The RBI's Monetary Policy Reaction Function
Does monetary policy in India follow an inflation targeting rule?

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Abstract

The paper assesses the RBI's monetary policy response function to economic conditions in India using limited dependent models. Given the non-uniform and discrete nature of intervention, these models are likely to provide a more appropriate framework of analysis than the linear "Taylor Rules" usually used. The main result of this paper is that the RBI's monetary policy, since 2000, seems to have targeted the current output gap rather than inflation. There is evidence of greater persistence in the rate hike sequence than in the rate cut, which might be construed as indirect evidence of asymmetry in the response function. As possible explanation of the targeting of the output gap, we find that the current and lagged output gap does indeed affect inflation.

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I. INTRODUCTION

The statistical analysis of the determinants of monetary policy stance of central banks has been mainly centred around the estimation of dynamic linear regression models in the spirit of the so-called "Taylor Rules". These rules characterize the appropriate optimal policy reaction function of a central bank in terms of the adjustment of a short-term interest rate under its control (see Taylor [1993, 1999]). Conventionally, adjustments in the interest rate targets are related to inflation, output gaps exchange rate and foreign interest rates in an open economy framework. For the most part, derivations of optimal rules for the conduct of monetary policy have taken place in a linear-quadratic framework arising out of a quadratic objective function for the central bank and a linear dynamic system describing the economy. When the policy instrument is a short-term interest rate, this combination results in a linear reaction function (Taylor Rule), whereby central banks adjust nominal interest rates proportionately to inflation and output deviations from their targets.

This approach, however, might be too restrictive when analyzing some distinctive features that characterize a central bank's intervention. The critique may be grouped into two distinct features.

The first set of problems of the linear quadratic response functions relate to the nature of the central bank interventions. First, the policy interest rate is changed irregularly, sometimes as often as twice a month and at other times as seldom as once in two quarters. Secondly, the changes are done in discrete adjustments, typically of 25 basis points, rather than in a continuous fashion. The infrequent and discrete nature of interest rate might render standard time series techniques inappropriate since they are devised to model continuous data arriving at fixed intervals of time.

The second set relates to the nature of the inflation-output tradeoff itself. In the short term, this trade-off might be non-linear. There is also a growing body of research that indicates that central banks may have asymmetric preferences with respect to inflation and / or output gaps. Some central banks, for instance, may have a greater aversion to recessions than expansions. Others find that some central banks associate a larger loss to positive rather than negative deviations of inflation, resulting in the inclusion of the conditional variance of inflation as an additional argument in the Taylor rule.

There are a number of empirical studies in the literature which use variants of these techniques. Dolado and Dolores (2002), Dolado et al. (2003) use Marked Point Processes to investigate the actions of the Bank of Spain and other European central banks. Gascoigne and Turner (2003) use simpler ordered probit models to look at the response behaviour of the Bank of England. Our paper expands the scope of the latter in analyzing the conduct of monetary policy in India.

This paper attempts to examine the validity of some of these issues in the Indian context. Our approach in this paper is based upon the estimation of limited dependent models (both Probit and Logit) to determine the probability of an intervention by the Reserve Bank of India (RBI). Both binary and ordered representations are used. In general, attempts to address these issues through a standard linear Taylor Rules approach is likely to lead to misleading inferences.

The paper is organized as follows. Section II provides a brief overview of the RBI's evolving approach to monetary policy making and its views on transmission channels of monetary policy actions. Section III details the methodologies that we have adopted in the paper. Section IV explains our inferences and results of the models. Section V looks at the empirical relation between inflation and the potential output gap in India. Section VI concludes and indicates avenues for future research.

II. THE RBI'S APPROACH TO MONETARY POLICY

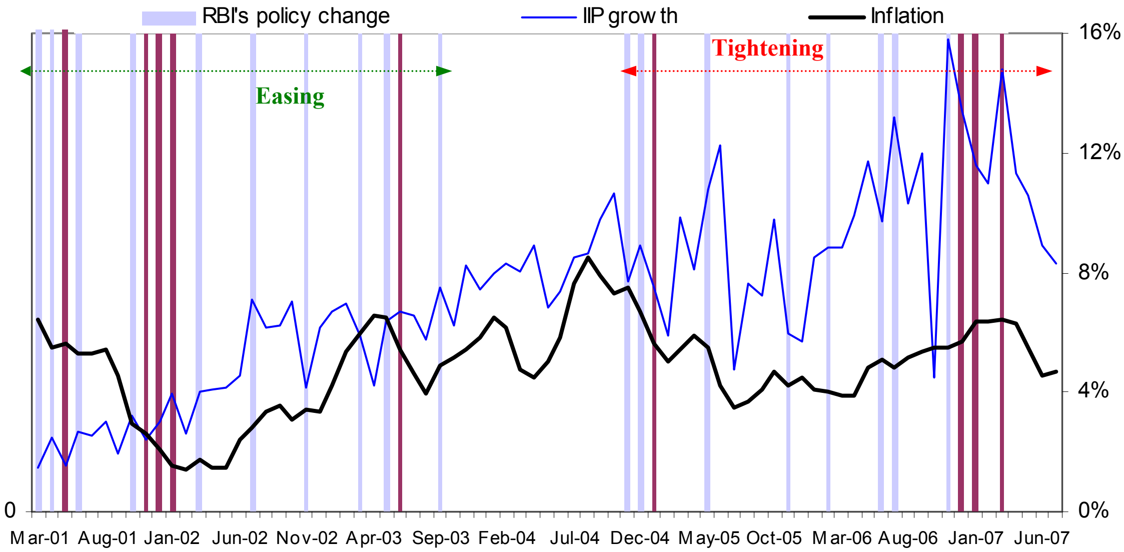
From the mid-1980s until 1998, the RBI used a monetary-targeting framework focused on interest rates, while at the same time monitoring developments in the real sector. Since 1998, it has widened the framework and begun to pursue a multiple-indicator approach. The RBI's Working Group on Money Supply (RBI, 1998) pointed out that monetary policy exclusively based on money demand could lack precision. As a result while money supply continued to serve as an important information variable, the RBI felt it necessary to monitor a set of additional indicators for monetary policy formulation. Accordingly, the RBI adopted a multiple indicator approach from 1998 wherein, besides monetary aggregates, information pertaining to a range of rates of return in different financial market segments along with the movements in currency, credit, the fiscal position, merchandise trade, capital flows, the inflation rate, the exchange rate, refinancing and transactions in foreign exchange – which are available on a high frequency basis – were juxtaposed with data on output and the real sector activity for drawing policy perspectives. Under this approach, the role of monetary aggregates as the exclusive intermediate target have been de-emphasised and short-term policy interest rates have gradually emerged as the operating target of monetary policy. Within the multiple goals assigned to the monetary authority, the achievement of price and financial stability received greater emphasis. This widening of the scope of variables monitored has partly been enabled by the development of more sophisticated econometric models.

In this context, a recent paper (Kannan *et al*., 2006) provides valuable insights into the current thinking at the central bank on monetary policy responses in India in an open economy framework. It constructs a Monetary Conditions Index taking into account both interest rate and exchange rate channels. Their results indicate that interest rates have been more important than exchange rates in influencing monetary conditions in India.[1] This Index is seen as supplementing the set of multiple indicators referred to above.

Chart 1 below depicts some of the monetary policy actions of the RBI during 2001to 2007 (till June), in the context of two of the more common variables included in "Taylor Rules" approaches, viz., output and inflation. During this period, the RBI has lowered CRR from 8.8% to 4.5% (in 6 steps) and then raised it to 7.5% (also in 6 steps, although the last two were in August and October), The repo / reverse repo rate had been reduced 8 times (from 10% to 6%) and then raised 9 times (to 7.75%). The bank rate was reduced thrice (to 6% in April '03) and then kept unchanged. It has used the three instruments simultaneously only once (in November '02) but has lately used a combination of the CRR and repo rates. It has also occasionally used the repo – reverse repo corridor as an instrument.

[1] The authors have noted elsewhere that there is also a switching behaviour in the policy response between domestic interest rates and currency considerations, the most recent such episode being the middle of 2007, when the Rupee had appreciated sharply.

Chart 1: Timing and type of RBI monetary Policy actions



Notes:
The lighter vertical lines indicate changes in repo, reverse repo and bank rates; darker vertical lines are CRR changes.

The easing phase of the RBI's policy ended around the middle of 2003. The tightening phase started in late 2004, patently designed to deal with rising inflation, couple with what must have been perceived as unsustainably high industrial output growth. Casual empiricism from the chart above indicates that that inflation was certainly restrained by the policy tightening, but industrial output growth had become much more volatile.

II.a Issues and hypotheses

Given this background, the following issues are sought to be explored in the paper. The ongoing statements from the RBI leave no doubt that they consider one or two of the list of their multiple objectives to be of primary importance. For instance, liquidity management has of late repeatedly been cited as one of the primary concerns of the RBI. The primary target, in line with other central banks in the recent past has remained inflation. So what then, is the primary strategy of the RBI? The paper attempts to understand the process of targeting adopted by the RBI.

One of the assumptions of the paper is that there are two primary targets for monetary policy: (i) inflation and (ii) an output gap.[2] The other stated objectives are intermediate targets. Is there any primacy in these two primary targets in the sense the RBI has given undue weight to one, or are both equal in terms of their influence on the RBI's policy response. This issue is important since there is a significant corpus of research that seems to indicate that many central banks target the current output gap. The logic is that this is similar to targeting future inflation.

The second issue relates to the persistence of the responses. Given that an intervention has happened, does the probability of another intervention change? Is there an asymmetry in this persistence as well? Are the chances of a cut following a prior cut the same as those of a hike following a prior hike?

A third issue is that of asymmetry in the monetary policy approach, with respect to the phase of the business cycle. In other words, was the response behaviour different during a downturn compared to that in an upswing?

III. MODELS AND METHODOLOGY

III.a Data

We have used monthly and quarterly data from June 2000 to August 2007 in our regressions. We have used WPI inflation data since this is what the RBI declares as its target. We have chosen the Index of Industrial Production (IIP) and GDP as our output measures (for month and quarter periods, respectively) for the reasons specified below. Our policy interest rate is the repo rate, since this has become the most operation policy rate over the past few years.[3] For quarterly data, the end quarter repo rate is taken as the rate for that quarter. Quarterly inflation is the average rate over that quarter.

We have confined ourselves to the period post 2000 since our earlier work indicates significant structural breaks during the late Nineties; these breaks are likely to have

[2] This is a simplification of the dynamics of the response function. In India, exchange rate management is a significant response parameter, especially in the recent past. In 2007, there has been at least one episode where the RBI has shown a distinct "switching" behaviour in its response, with systematic and sustained intervention in the currency markets overriding inflation targeting.
[3] The RBI has also used the width of the LAF repo and reverse repo corridor as a policy instrument, but the use has been more infrequent.

induced significant mis-specifications in our regressions. In addition, the RBI's monetary policy framework had changed significantly after the release of the Report of the Working Group on monetary policy (op cited).

III.b Measurement of potential output

An important issue, especially in India, is the measurement of the output gap; unlike developed countries, there are no official measures of potential output levels. Virmani (2004) has earlier attempted an estimation of potential GDP, by comparing an Unobserved Components model with an estimate derived from a Hodrick-Prescott (HP) based smoothing. He found that sensitivities of the two models were not very different. In other studies, estimates of the long run equilibrium level of output are found to be sensitive to the method of estimation (see Mishkin (2007) for a recent overview and references therein). We have used both monthly and quarterly measures of output, for reasons explained below.

For the monthly exercise, the Index of Industrial Production (IIP) is a natural choice as the output measure, for a variety of reasons. The most important was that would allow us to model the monetary reactions on a monthly basis. Moreover, the IIP is a much more homogenous measure of the Data Generation Process for economic activity. The agriculture and allied products segments of the GDP are driven by many factors that are relatively exogenous to the monetary policy stance. In addition, large segments of the services sectors (transport, storage, communications, etc.) and construction are driven by the industrial segment.

On the other hand, the quarterly GDP measure is a more comprehensive measure and is a more natural fit to the quarterly reviews of monetary policy that is the RBI's standard practice.

We have attempted to measure the output gap using three different measures:

i. Cyclical component of output growth (the residual of the HP filter)
ii. Residuals from regressing output growth on time trends
iii. Residuals from AR models of output growth

Details of the regression outputs are given in Appendix 7.

Chart 2a: Estimates of deviation of actual from potential industrial output in India

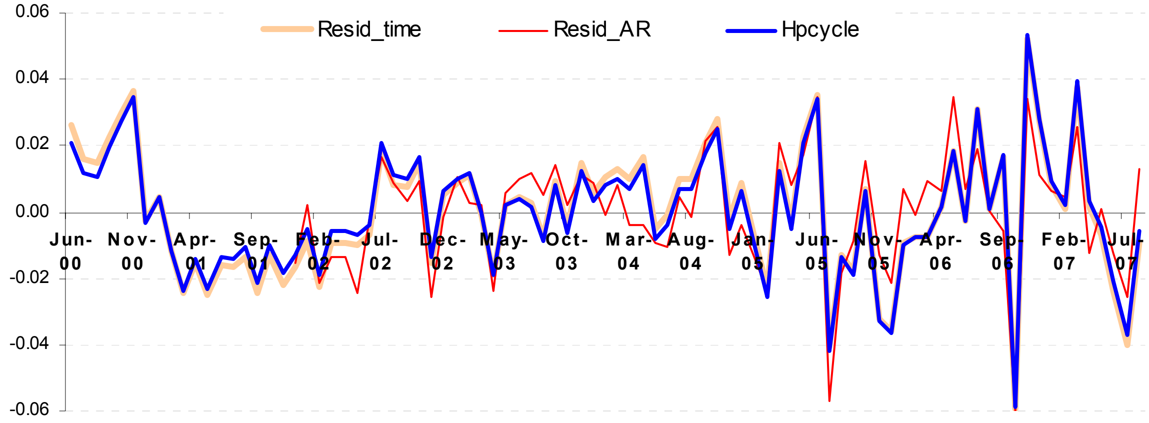
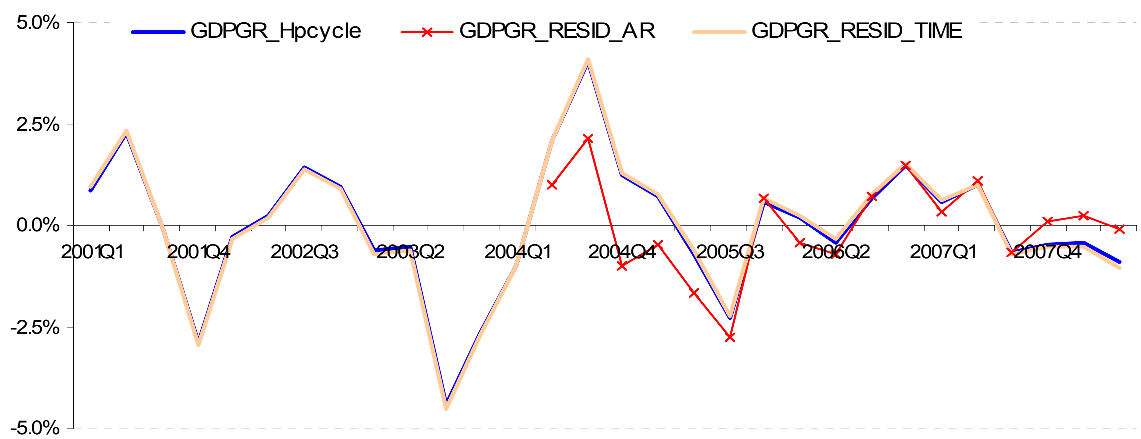


Chart 2b: Estimates of potential output gap using quarterly GDP for India



Notes:

1. The Resid_time series are the residuals obtained from regressing the growth rate of the respective output measure on time (t = 1,2,3….).
2. Resid_AR are the residuals obtained from an AR representation of the growth rate of the respective output measure.
3. HP_Cycle represents the cyclical component residual from the long term HP filter.

Chart 2 above shows that the three measures of potential output seem to be congruent, given the residuals are more or less of the same magnitude. In the rest of the paper, we have used the HP-cycle method to measure the output gap[4] using output growth.

III.c Limited Dependent Models

$$Prob\ (Repo\_order) = F(\Pi_t,\ Y_t,\ Lagged\_cut,\ Lagged\_hike)\ \ldots.\ (1)$$

where "Lagged_cut" and "Lagged_hike" are dummy variables, Π_t is inflation, Y_t is the output measure.

The target variable "Repo_order" is a categorical variable constructed from the changes in the repo rate. Given the unbalanced nature of the sample (zero changes occur more frequently than either increases or cuts), we have used both Probit and Logit functional forms to check for parameter instability and other mis-specifications.

The ordered variable (Repo_order) constructed from the repo rate change is distributed as follows, for the monthly and quarterly data models.

Table 1: Repo rate changes: Distribution for ordered models

	Monthly data		**Quarterly data**	
Description	**Repo_order**	**Frequency**	**Repo_order**	**Frequency**
Cut > 25 bps	0	7	1	6
Cut ≤ 25 bps	1	4	2	2
No change	2	67	3	13
Hike ≤ 25 bps	3	7	4	7
Hike > 25 bps	4	2	5	2

One implication of the fact that interest rate changes have tended to be small in magnitude, (typically 25 bps), it is likely that total desired change would not be achieved in a single adjustment. As Chart 1 above shows, policy rate changes have often tended to be clustered. Clustered policy changes have also been universally in the same direction. To test this formally, we have used dummy variables ("Lagged_cut" and "Lagged_hike")

[4] This ideal output is occasionally referred to as potential output in places in the paper.

that capture the direction of movement of the policy rate in the previous period. The objective of including the dummies was to test the persistence of rate cuts (and hikes) and thereby (indirectly) to check if there were any asymmetries in the implementation of a rate cut or a rate hike.

These variables are defined as follows:

Lagged_cut	*= 1,*	*if interest rate was cut in previous month*
	= 0,	*otherwise*
Lagged_hike	*=1,*	*if interest rate was raised in previous month*
	= 0,	*otherwise*

III.d Estimation of limited dependent models

The following is a summary of the methodology adopted in the following section. The ordered probit and logit models (for both monthly and quarterly data, respectively) were estimated by a two-step method. First, current inflation and output gap were considered as explanatory variables. The objective was to understand whether the RBI really did use inflation as the predominant target of its policy rather than the current output gap as the target. In the second step, the dummies Lagged_cut and Lagged_hike were included in the set of explanatory variables in order to assess persistence of policy actions and possible partial adjustment. Even though the distribution of the order variable looked symmetric (hence closer to a normal distribution), we have estimated both logit and the probit models, in order to compare the robustness of the estimations to distributional assumptions.

For the main regressions, two sets were conducted with monthly and quarterly data. One problem with monthly data is its unbalanced nature, since the frequency of 'no change' in the repo rate was very high, both as a result of the intermittent nature of policy changes and since these changes do not happen on a monthly basis. The distribution of changes in quarterly data is much more balanced. In India, moreover, since monetary policy decisions are (mostly) taken on a quarterly basis, the quarterly data might be a truer representation of the data generation process underlying the repo rate changes.

A set of linear "Taylor Rules" type regressions are also finally reported to provide a basis for comparison with the non-linear models, both to validate the results here and check how many of the inferences turn out to be robust to the type of regression.

IV. RESULTS

Details of the regression outputs for the specific models are given in Appendices 1 through 4. The following sections report the main inferences from the results. All estimates were obtained using EViews 5.

IV.a Inferences with monthly data

In the first stage, we estimated ordered regressions for interest rate changes in which the explanatory variables were the current rate of inflation and the growth rate of adjusted IIP. The outputs of the logit and the probit models are similar in terms of the model selection criteria, with no particular reason to favour one over the other. The indicated coefficients are also similar, although the strengths of the coefficients vary.

In both the logit and the probit models, the output gap was found to be more significant than the current level of inflation. The contribution of the current rate of inflation in determining the probability of interest rate changes is much smaller, as can be seen by the low level of significance of this variable and the fact that its sign is opposite to that expected. On the other hand, the output gap coefficient both has the correct sign and is statistically more significant than the inflation coefficient.

The coefficients of the limits points (corresponding to the cut-off values of categories) remain robust in sign and significance (and to an extent in magnitude) between the two models and also to the inclusion of the lagged policy response dummies.

These lagged response dummies were added to check persistence of policy responses as well as to capture possible inertia in policy responses. Although this behaviour is not well understood in India as yet, it has been extensively studied for the US Federal Reserve. It has been conjectured that the Fed's tends to smooth changes in interest rates and adjust its target for the Federal Funds Rate in a measured fashion. Such a reaction function, generalizing the Taylor Rules, was studied by Clarida *et al*. (2000).

We have used a simplified version of their approach, by adding dummies for one-period lagged cuts and hikes in a re-specified regression framework. After adding the lag response dummies, the pseudo R^2 improved from .01 to .02 in both the logit and probit models. However, none of the dummies were significant. Recall that the "Lagged_cut" dummy indicates the chance of a cut in interest rate given that there was a cut in the previous month. "Lagged_hike" indicates the same for a hike.

The logit model performed marginally better than the probit according to the various model selection criteria. Note that the inclusion of the lagged adjustment terms makes little difference to the estimated coefficients for inflation and the output gap.

The results from our two functional forms were somewhat contradictory. In the logit model, *Lagged_cut* dummy is more significant than the *Lagged_hike* dummy. On the other hand, in the probit model, the *Lagged_hike* dummy was relatively stronger.

The high p-values of the coefficients in both the models suggest that there is no statistically significant persistence in the monetary policy actions of the RBI.

IV.b Inferences with quarterly data

The unbalanced nature of the changes above is likely to have resulted in inefficient estimation in the above equations. One way to correct for this distortion is to consider monetary policy changes at quarterly intervals. The RBI, unlike many other central banks, conducts a quarterly, rather than monthly, review of its monetary policy[5]. The probability, therefore, of recording a change for any given quarter increases.

The following are some of the main differences and similarities with the model based on monthly data. As with the models with monthly data, the output gap is always more significant than inflation in both models.

The month-based logit and probit model showed different results for persistence effects, while the results of the quarterly model were similar. For monthly data, *Lagged_cut* was

[5] Although it has occasionally taken a mid-review monetary policy action.

more significant than *Lagged_hike* in the ordered logit model. On a quarterly time frame, *Lagged_hike* dummy was more significant than *Lagged_cut* in both the models and the results were also stronger. Overall, then, there is evidence of greater persistence of a rate hike following another.

To understand the results of the logit regressions, we decided to benchmark them against a linear "Taylor Rules" type of regression. The results of this regression are given in Appendix 2. While the two regression results are not completely comparable, the overall fit of the limited dependent regressions was slightly better than the linear model.

IV.c Asymmetry in monetary policy

In order to examine the existence of asymmetries in the monetary policy, the ordered probit and logit models were re-specified. The output gap series was decomposed into two parts: positive output gap (output_plus) and negative output gap (output_minus).

The results indicate relatively weak directionality in the response function. The monthly data could not differentiate between the periods of positive and negative output gaps. The quarterly data indicated a significant coefficient of the negative output gap variable, which implies that the RBI is more likely to take policy action when output is below the potential level than when it is above that level. However, the insignificant coefficients of the limit points in the quarterly model suggest that the model is weak in categorizing the estimated values, while the significant limit points in the monthly data indicated the strength of the model. The results of these regressions are given in Appendix 3.

IV.d Marginal Effects

Marginal effects measure the change in predicted probability associated with changes in the explanatory variables. The derived marginal probabilities from the ordered models are given in Appendix 4. The marginal effects of output gap are found to be stronger than inflation across all possible response categories. An increase in output gap raises the probability of a larger response. Persistence effects are low and similar in both the models, symmetric across cuts and hikes.

IV.e Limited Dependent models with binary dependent variables

Given the strong unbalanced classification in the ordered models, which might be causing distortions in the estimated probabilities, we wished to substantiate the results of symmetric responses of the RBI's monetary policy. We investigate this further with a simpler binary limited dependent model. Binary logit / probit models were estimated with the binary repo rate indicators constructed as follows:

Repo_binary = 1, if the repo rate is hiked
= 0, if the repo rate is cut or unchanged

Table 2: Repo rate changes distribution for binary models

Description	Repo_binary	Frequency
Hike	1	9
Cut or No change	0	78

The results are reported in Appendix 5. Here, too, the output gap turns out to be more significant than inflation. The difference in this regression compared to the ordered models are the strengths of the lagged dummy variables, which are proxies for the persistence in policy actions and hence might be indicative of asymmetry in response actions. The lagged_cut dummies were more significant than the lagged_hike in both the logit and probit models. This means that a cut was more likely to follow a prior cut than a hike following a prior hike.

IV.f Binary dependent variables with a structural regime break

We also checked for the robustness of the results to a possible structural change in the RBI's monetary policy; Chart 1 above shows two distinct phases over the sample period considered in this study. A dummy variable for a regime shift was introduced as an explanatory variable into the binary regression framework. This dummy is defined as follows:

Regime_Shift_dummy = 1, if policy regime was "Easing"
= 0, if policy regime was "Tightening"

The corresponding probit regression for the full sample is as follows:

$$Prob\ (Repo\_Change\_binary) = F(\ \Pi_t\ ,\ Y_t\ ,\ Regime\_Shift\_dummy)\ \ldots.\ (2)$$

Two other probit regressions were then done separately for the "Easing" and "Tightening" phases of monetary policy (with the Regime Shift dummy obviously deleted) to check for asymmetries in the policy regimes during these different regimes. The binary dependent variable was re-specified as follows:

Table 3: Repo rate changes distribution for binary models

Description	Repo_change_binary	Frequency
Change	1	20
No change	0	67

The results for these regressions are reported in Appendix 6. First, there are no indications of a significant influence of the regime shift dummy on policy response. The indicated strength of the inflation and output gap variables in this re-specified equation is also consistent with the results if the regression reported in the previous section.

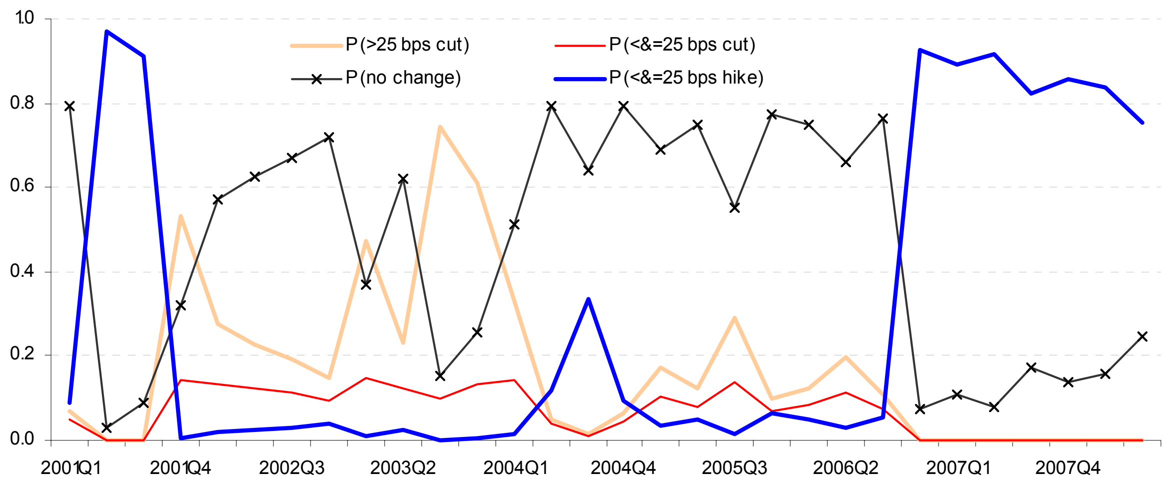
Splitting the sample into two parts degrades the performance of the models, partially, of course, due to the reduction in the degrees of freedom in the respective models. Keeping in mind the non-significance of the parameters in the split regressions, it should be pointed out that the dominance of the output gap parameter in explaining a policy change seems to have reduced. A possible explanation is a marked de-linking of inflation and the output gap since 2005, as well as the actual output fluctuating more narrowly around potential output than in the previous easing episode.

IV.f Forecasts from the ordered models

Given the results of the various models, how accurate might these have been in predicting the actions of the RBI? Chart 4 below shows the effectiveness of the logit models (using quarterly GDP data) in predicting the RBI's responses. The most striking aspect is the sharp increase in the calculated probability of a rate hike in the third quarter of Fiscal

2007-08. The last time there had been an equivalent increase was in 2000-01, at the time of the internet boom. These results need to be viewed with some caution given the likelihood of an upward bias in the probability of "no change in rates" (as there are 13 cases of no change among 30 cases in the case of quarterly data).

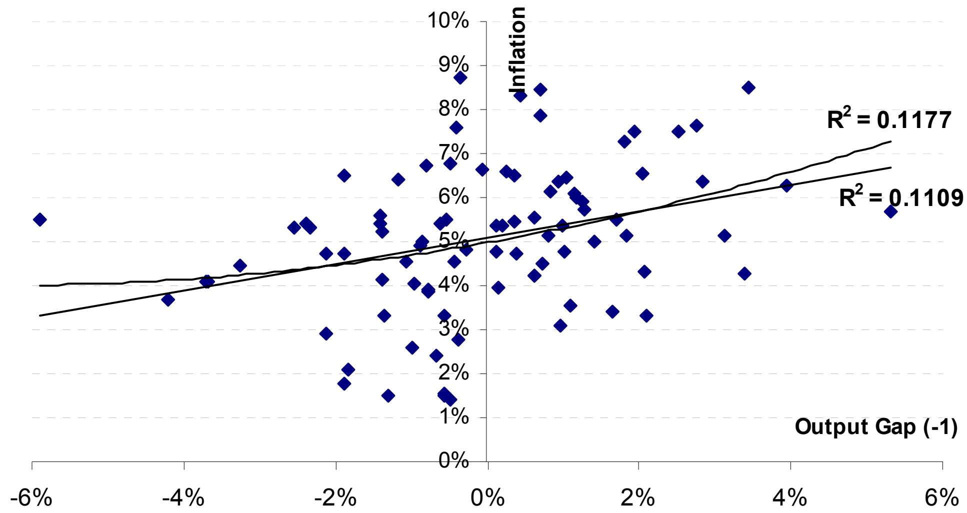
Chart 4: Predicted probabilities from the logit model



V The relation between Inflation and lagged output

To validate the results of the previous section, we test for the relationship between inflation and the output gap. It has been conjectured (see Gascoigne and Turner [2003], for instance) that central banks react to output gaps faster than they do to inflation, presumably on the presumption that a positive gap forecasts future inflation. Chart 3 below depicts a scatter plot of inflation (vertical axis) against the output gap (as measured by the residual of the actual IIP growth from its HP trend. As can be observed, there is some weak evidence of convexity in the relation. Some of this convexity might be explained by the real-wage rigidity that characterizes Indian labour markets, giving rise to a steeper inflation output trade-off when output is above the natural level, compared to when it is below it. At this point, we use a linear hypothesis as our working one.

Chart 3: Philips Curve in India - Inflation and lagged Output Gap



To understand the dynamics of inflation output gap, the following equation was estimated:

$$\pi_t = \alpha + \beta_0 y_t + \beta_1 y_{t-1} + \mu \qquad (2)$$

where,
y = output gap, π = inflation

Table 4: Regression results

Monthly IIP data

	Coefficient	t-Statistic	p-value
C	0.05	29.9	0.00
IIP Growth	0.18	1.91	0.06
IIP Growth (lag 1)	0.27	2.87	0.01

Quarterly GDP data

	Coefficient	t-Statistic	p-value
C	0.05	16.18	0.00
GDP Growth	-0.15	-0.74	0.46
GDP Growth (lag 1)	0.07	0.32	0.75

Regression diagnostics

Monthly IIP data

R-squared	0.15	Mean dependent var	0.05
Adjusted R-squared	0.13	S.D. dependent var	0.02
S.E. of regression	0.02	Akaike info criterion	-5.43
Sum squared resid	0.02	Schwarz criterion	-5.35
Log likelihood	237	F-statistic	7.18
Durbin-Watson stat	0.28	Prob(F-statistic)	0.00

Quarterly GDP data

R-squared	0.02	Mean dependent var	0.05
Adjusted R-squared	-0.05	S.D. dependent var	0.02
S.E. of regression	0.02	Akaike info criterion	-5.24
Sum squared resid	0.01	Schwarz criterion	-5.10
Log likelihood	78.9	F-statistic	0.28
Durbin-Watson stat	0.55	Prob(F-statistic)	0.76

This equation was estimated to validate our hypothesis that inflation responds to output gap with a lag. The results seem consistent with the hypothesis. This regression supports the hypothesis that inflation responds with a lag to the output gap. To check the strength of the result we tried other lags as well, but none of them turned out to be significant other than the first lag.

VI. CONCLUSIONS

The RBI has been very clear that its primary monetary policy objective in the recent past has been inflation targeting, employing a host of intermediate targets to achieve this objective. This paper sought to understand the objectives of its policy over the past 7 years and the methods that it has employed to achieve this goal. Although the regression coefficients are quite weak, the multiple methods of estimation that we have used impart a degree of robustness to the inferences.

The evidence in India seems to be more consistent with changes in policy interest rates being determined by the output gap rather than current inflation. This is a conclusion that is validated consistently across models and time aggregations. A negative output gap seems to be more influential than a positive gap. The influence of inflation as an explanatory factor is much less consistent. As partial explanation of this policy response function, there is evidence that current and lagged output gap does indeed influence (future) inflation.

Consistent with the evidence of a greater influence of the output gap on policy decisions, there appears to be some asymmetry in the response, with a propensity to act on a negative output gap, indicating greater concern about economic slowdown rather than inflation. On the other hand, there seems to be greater persistence in the rate hike process than in the rate cut, which might be construed as some indirect evidence of an opposite asymmetry in the policy response function. It is likely that this is the result of the structural economic changes that are currently underway in India, whereby the growth impulses have been consistently strong over the past few years.

Extensions to this paper include a forward looking approach to the policy response function, which might include forecasts of inflation and economic activity. Asymmetry features need to be addressed in greater detail. The error dynamics of the limited dependent class of models used here needs to be explored further. The regime switching aspect of monetary policy also needs to be incorporated into the models.

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APPENDIX 1a

AT 1a 1: Ordered Logit for IIP monthly growth

	Coefficient	z-Statistic	p-value	Coefficient	z-Statistic	p-value
INFLATION	-7.29	-0.47	0.64	-5.32	-0.34	0.73
OUTPUT GAP_IIP	16.44	1.19	0.23	16.67	1.20	0.23
LAGGED_CUT				-0.86	-1.13	0.26
LAGGED_HIKE				-0.79	-0.91	0.36
Limit Points[6]						
LIMIT_1	-2.85	-3.20	0.00	-2.99	-3.28	0.00
LIMIT_2	-2.35	-2.73	0.01	-2.48	-2.82	0.00
LIMIT_3	1.81	2.18	0.03	1.78	2.11	0.03
LIMIT_4	3.42	3.28	0.00	3.39	3.22	0.00

AT 1a 2: Ordered Probit for IIP monthly growth

	Coefficient	z-Statistic	p-value	Coefficient	z-Statistic	p-value
INFLATION	-4.17	-0.50	0.62	-2.88	-0.34	0.73
OUTPUT GAP_IIP	8.83	1.20	0.23	9.97	1.33	0.18
LAGGED_CUT				-0.33	-0.84	0.40
LAGGED_HIKE				-0.47	-1.08	0.28
Limit Points						
LIMIT_1	-1.62	-3.40	0.00	-1.68	-3.47	0.00
LIMIT_2	-1.37	-2.94	0.00	-1.41	-3.00	0.00
LIMIT_3	1.07	2.36	0.02	1.07	2.32	0.02
LIMIT_4	1.83	3.50	0.00	1.82	3.46	0.00

Comparison of the two models for IIP monthly growth

Model selection criteria	Basic		Augmented with lagged response variable	
	Logit	Probit	Logit	Probit
Akaike info criterion	1.79	1.79	1.82	1.82
Log likelihood	-71.93	-71.90	-71.02	-71.09
Restr. log likelihood	-72.65	-72.65	-72.65	-72.65
LR statistic (2 df)	1.44	1.48	3.26	3.12
Probability(LR stat)	0.49	0.48	0.52	0.54
Schwarz criterion	1.96	1.96	2.04	2.04
Hannan-Quinn criter.	1.86	1.86	1.91	1.91
Avg. log likelihood	-0.83	-0.83	-0.82	-0.82
LR index (Pseudo-R2)	0.01	0.01	0.02	0.02

[6] The Limit Points are the estimates of the threshold coefficients of the distribution function. That is, if $F(X'\beta)$ is the distribution function of the unobserved continuous latent variable in an ordered probit model, $F(X'\beta) \leq$ Limit_i, implies that the dependent variable falls into category i.

APPENDIX 1b

AT 1b 1: Ordered Logit for GDP quarterly growth

	Coefficient	z-Statistic	p-value	Coefficient	z-Statistic	p-value
INFLATION	17.63	0.78	0.44	13.70	0.55	0.58
OUTPUT GAP_GDP	55.61	2.24	0.03	53.65	2.19	0.03
LAGGED_CUT				-0.74	-0.83	0.41
LAGGED_HIKE				2.50	2.49	0.01
Limit Points						
LIMIT_1	-0.70	-0.58	0.56	-0.92	-0.65	0.52
LIMIT_2	-0.27	-0.22	0.82	-0.43	-0.31	0.75
LIMIT_3	1.82	1.50	0.13	2.49	1.69	0.09
LIMIT_4	3.74	2.65	0.01	5.03	2.86	0.00

AT 1b 2: Ordered PROBIT for GDP quarterly growth

	Coefficient	z-Statistic	p-value	Coefficient	z-Statistic	p-value
INFLATION	11.01	0.86	0.39	5.46	0.41	0.68
OUTPUT GAP_GDP	33.51	2.44	0.01	31.23	2.18	0.03
LAGGED_CUT				-0.40	-0.76	0.45
LAGGED_HIKE				1.13	2.22	0.03
Limit Points						
LIMIT_1	-0.37	-0.52	0.60	-0.59	-0.76	0.44
LIMIT_2	-0.12	-0.17	0.87	-0.33	-0.44	0.66
LIMIT_3	1.16	1.63	0.10	1.22	1.59	0.11
LIMIT_4	2.26	2.81	0.01	2.53	2.89	0.00

Comparison of the two models: model selection criteria

	Basic		Augmented with lagged response variable	
	Logit	**Probit**	**Logit**	**Probit**
Akaike info criterion	2.97	2.95	2.75	2.83
Log likelihood	-38.5	-38.2	-33.2	-34.4
Restr. log likelihood	-41.5	-41.5	-41.5	-41.5
LR statistic (2 df)	5.99	6.64	16.52	14.21
Probability(LR stat)	0.05	0.04	0.00	0.01
Schwarz criterion	3.25	3.23	3.13	3.20
Hannan-Quinn criter.	3.06	3.04	2.87	2.95
Avg. log likelihood	-1.29	-1.27	-1.11	-1.15
LR index (Pseudo-R2)	0.07	0.08	0.20	0.17

Appendix 2
Results of linear regressions for policy rate changes

AT 2 1: Dependent variable: repo rate; Monthly data

Regression results

	Coefficient	t-Statistic	p-value
Constant	7.05	12.57	0.00
INFLATION	3.93	0.37	0.71
OUTPUT GAP_IIP	6.78	0.72	0.48
LAGGED_CUT	1.88	3.63	0.00
LAGGED_HIKE	0.78	1.38	0.17

Regression diagnostics

R-squared	0.16	Mean dependent var	7.57
Adjusted R-squared	0.12	S.D. dependent var	1.68
S.E. of regression	1.58	Akaike info criterion	3.80
Sum squared resid	204	Schwarz criterion	3.94
Log likelihood	-160	F-statistic	3.97
Durbin-Watson stat	0.55	Prob(F-statistic)	0.01

AT 2 2: Dependent variable: repo rate; Quarterly data

Regression results

	Coefficient	t-Statistic	p-value
Constant	6.25	5.43	0.00
INFLATION	16.04	0.77	0.45
OUTPUT GAP_GDP	17.37	0.84	0.41
LAGGED_CUT	0.92	1.11	0.28
LAGGED_HIKE	1.04	1.32	0.20

Regression diagnostics

R-squared	0.12	Mean dependent var	7.63
Adjusted R-squared	-0.02	S.D. dependent var	1.77
S.E. of regression	1.79	Akaike info criterion	4.15
Sum squared resid	80.1	Schwarz criterion	4.39
Log likelihood	-57.3	F-statistic	0.87
Durbin-Watson stat	0.26	Prob(F-statistic)	0.49

APPENDIX 3
Asymmetry in monetary policy

AT 3 1: Monthly data (IIP)

	Ordered Logit			Ordered PROBIT		
	Coefficient	**z-Statistic**	**Prob.**	**Coefficient**	**z-Statistic**	**Prob.**
INFLATION	-7.41	-0.48	0.63	-4.21	-0.51	0.61
OUTPUT_PLUS	21.16	0.82	0.41	9.49	0.73	0.47
OUTPUT_MINUS	12.37	0.52	0.61	8.18	0.61	0.55
Limit Points						
LIMIT_1:C(4)	-2.79	-3.00	0.00	-1.62	-3.24	0.00
LIMIT_2:C(5)	-2.29	-2.54	0.01	-1.36	-2.80	0.01
LIMIT_3:C(6)	1.87	2.12	0.03	1.08	2.27	0.02
LIMIT_4:C(7)	3.49	3.20	0.00	1.83	3.39	0.00

AT 3 2: Quarterly data (GDP)

	Ordered Logit			Ordered Probit		
	Coefficient	**z-Statistic**	**Prob.**	**Coefficient**	**z-Statistic**	**Prob.**
INFLATION	23.91	0.98	0.33	13.16	0.99	0.32
OUTPUT_PLUS	4.42	0.11	0.91	7.51	0.32	0.75
OUTPUT_MINUS	116.30	2.18	0.03	65.93	2.21	0.03
Limit Points						
LIMIT_2:C(4)	-1.10	-0.85	0.40	-0.60	-0.80	0.42
LIMIT_3:C(5)	-0.61	-0.49	0.62	-0.34	-0.46	0.65
LIMIT_4:C(6)	1.54	1.21	0.23	0.96	1.30	0.19
LIMIT_5:C(7)	3.48	2.38	0.02	2.07	2.48	0.01

APPENDIX 4

Marginal Probability effects for the ordered models (using monthly IIP data)

Ordered Probit Model

	Inflation	Output gap	Lagged cut	Lagged hike
Cut > 25 bps	-0.281	0.973	-0.033	-0.046
Cut ≤ 25 bps	-0.141	0.489	-0.016	-0.023
No change	-0.229	0.792	-0.027	-0.038
Hike ≤ 25 bps	0.430	-1.489	0.050	0.071
Hike > 25 bps	-0.221	0.765	-0.026	-0.036

Ordered Logit Model

	Inflation	Output gap	Lagged cut	Lagged hike
Cut > 25 bps	-0.242	0.760	-0.039	-0.036
Cut ≤ 25 bps	-0.137	0.429	-0.022	-0.020
No change	-0.278	0.870	-0.045	-0.041
Hike ≤ 25 bps	0.489	-1.532	0.079	0.072
Hike > 25 bps	-0.168	0.526	-0.027	-0.025

APPENDIX 5
Results with binary dependent variables on IIP monthly data

AT 5 1: Binary Logit

	Coefficient	z-Statistic	p-value
CONST	-2.64	-2.01	0.04
INFLATION	4.92	0.21	0.84
OUTPUT GAP_IIP	47.35	2.12	0.03
LAGGED_CUT	-0.33	-0.28	0.78
LAGGED_HIKE	-0.25	-0.21	0.83

AT 5 2:Binary Probit

	Coefficient	z-Statistic	p-value
CONST	-1.50	-2.14	0.03
INFLATION	2.82	0.22	0.83
OUTPUT GAP_IIP	25.85	2.08	0.04
LAGGED_CUT	-0.17	-0.27	0.78
LAGGED_HIKE	-0.20	-0.31	0.76

Comparison of the two models: model selection criteria

	Logit	Probit		Logit	Probit
S.E. of regression	0.30	0.30	Probability(LR stat)	0.22	0.21
Sum squared resid	7.45	7.48	Akaike info criterion	0.71	0.71
Log likelihood	-26.1	-26.0	Schwarz criterion	0.86	0.85
Restr. log likelihood	-28.9	-28.9	Hannan-Quinn criter.	0.77	0.77
LR statistic (4 df)	5.75	5.87	Avg. log likelihood	-0.30	-0.30
			McFadden R-squared	0.10	0.10

APPENDIX 6

AT 6.1: Binary Probit with a dummy for a policy regime shift

	Coefficient	z-Statistic	Prob.
CONST	-1.50	-2.58	0.01
INFLATION	8.80	0.90	0.37
OUTPUT GAP_IIP	15.92	1.67	0.09
REGIME_SHIFT_DUMMY	0.44	1.36	0.18

Regression diagnostics

Mean dependent var	0.22	S.D. dependent var	0.42
S.E. of regression	0.41	Akaike info criterion	1.08
Sum squared resid	13.71	Schwarz criterion	1.19
Log likelihood	-42.38	Hannan-Quinn criter.	1.12
Restr. log likelihood	-45.42	Avg. log likelihood	-0.49
LR statistic (3 df)	6.06	McFadden R-squared	0.07
Probability(LR stat)	0.11		

AT 6.2: Binary probit model

	Easing Phase			Tightening Phase			Full Period		
	Coefficient	z-Statistic	Prob.	Coefficient	z-Statistic	Prob.	Coefficient	z-Statistic	Prob.
CONST	-1.48	-2.41	0.02	0.26	0.22	0.83	-1.20	-2.25	0.02
INFLATION	17.67	1.58	0.12	-23.27	-1.02	0.31	8.12	0.83	0.41
OUTPUT GAP_IIP	13.17	0.88	0.38	24.00	1.87	0.06	15.59	1.72	0.08

Comparison: Model selection criteria

	Easing Phase	Tightening Phase	Full Period
Mean dependent var	0.28	0.19	0.23
S.E. of regression	0.44	0.39	0.41
Sum squared resid	8.36	5.89	14.46
Log likelihood	-25.2	-18.3	-44.4
Restr. log likelihood	-27.4	-20.5	-46.9
LR statistic (2 df)	4.41	4.32	5.10
Probability(LR stat)	0.11	0.12	0.08
S.D. dependent var	0.46	0.4	0.42
Akaike info criterion	1.23	1.01	1.09
Schwarz criterion	1.34	1.14	1.17
Hannan-Quinn criter.	1.27	1.06	1.12
Avg. log likelihood	-0.55	-0.44	-0.51
McFadden R-squared	0.08	0.11	0.05

APPENDIX 7
Regression results for estimating potential output

Method 1: The Hodrick-Prescott Filter
The λ used in HP filter was 14,400 for monthly data and 1,600 for quarterly data.

Method 2: Results of the regression of output growth on time trends
The output growth series was regressed on time (level and squared) in order to de-trend the series. The residuals from this regression represent the deviation of the series from the trend value at each point of time. This residual series was then considered as a proxy of the output gap. The results of the regression are as follows:

IIP growth

Regression results

	Coefficient	**t-Statistic**	**p-value.**
Constant	0.032	4.993	0.000
TIME	0.001	2.089	0.040
TIME2	0.000	0.790	0.432

Regression diagnostics

R-squared	0.615	Mean dependent var	0.071
Adjusted R-squared	0.605	S.D. dependent var	0.031
S.E. of regression	0.020	Akaike info criterion	-4.985
Sum squared resid	0.033	Schwarz criterion	-4.900
Log likelihood	219.9	F-statistic	66.97
Durbin-Watson stat	1.495	Prob(F-statistic)	0

GDP growth

Regression results

	Coefficient	**t-Statistic**	**p-value.**
Constant	0.040	3.850	0.001
TIME	0.002	1.245	0.224
TIME2	0.000	0.084	0.934

Regression diagnostics

R-squared	0.527	Mean dependent var	0.070
Adjusted R-squared	0.492	S.D. dependent var	0.025
S.E. of regression	0.018	Akaike info criterion	-5.153
Sum squared resid	0.008	Schwarz criterion	-5.013
Log likelihood	80.29	F-statistic	15.04
Durbin-Watson stat	1.081	Prob(F-statistic)	0

APPENDIX 7 (contd)

Regression results for estimating potential output

Method 3: Results of the AR models of output growth

Residuals from an AR model of output growth were used as a proxy of output gap. The partial autocorrelogram of IIP growth indicated lags 1,2,12,13,18 as the significant lags, and 1,5,13 for the GDP growth. The results of the AR regression are given below:

<u>IIP growth</u>

Regression results

	Coefficient	t-Statistic	p-value.
C	0.141	1.214	0.229
AR(1)	0.184	1.623	0.109
AR(2)	0.306	2.620	0.011
AR(3)	0.139	1.213	0.229
AR(4)	0.255	2.165	0.034
AR(12)	-0.330	-2.451	0.017
AR(18)	0.373	3.182	0.002

Regression diagnostics

R-squared	0.593	Mean dependent var	0.079
Adjusted R-squared	0.554	S.D. dependent var	0.0279
S.E. of regression	0.018	Akaike info criterion	-5.027
Sum squared resid	0.021	Schwarz criterion	-4.801
Log likelihood	180.4	F-statistic	15.10
Durbin-Watson stat	1.954	Prob(F-statistic)	0

<u>GDP growth</u>

Regression results

	Coefficient	t-Statistic	p-valuee
C	0.090	10.574	0.000
AR(1)	0.300	1.310	0.213
AR(5)	0.014	0.081	0.937
AR(13)	0.030	0.177	0.862

Regression diagnostics

R-squared	0.126	Mean dependent var	0.088
Adjusted R-squared	-0.076	S.D. dependent var	0.013
S.E. of regression	0.013	Akaike info criterion	-5.60
Sum squared resid	0.002	Schwarz criterion	-5.40
Log likelihood	51.6	F-statistic	0.625
Durbin-Watson stat	1.549	Prob(F-statistic)	0.611