoint test. The idea behind the Quandt-Andrews test is that a single Chow breakpoint test is performed at every observation between two dates, or observations, τ_1 and τ_2 . The model in the Andrews test takes the following form:

$$y_t = x_t'\beta + \varepsilon_t, t = 1, ...n \tag{8}$$

The null of no structural change implies that $\mathrm{H}_0 : \beta_t = \beta$. If there is a single break at time m, then alternative hypothesis implies

$$H_1 : \beta_t = \beta, t \leq m$$

$$\beta_t = \beta + \gamma, t > m, \gamma \neq 0$$

The individual test statistics can be summarized into three different statistics; the Sup or Maximum statistic, the Exp statistic, and the Ave statistic[10]. The distribution of these test statistic is non-standard. Andrews (1993) developed their true distribution, and Hansen (1997) provided approximate asymptotic p-values. The distribution of these statistics becomes degenerate at the beginning of the equation sample, or at the end of equation sample. To compensate for this behavior, it is generally suggested that the ends of the equation sample not be included in the testing procedure. A standard level for this "trimming" is 15%, where we exclude the first and the last 7.5% of the observations.

Table 3 shows the results for Andrews breakpoint test for alternative model specifications. We follow the standard trimming procedure and exclude the first and the last 7.5% of the observations. The results in table 3 indicate that not only there is a break in the dynamics of inflation, there is a structural break in the coefficient on real money gap and the money growth indicator. Hansen's (1997) p-values for the Sup or Maximum statistic, the Exp statistic, and the Ave statistic are shown in the table. The results provide strong evidence for parametric instability in the inflation dynamics. Parametric instability in the autoregressive coefficient also induces instability in the predictive power of regressors. We also find that the maximum statistic for all models is centered around the last quarter of 1995. To confirm the findings of the Andrews breakpoint test, we calculate the mean and the standard deviation of inflation for pre-1995 and post-1995 period. Table 4 shows there has been a significant reduction in the mean and volatility of inflation after 1995 which reinforces the result obtained from Andrews breakpoint test.[11].

The forecasting results presented in the previous sub-section assume that there has been no break in the inflation dynamics. However, we find that the inflation dynamics has witnessed a structural change in 1995. This will have implications for the predictive power of different predictors. Therefore we want to investigate the predictive power of real money

[10] See Andrews (1993) and Andrews and Ploberger (1994).

[11] We also perform a Chow test for a break in the last quarter of 1995, and the p-value for the null hypothesis of no break is 0.00.

gap and other predictors before and after the break. We also need to examine whether the cointegrating relationship that the characterizes the money demand equation is stable or not. There has been ample evidence in the literature (Callen and Chang (1999)) that shows that the money demand function in India has been stable over time. Our benchmark model considers a stable cointegrating model for money demand in India. For robustness purposes, we also estimate the cointegrating relationship as presented in equation (5) for two sub-samples separately. The estimated cointegrating money demand functions for two sub-sample periods are:

$$\widetilde{m}_t^* = 3.01 + 1.25y_t + 0.05r_t - 0.006e_t(1982 - 1995) \tag{9}$$

$$\widetilde{m}_t^* = 3.64 + 1.24y_t - 0.03r_t + 0.006e_t(1996 - 2007) \tag{10}$$

The opportunity cost of holding real money balance has the opposite sign, but it is insignificant in the first sample period. The insensitivity of the real money balance to interest rate in the first sub-period is not surprising since most of the interest rates were regulated and changed very infrequently during that time period. The sign gets reversed in the second period and is consistent with the theory. The estimated sign for the interest rate is also significant and correct for the whole sample period as shown in equation (7). This implies that the second sub-period dominates in the estimation of the semi-elasticity of money demand with respect to interest rate.

Table 5 shows the regression results for the pre-1996 sample period. We use the full sample cointegration vector to estimate the real money gap. The results for the re-estimated cointegration vectors are shown in table 7. We find significantly different results for the pre-1996 period as compared to the full sample results. The autoregressive model of inflation shows that the lagged dependent variable explains 21% of the variation in next quarter's inflation. This is substantially higher than the R-square for the full sample model. The real money gap is a significant predictor of inflation, but the predictive power for the pre-1996 period is smaller than for the full sample. The results indicate that RMDEV explains 20% of the variation in next quarter's inflation. This is significantly higher than the full sample R-square. We do not find the output gap, changes in exchange rate to be significant predictors of inflation, which is consistent with the Granger causality test results. Therefore, our results indicate that the deviation of broad money growth from its target, RMDEV, is a better predictor of a quarter ahead inflation than the real money gap before 1996. It also encompasses all the information contained in the real money gap, as shown in models 6 and 7 in table 5.

Table 6 presents the forecasting results for the post-1995 sample period. The result from the autoregressive model shows that the degree of persistence in quarterly inflation has declined and so has the R-square. We find that the real money gap is the single most important predictor of future inflation after 1995. The real money gap by itself explains 16 percent of the variation in next quarter's inflation, which is 60 percent higher than the first sample period. The predictive power of RMDEV has declined significantly in the second sub-sample. It explains only 5 percent of the variation. We also find that in a model with real money gap as a regressor, RMDEV is no longer significant. This implies that for the later sample period, the real money gap encompasses all the information that is contained in the deviation of broad money growth from its target, RMDEV. We also find that exchange rate changes have become significant predictor of future inflation, as shown in model 7. This is not a surprising result, since the changes in exchange rates in the post-1996 period has become a better indicator of the overall health of the economy and is allowed to respond to different macroeconomic shocks.

For robustness purposes, we re-estimate the cointegrating equation and hence, the cointegrating residuals for pre-1996 and post-1996 period. The results for the re-estimated cointegrating vectors are shown in tables 7 and 8. We do not find any qualitative difference in the results we report when we use the full sample cointegrating vector for both sub-samples (tables 5 and 6).

One striking result across all model specifications is that the overall predictability of inflation has declined substantially in the second sub-sample. This is clearly characterized by a lower R-square for all model specifications in the second sub-sample. The reduction in predictability of inflation has coincided with a reduction in the persistence of quarterly inflation. This is an interesting result since the inflation dynamics in the US has also witnessed a similar decline. It has been noted by several authors, including Stock and Watson (2007), that the overall predictability of inflation has declined in the U.S. in the 1990s. It has also been shown that the forecasts generated from a random walk model have become harder to outperform in the 1990s. However, in the models presented above, we have shown that inflation is still predictable in the Indian case, and, that some variables are still significant predictors of inflation. In the U.S., the competing explanations for lower predictability include better monetary policy and smaller shocks. Hence, the question worth asking in the Indian context is: what caused the decline in the predictability of inflation in India after 1995?.

7 Conclusions

The Reserve Bank of India has moved away from explicit monetary growth targeting to a multiple indicator approach in 1998. It followed a strict monetary targeting regime from 1983 to 1998. Money growth still plays a significant role in the monetary policy formulation as can be seen from the central bank's policy documents. In this paper, we investigate the role of monetary indicators in the future movements of inflation. We follow the P-star modeling approach of Gerlach and Svensson (2003), where inflation is linked to the real money gap-the difference between current real money balance and the long-run equilibrium level of the real money balance. Our results show that the real money gap is a significant predictor of future inflation for the full sample period. There is also strong evidence in favor of a structural break in inflation dynamics and the predictability of inflation in the last quarter of 1995. We find that the predictable component of inflation has declined considerably in the later part of the sample. However, real money gap remains a strong predictor of inflation. Our results imply that even though the RBI moved away from explicit monetary growth targeting regime, the real money gap still plays a significant role in price movements.

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APPENDIX

Table A.1: Unit Root Tests[1]

Variable	ADF P-value	Phillips-Perron P-value
Real Money Balance	0.95	0.93
Industrial Production	0.58	0.15
Bank Rate	0.89	0.86
Exchange Rate	0.99	0.99

Table A.2: Johansen Cointegration Test with Linear Trend in the Data[2]

Null	Trace Statistic	0.05 Critical Value	L-Max Statistic	0.05 Critical Value
r=0	59.87	47.85	32.63	27.58
r=1	27.24	29.79	16.45	21.13
r=2	10.78	15.49	9.41	14.26
r=3	1.375	3.84	1.37	3.84

Table A.3: Unit Root Test for Cointegrating Residual (Real Money Gap)

Test	Real Money Gap
ADF Test P-value	0.03
Phillips-Perron P-value	0.00

[1] Null hypothesis implies unit root. The test equation includes a constant and a linear trend.
[2] A constant is included in the cointegrating relation. 4 lags of VAR model were used.

Table 1: Granger Causality Test

Granger Causality Test	1982-2007	1982-1995	1996-2007
RMGAP does not Granger cause inflation	0.00	0.02	0.04
RMDEV does not Granger cause inflation	0.09	0.03	0.04
Output gap does not Granger cause inflation	0.13	0.27	0.71
Exchange Rate does not Granger cause inflation	0.75	0.60	0.67

Table 2: Prediction Regressions (1982:01-2007:04)

Dependent Variable: Inflation							
Model #	Constant	Lag	RMGAP	RMDEV	GAP	de	R^2
1	**3.53**	**0.40**					0.16
	(0.00)	**(0.00)**					
2	**3.55**		**0.42**				0.16
	(0.00)		**(0.00)**				
3	**5.81**			**0.24**			0.08
	(0.00)			**(0.06)**			
4	**3.47**	**0.34**	**0.37**				0.27
	(0.00)	**(0.00)**	**(0.00)**				
5	**3.61**	**0.38**			-0.20		0.18
	(0.00)	**(0.00)**			(0.15)		
6	**3.50**	**0.30**	**0.50**	0.09	0.33		0.31
	(0.00)	**(0.00)**	**(0.00)**	(0.22)	(0.24)		
7	**3.22**	**0.28**	**0.53**	0.09	0.43	**0.06**	0.36
	(0.00)	**(0.00)**	**(0.00)**	(0.20)	(0.11)	**(0.02)**	

[a] P-values are in parentheses. Newey-West heteroscedastic errors are used in estimation. RMGAP is real money gap (difference between current real money and long-run equilibrium real money balance), RMDEV is deviation of broad money growth from its target, GAP is output gap, de is rate of change of exchange rate, and lag represents the lag of dependent variable. RMGAP is calculated using the cointegration vector from the full sample

Table 3: Andrews' Breakpoint Test

Model	Null	Sup	Exp	Ave	Break date
$\pi_{t+1} = \delta + \lambda\pi_t + \varepsilon_{t+1}$	$\lambda_1 = \lambda_2$	0.03	0.03	0.05	1995:04
$\pi_{t+1} = \delta + \lambda\pi_t + \varepsilon_{t+1}$	$\delta_1 = \delta_2$	0.00	0.00	0.00	1995:04
$\pi_{t+1} = \delta + \alpha_m RMGAP_t + \varepsilon_{t+1}$	$\alpha_{m1} = \alpha_{m2}$	0.01	0.03	0.01	1995:04
$\pi_{t+1} = \delta + \alpha_z RMDEVt + \varepsilon_{t+1}$	$\alpha_{z1} = \alpha_{z2}$	0.10	0.00	0.00	1995:04

[a] Appropriate P-values for null of no structural change are reported here

Table 4: Descriptive Statistics (Inflation)

Inflation	1982:01-1995:04	1996:01-2007:04
Mean	7.91	4.68
Standard Deviation	3.58	2.69

Table 5: Prediction Regressions (1982:01-1995:04)

Dependent Variable: Inflation							
Model #	Constant	Lag	RMGAP	RMDEV	GAP	de	R^2
1	**6.46**	**0.42**					0.21
	(0.00)	**(0.02)**					
2	**7.28**		**0.37**				0.10
	(0.00)		**(0.02)**				
3	**8.02**			**0.44**			0.20
	(0.00)			**(0.00)**			
4	**5.84**	**0.37**	**0.38**				0.29
	(0.00)	**(0.04)**	**(0.03)**				
5	**5.16**	**0.43**			-0.19		0.23
	(0.00)	**(0.03)**			(0.27)		
6	**4.95**	0.09	0.47	**0.54**	0.52		0.45
	(0.07)	(0.59)	(0.23)	**(0.09)**	(0.12)		
7	**4.92**	0.07	0.33	**0.54**	0.53	0.01	0.45
	(0.07)	(0.75)	(0.45)	**(0.09)**	(0.13)	(0.57)	

[a]P-values are in parentheses. Newey-West heteroscedastic errors are used in estimation. RMGAP is real money gap (difference between current real money and long-run equilibrium real money balance), RMDEV is deviation of broad money growth from its target, GAP is output gap, de is rate of change of exchange rate and lag represents the lag of dependent variable. RMGAP is calculated using the cointegration vector from the full sample

Table 6: Prediction Regressions (1996:01-2007:04)

Dependent Variable: Inflation							
Model #	Constant	Lag	RMGAP	RMDEV	GAP	de	R^2
1	**2.73**	**0.23**					0.06
	(0.00)	**(0.04)**					
2	**3.55**		**0.27**				0.16
	(0.00)		**(0.00)**				
3	**3.52**			**0.11**			0.05
	(0.00)			**(0.06)**			
4	**2.91**	0.18	**0.25**				0.20
	(0.00)	(0.11)	**(0.00)**				
5	**2.91**	**0.22**			**-0.24**		0.10
	(0.00)	**(0.08)**			**(0.09)**		
6	**3.01**	0.14	**0.23**	0.06	-0.04		0.21
	(0.00)	(0.26)	**(0.01)**	(0.30)	(0.84)		
7	**2.92**	0.15	**0.32**	0.04	0.04	**0.05**	0.24
	(0.03)	(0.24)	**(0.00)**	(0.13)	(0.78)	**(0.02)**	

[a] P-values are in parentheses. Newey-West heteroscedastic errors are used in estimation. RMGAP is real money gap (difference between current real money and long-run equilibrium real money balance), RMDEV is deviation of broad money growth from its target, GAP is output gap, de is rate of change of exchange rate and lag represents the lag of dependent variable. RMGAP is calculated using the cointegration vector from the full sample

Table 7: Prediction Regressions (1982:01-1995:04)

Dependent Variable: Inflation							
Model #	Constant	Lag	RMGAP	RMDEV	GAP	de	R^2
1	**6.46**	**0.42**					0.21
	(0.00)	**(0.02)**					
2	**7.28**		**0.36**				0.09
	(0.00)		**(0.01)**				
3	**8.02**			**0.44**			0.20
	(0.00)			**(0.00)**			
4	**3.02**	**0.43**	**0.35**				0.29
	(0.00)	**(0.02)**	**(0.04)**				
5	**5.16**	**0.43**			-0.19		0.23
	(0.00)	**(0.01)**			(0.27)		
6	**7.71**	0.11	0.07	**0.56**	0.31		0.42
	(0.00)	(0.54)	(0.42)	**(0.02)**	(0.20)		
7	**7.44**	0.11	0.07	**0.57**	0.31	0.01	0.42
	(0.03)	(0.57)	(0.45)	**(0.02)**	(0.20)	(0.86)	

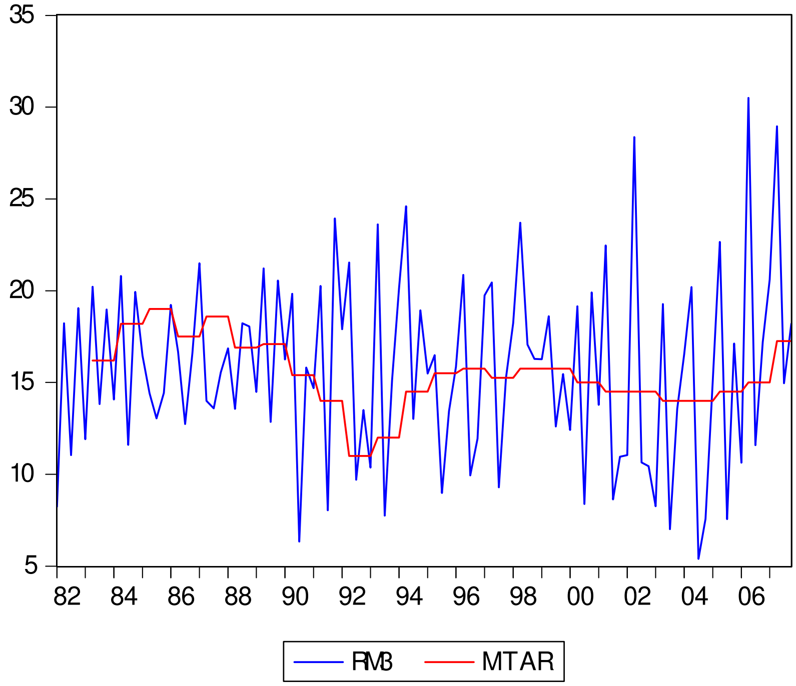
[a]P-values are in parentheses. Newey-West heteroscedastic errors are used in estimation. RMGAP is real money gap (difference between current real money and long-run equilibrium real money balance), RMDEV is deviation of broad money growth from its target, GAP is output gap, de is rate of change of exchange rate and lag represents the lag of dependent variable. RMGAP is calculated using the cointegration vector from the first sub-sample

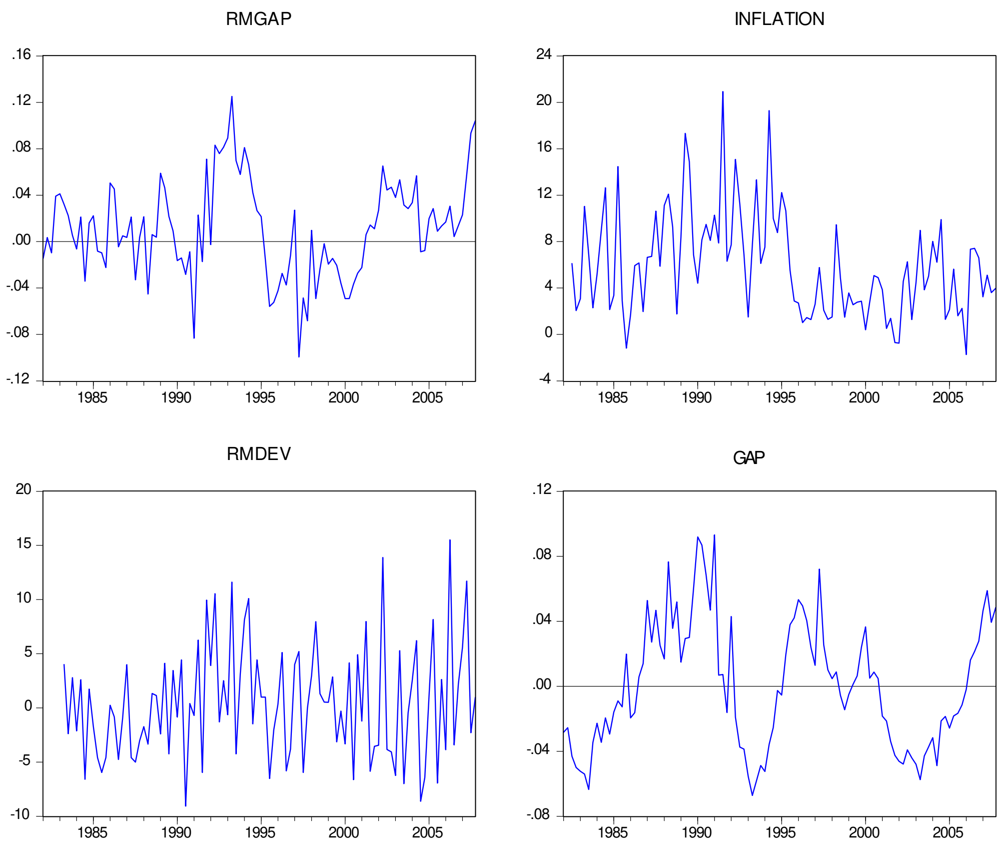
Table 8: Prediction Regressions (1996:01-2007:04)

Dependent Variable: Inflation							
Model #	Constant	Lag	RMGAP	RMDEV	GAP	de	R^2
1	**2.73**	**0.23**					0.05
	(0.00)	**(0.04)**					
2	**3.43**		**0.32**				0.14
	(0.00)		**(0.00)**				
3	**3.52**			**0.11**			0.05
	(0.00)			**(0.06)**			
4	**2.68**	**0.21**	**0.31**				0.20
	(0.00)	**(0.00)**	**(0.00)**				
5	**2.68**	0.21	**0.30**		-0.03		0.19
	(0.00)	(0.11)	**(0.01)**		(0.82)		
6	**2.79**	0.17	**0.28**	0.06	-0.06		0.20
	(0.00)	(0.16)	**(0.01)**	(0.30)	(0.84)		
7	**2.67**	0.19	**0.35**	0.04	-0.03	**0.04**	0.22
	(0.03)	(0.24)	**(0.00)**	(0.43)	(0.84)	**(0.05)**	

[a]P-values are in parentheses. Newey-West heteroscedastic errors are used in estimation. RMGAP is real money gap (difference between current real money and long-run equilibrium real money balance), RMDEV is deviation of broad money growth from its target, GAP is output gap, de is rate of change of exchange rate and lag represents the lag of dependent variable. RMGAP is calculated using the cointegration vector from the second sub-sample

Figure 1: Money Growth and Target




RMGAP
.16
.12
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.04
.00
-.04
-.08
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1985
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1995
2000
2005
INFLATION
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20
16
12
8
4
0
-4
1985
1990
1995
2000
2005
RMDEV
20
15
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5
0
-5
-10
1985
1990
1995
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2005
GAP
.12
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