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Regime Shifts in India's Monetary Policy Response Function

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Regime-Shifts in India's Monetary Policy Response Function

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Abstract

The objectives of monetary policy have always been a topic of intensive debate. This debate has resurfaced during the past few years. In India too monetary policy-making appears to have undergone significant change during the last two decades and has also been responding to changing macroeconomic environment. Against this backdrop an attempt has been made in this paper to model the monetary policy response function for India, for the period April 1996 to July 2015. Using 91-day Treasury bill rate as the policy rate, we find that the monetary policy has been responsive to inflation rate, output gap and exchange rate changes during this period. We find substantial time-varying behavior in the reaction function. The regime shift tests show that the transition is driven by inflation gap as well as exchange rate changes. Highly complex nature of dynamics of interest rate does not allow us to estimate many models, but the models estimated show that the monetary policy responds to inflation gap as well as exchange rate changes. Another important finding is that there is a high degree of inertia in the policy rates.

Keywords: Monetary policy, reaction function, smooth transition regression, India.

JEL Classification codes: E52, C22.

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1. Introduction

During the last three decades, monetary policy making has undergone a sea change. In particular, increasing openness of economies and financial liberalization have posed significant challenges for monetary policy making. Accordingly, both targets (final as well as intermediate) and operating procedures have undergone drastic changes. In addition to price stability and growth, the central banks have also included financial stability as their objective. Even for targeting price stability, the intermediate targets have changed. India has not been an exception to this, and its policy has undergone several changes, from primarily quantity-based to price-based policy. In terms of objectives, it now has financial stability as an important consideration. Furthermore, with high level of instability in the money demand function, it had to abandon the policy of monetary targeting adopted in mid-1980s and adopt multiple indicator approach in late 1990s. This shift gave way to explicit inflation targeting approach with the adoption of flexible inflation targeting starting 2013.

Against this backdrop an attempt has been made, in this paper, to model empirically the monetary policy response function for the Indian economy, with the help of monthly data for the period 1996:04 to 2015:07. Following the changes in the making of monetary policy mentioned above, and the extreme macroeconomic events such as episodes of external sector volatility and high inflation, one can expect the response function to change over time. Therefore, we also test for regime shift in this function.

We find that the monetary policy in this period has responded to inflation gap, as well as exchange rate depreciation, which is used as a proxy for volatility. Rolling regression clearly shows variation in this function over time, following which we test for regime change explicitly. These tests provide evidence of nonlinearity driven by inflation rate and exchange rate movements. The limited set of smooth transition regression models that we are able to estimate provide evidence for the reaction function undergoing changes with inflation and exchange rate depreciation.

2. Theoretical Underpinnings

The literature on monetary policy reaction functions follow the basic function suggested by Taylor (1993), in which the policy interest rate is modeled as a function of inflation gap and output gap. This has over time been extended to include variables such as asset prices and exchange rate, in view of the increasing attention being paid to these variables by the policymakers. Further, there are issues of interest smoothing and forward-looking vs. backward looking behaviour. The former refers to the arguments that the lagged interest rates too should enter the monetary policy reaction function. There are several arguments for this, e.g., model uncertainty, need to build consensus for policy actions, reluctance of central banks to change rates since large changes might need policy reversals which would reduce credibility of central bank, etc. The other debate is about whether the leads or lags of indicators should appear in the reaction function. One line of thought is that the central banks are forward-looking and they target the anticipated future values of the target variables. The other view is that the data for the indicators used by the central banks for the purposes of policy become available only with lags, and therefore the policy rules should be based on lags of the indicator variables. Thus, while the basic framework is to model the policy interest rate as a function of inflation gap, output gap and asset prices and/or exchange rates, it is now usually augmented by the lags of the dependent variable and also the explanatory variables are replaced by their expectations, in many studies.

3. Review of Literature

A number of authors have tried to study the monetary policy reaction function for the Indian economy during the last one-and-a-half decades. These include Virmani (2004), Singh and Kalirajan (2006), Ranjan et al. (2007), Banerjee and Bhattacharya (2008), Singh (2010), Patra and Kapur (2012) and Hutchison et al. (2013). However, with the exception of three, all others estimate a single function for the entire period. Only Ranjan et al. (2007), Singh (2010) and Hutchison et al. (2013) allow for changes in this function over time.

Ranjan et al. (2007) find significant response of monetary policy index to output gap and inflation gap over the period 1951-2005. Both these coefficients go up when the sample is restricted to begin in 1992. When the output gap is replaced by its first lag, the coefficient values decline in almost all the models, in both the periods. The authors estimate three different measures of output gap and results are robust to choice of such a measure. However, the authors do not test for regime change and even the choice of 1992 is not determined on the basis of data. Also, they do not allow for interest rate smoothing and all their models have very low explanatory power, with adjusted R^2 values below 0.25.

Singh (2010) estimates monetary policy reaction function for the Indian economy for the period 1951-2009. The function has exchange rate and interest rate smoothing terms in addition to inflation gap and output gap. In addition to estimating for the whole period, the author also estimates these functions separately for the period upto 1988 and thereafter. The coefficients have expected signs in most of the models. While the coefficients are significant in very few models in the pre-1989 period, in the remaining period these coefficients are significant in most of the models. This is in line with the findings of Ranjan et al. (2007). The interest rate smoothing term is highly significant in most of the models, more in the pre-1989 period than after that.

Hutchison et al. (2013) study the monetary policy reaction function for the Indian economy during the period 1987q1 to 2008q4 and allow for regime switching using Markov-chains. They find that the policy of the RBI can be characterised by two regimes: *hawk* and *dove*. In the first regime the RBI puts more emphasis on inflation, while in the latter output gap and exchange rate are targeted more.

In contrast to these studies, our study covers the period from 1996M4 to 2015M7. More importantly, with the exception of Hutchison et al. (2013) no other study tests for the presence of structural break, let alone detect the date of transition. The last one, although tests for these statistically, allows for stochastic regime-switching which, even though gives separate regimes, is silent on what governs the regime change. To address these issues, we allow for regime-switching behavior in the framework of smooth transition regression popularized by Terasvirta et al. (1994). The following section discusses the methodology and data in detail.

4. Methodology and Data

4.1 Methodology

We study the regime-switching behavior in the framework of Smooth Transition Regression (STR) popularized by Terasvirta (1994). The advantages of this approach are that it allows both the transition point as well as the speed of transition to be estimated endogenously. One advantage of this, apart from determining the change point endogenously, is that it does not force the regime-change to be abrupt. After testing for nonlinearity using the tests suggested by Terasvirta (1994) and Escribano and Jorda (2001), we estimate the simple nonlinear models. We start with simple models with one transition function. In this class, we consider models with logistic functions of first order (henceforth, referred to as L1 model) and second order (L2 model). However, while the L2 model allows three regimes, it forces the extreme regimes to be identical, which may not be too restrictive here. Therefore, we estimate a 3-regime model with three distinct regimes, using slight modification of the multiple-regime STAR (MRSTAR) model. Thus, we estimate the following models:

$$y_t = x'_{1t}\beta_1[1 - F_1(w_t)] + x'_{2t}\beta_2 F_1(w_t) \tag{1}$$

and

$$y_t = x'_{1t}\beta_1[1 - F_1(w_t)][1 - F_2(w_t)] + x'_{2t}\beta_2 F_1(w_t)[1 - F_2(w_t)] + x'_3\beta_3 F_1(w_t)F_2(w_t) \tag{2}$$

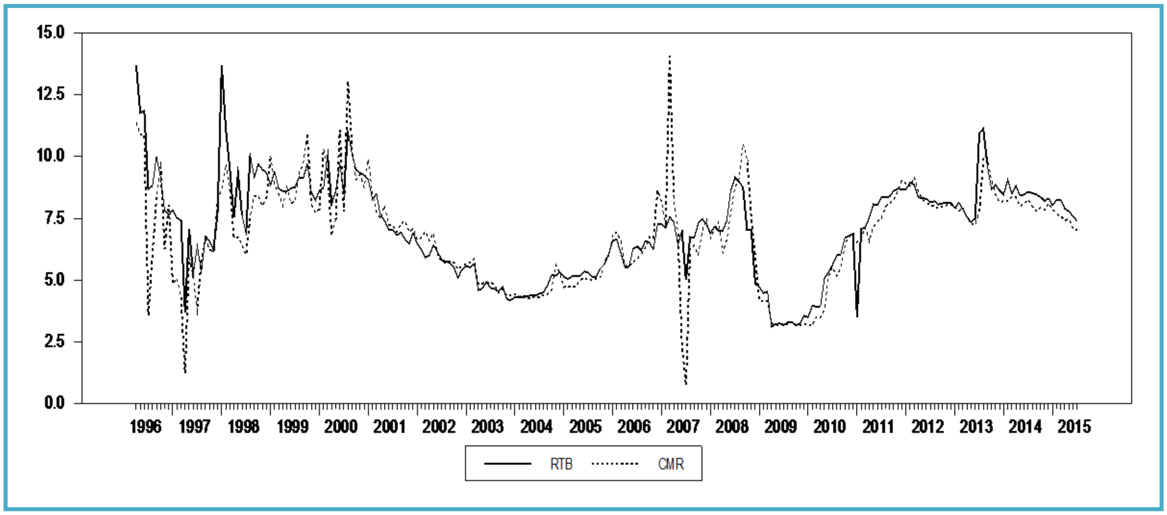
The model (1) was estimated with first order and second order logistic functions, and these are labeled as L1 and L2 respectively. In the L1 model, coefficient β_1 and β_2 are coefficient vectors in the regimes corresponding to low and high values respectively of w_t, while, in the L2 model, these correspond to middle and extreme values respectively of w_t. In model (2) both the transition functions are logistic function of first order in the same transition variable, with the second function capturing transition at a larger value of transition variable than the first one. The coefficients corresponding to the low, middle and high values of the transition variable in this specification are given by β_1, β_2 and β_3, respectively.

4.2 Data

4.2.1 The dependent variable

Following the discussion in the section on theoretical underpinnings, we estimate a function in which the policy interest rate is a function of inflation gap, output gap, and rate of depreciation. The choice of appropriate variable to represent policy stance itself is very difficult here, in view of the multiple instruments used by the RBI, viz., bank rate, reserve requirements, outright open market operations and repo operations. Though since the year 2000 the repo rate emerged as the principal operating instrument, it has been supplemented by other measures from time to time, thus necessitating the search for some other indicator. One option is the overnight call money rate, which is the operating target of monetary policy. However, this is found to be excessively volatile at times. Yet another indicator which has been found to be moving with this variable at most horizons without being excessively volatile is the yield on the treasury bills. Therefore, we take the yield on treasury bills with residual maturity ranging from 15 to 91 days (INT) as the dependent variable. As can be seen from Fig. 1, it is cointegrated with the call money rate without being excessively volatile.

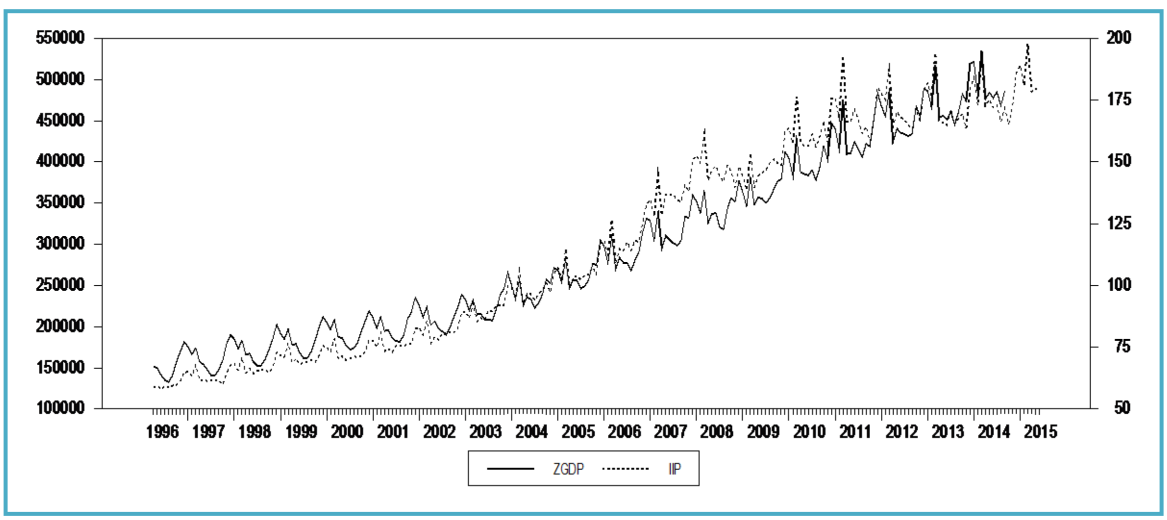
Figure 1: Co-movement of call money rate and yield on Treasury bill with residual maturity between 15 and 91 days.



4.2.2 Independent variables

For inflation gap we take the WPI inflation, excess over 5%, in view of the fact that till RBI formally adopted flexible inflation targeting in 2013, it was targeting WPI inflation and 5% was accepted as the target level of inflation.

Figure 2: Variation in IIP and real GDP



For output gap the GDP series is not available at monthly frequency. Therefore, we take GDP at quarterly frequency, and apply the procedure suggested by Denton (1971) in order to convert it into monthly frequency. The index of industrial production (IIP) was used as the reference monthly series for this conversion. The real GDP series and quarterly series are shown in Fig. 2 and it is clear that this procedure gives us monthly GDP figures while maintaining the longer term features of GDP. We then apply the Hodrick-Prescott filter to the annual growth rate of this ZGDP series. This filtered series is then used as the measure of output gap, labeled as GDPGAP.

Finally we add the monthly growth rate of average exchange rate of Indian Rupee against US Dollar.

The data on WPI, ZGDP and IIP were taken from the website of the Central Statistics Office (CSO), Government of India. The other series were taken from the Database on Indian Economy, Reserve Bank of India. The series were obtained for the period April 1996 to July 2015. However, since the data for ZGDP are available only till September 2014, all the estimations have been possible only till September 2014.

5. Discussion of Results

5.1 Preliminary investigation and linear model

To begin with, we look at the movement of the policy interest rate with the variables the policy is likely to target. We then estimate a linear specification and study the behavior of the coefficients over time using rolling regression. This is followed by testing for regime-shifts. Finally, we estimate the nonlinear models.

The linear specification we chose had two lags of the dependent variable (INT), and first lag each of the inflation gap (INFGAP), GDP gap (GDPGAP) and monthly depreciation rate (DEPRATE) of Indian rupee vs. US dollar[3]. We than estimate rolling regressions using this specification with a 10-year window[4]. In order to focus only on the coefficients which were significant we look at the significant coefficients only (i.e., take a coefficient as zero if it is not significant). This plot is given in Fig. 3. In this figure one can clearly identify three types of phases: (i) Till the period ending[5] 2007: 12, DEPRATE had a significant positive coefficient (ii) From 2010:08 to 2013:06 INFGAP had a significant positive coefficient (iii) in the rest of the period

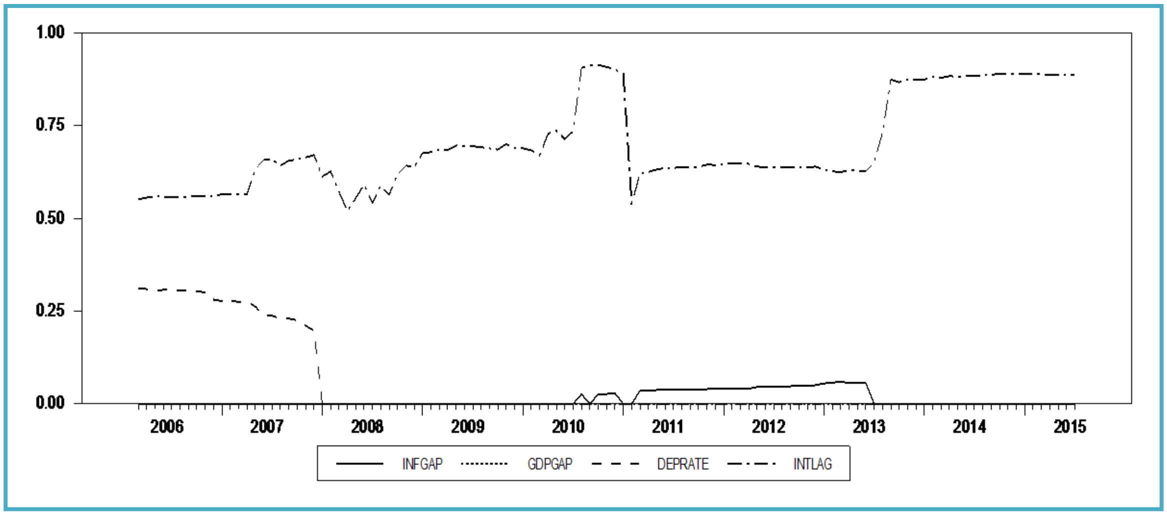
[3] We started with only one lag of the dependent variable, as has been done in other studies. However, that showed significant autocorrelation, forcing us to include the second lag also.

[4] A look at the coefficients suggested that the second lag is not required for all the periods. Therefore, we plotted coefficients from one-lag regression, taking coefficients from two-lag regression only for the periods in which the one-lag specification showed significant autocorrelation.

[5] In the following discussion, the period indicated refers to the end-point of the 10-year window for the concerned result.

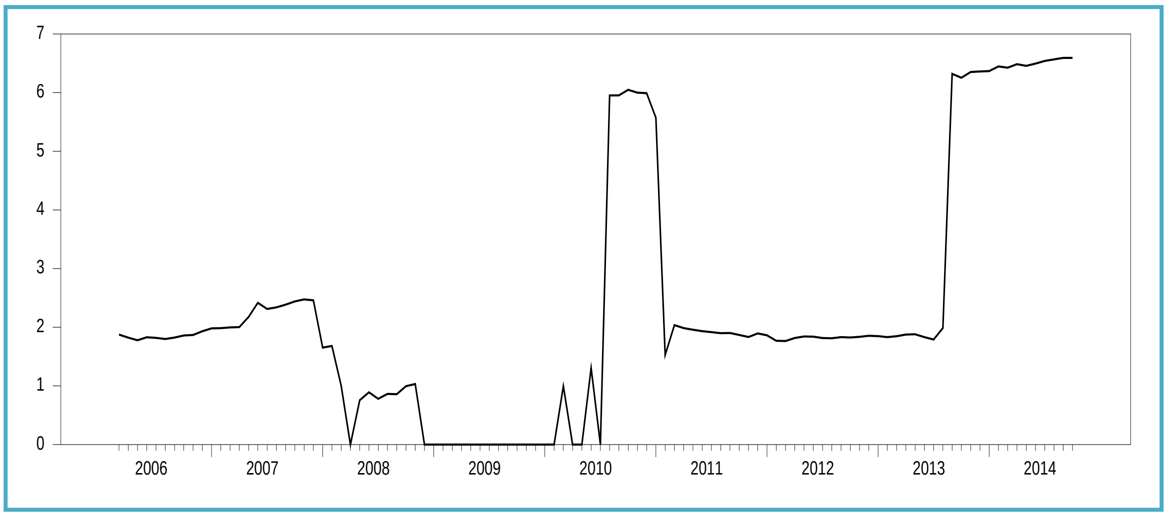
neither was significant. In fact, after 2013:06 one can clearly see a steep rise in the coefficient of lagged interest rate, indicating high inertia. It might be indicating the high inertia in the interest rate following persistently high CPI inflation and switch to CPI-inflation targeting by RBI.

Figure 3: Variation over time in Coefficients of independent variables (obtained using rolling regression)



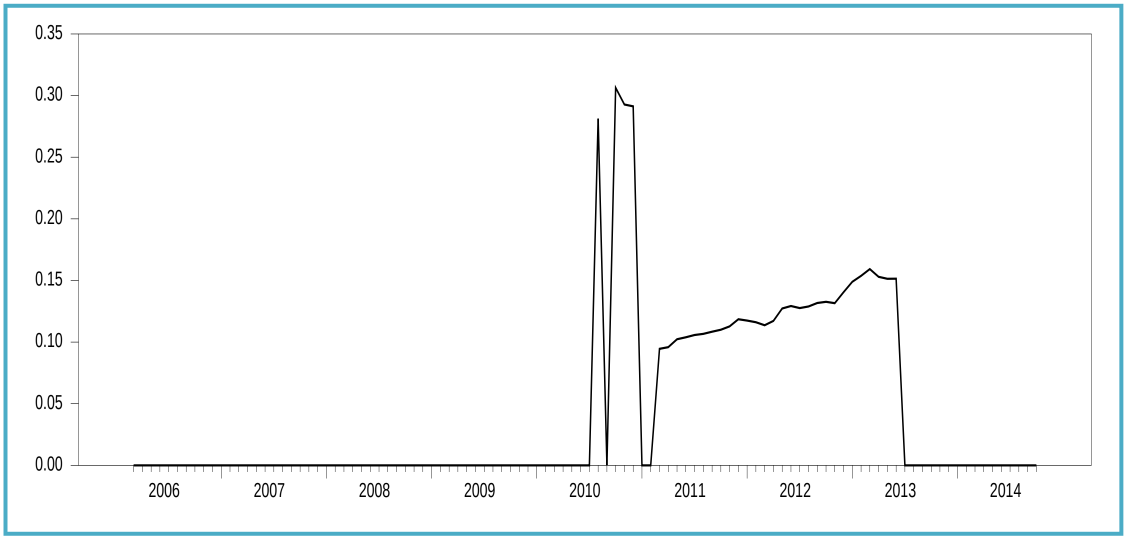
The plot of mean conditional on these macroeconomic variables (calculated by dividing the value of intercept by one minus sum of coefficients of lags) shows (Fig. 4) that the mean was at a level close to zero from 2008:12 to 2010:7 and then jumped to about 6%. It came down to about 2% in 2011:02 and remained around this level till 2013:08 but after that it jumped suddenly to levels above 6%.

Figure 4: Variation over time in Condition mean of interest rate (obtained using rolling regression)



These results show that in the immediate aftermath of the East Asian financial crisis the RBI was focusing on the exchange rate movements. From 1998 to 2013 the focus seems to be on inflation rate. Since then only the own lags have high effect, and mean interest rate has also risen. As stated earlier, this could be due to high level of inertia following inertia in CPI inflation in this period. Finally, according to Taylor rule, the long-run coefficient of inflation gap should be more than unity. This coefficient is given in the Fig. 5 and it is shown that even when inflation gap had a significant coefficient its value was nowhere close to the desired threshold.

Figure 5: Variation over time in Long-run coefficient of inflation (obtained using rolling regression)



Since it is possible that the policy was influenced by a variable but the coefficient was not significant at 5%, we take a look at the coefficients with p-values. The plot (Fig. 6) shows that the p-value for inflation gap declined drastically in the period ending around the middle of 2010 and has been below 0.25 since then. The p-value of the coefficient of GDPGAP declined in the period ending in 2009 and has been hovering around 0.3 since then (Fig. 7). The coefficient of DEPRATE had a very low p-value till the period ending 2007:12 after which it jumped steeply and has been at the high level since then (Fig. 8). These results give an indication that though till the period ending 2007 the monetary policy was focusing on exchange rate volatility, after that its focus has shifted to inflation gap and output gap, even though the reaction is weak.

Figure 6: Variation in coefficient and p-value of INFGAP over time

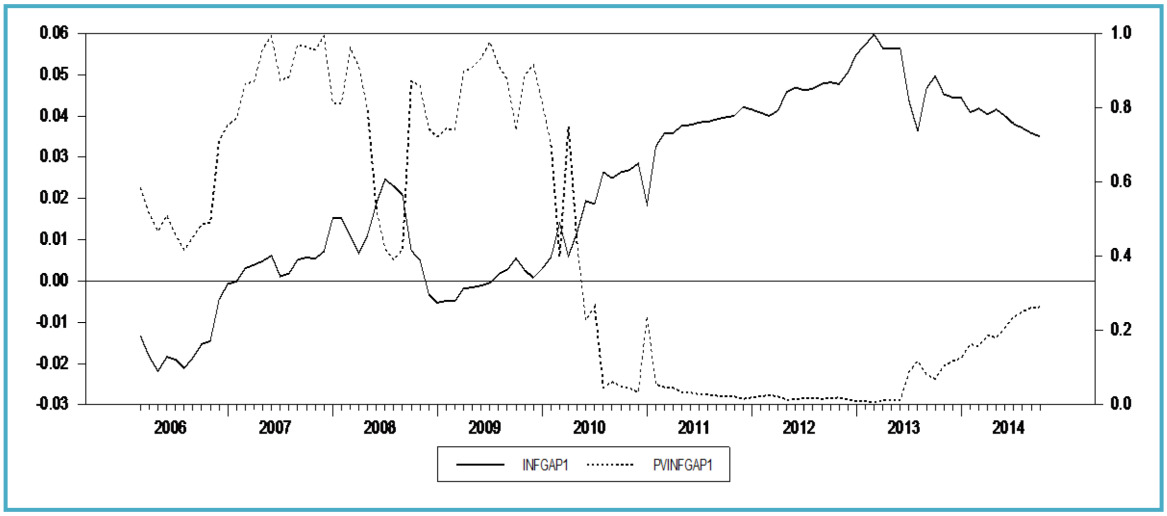


Figure 7: Variation in coefficient and p-value of GDPGAP over time

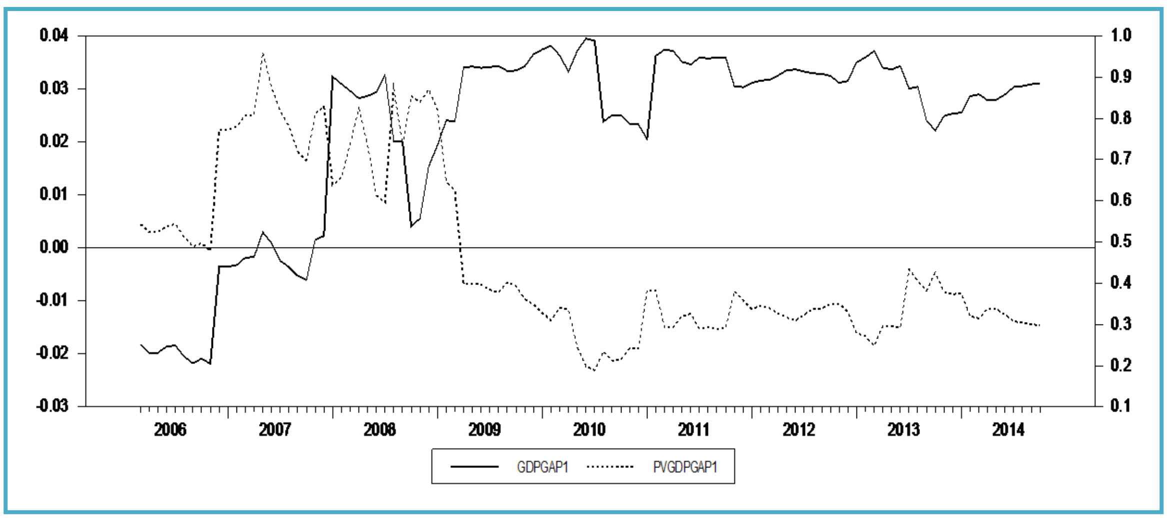
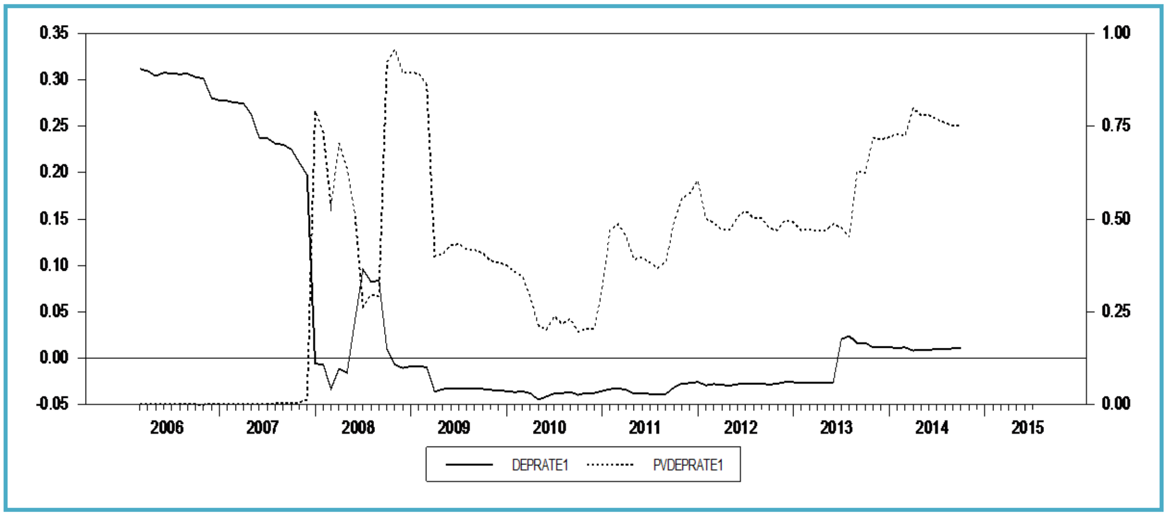


Figure 8: Variation in coefficient and p-value of DEPRATE over time



These results clearly highlight the fact that the response function of RBI's monetary policy is characterized by multiple regimes: one corresponding to exchange rate targeting, another by inflation targeting and finally one in which neither appeared to be a target; instead, the interest rates showed higher level of inertia at prevailing levels.

5.2 Test for nonlinearity

In order to test this statistically we used the tests devised by Terasvirta (1994) and Escribano and Jorda (2001) to the linear specification. The tests were conducted using four indicators:

(i) $TFR_t = t/T$, an index of time (TFR)
(ii) GDP gap[6] (GDPGAP)
(iii) Inflation gap (INFGAP)
(iv) Depreciation Rate (monthly) of INR vs. USD (DEPRATE)

The results are given in Table 1. According to these results there is a strong evidence for nonlinearity with TFR, INFGAP and DEPRATE. Further, it seems difficult to make out on the basis of these results as to what type of transition function is suitable for each of them. Therefore, we start by estimating L1 and then move on to L2 and L3. Since the objective here is to see what

[6]The three macroeconomic indicators were taken as three-period moving average, first lag. These variables are measured as indicated in the previous section.

factors might cause the regime-shift, we just focus on the macroeconomic indicators and do not estimate the nonlinear function with TFR as a transition variable.

Table 1: Results from Tests for Nonlinearity

Test	Null Hypothesis	TIME	INFGAP	GDPGAP	DEPRATE
Terasvirta	No Nonlinearity	1.16E-04	1.787e-4	0.026	1.263e-6
	H_{02}	0.008	0.003	0.256	3.958e-6
	H_{04}	0.268	0.011	0.030	0.231
	H_{03}	5.17e-4	0.084	0.148	0.004
Escribano- Jorda	No Nonlinearity	4.053e-5	4.377e-5	0.088	6.975e-6
	H_{0l}	0.074	0.098	0.778	0.142
	H_{0e}	0.070	0.347	0.070	0.014

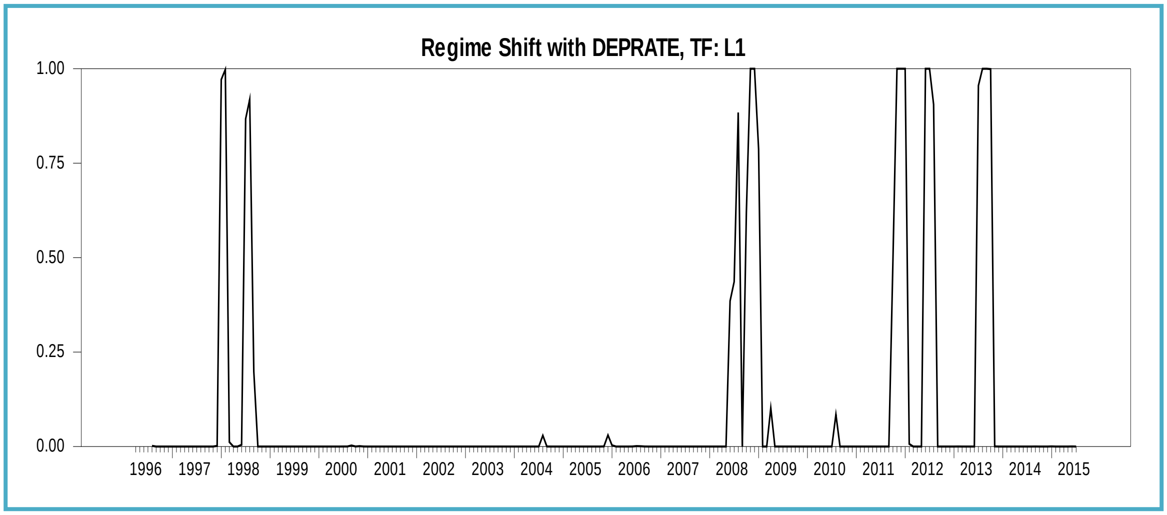
Next we move on to estimation of nonlinear models. We estimate three types of models for each indicator: L1, L2, and L3. Given the complex dynamics involved here but a small number of observation in comparison to that it was very difficult to achieve convergence. In many cases convergence could not be achieved despite starting with many combinations of initial values. We were able to estimate the L1 model only for depreciation rate while L2 could not be estimated for any combination. Finally, we were able to estimate L3 for at least two of them.

5.3 Models with DEPRATE

A look at the results from L1 model for DEPRATE shows that, in both high and low regimes, the lags of the dependent variable are highly significant. However, while in the low depreciation regime the coefficients of lags taken together have a very high positive value, in the high regime, the coefficient of the second lag is negative, higher than even the positive coefficient of the first lag. As a result, the total value of the coefficients is negative, though very small in magnitude. While in the low regime no other variable has a significant coefficient, in the high regime the coefficient of depreciation rate is highly significant. This implies that while the inertia marks the behavior of the policy rate in the low depreciation regime, in the high depreciation regime the policy rate responds to the exchange rate movements.

The results for L3 model suggest three regimes: one with DEPRATE less than -0.25, the other with DEPRATE between -0.25 and 2.0 and the third with DEPRATE more than 2.0. It means that there are three regimes: first, corresponding to appreciation (DEPRATE in negative territory), second corresponding to moderate depreciation (depreciation rate less than 2% per month) and high depreciation. The results show that in the appreciation regime only the first lag of the dependent variable is significant although its coefficient is more than 0.9. In the middle regime, even the second lag is significant, though the total coefficient is still around 0.9. There is hardly any difference between these two regimes with respect to the other variables. However, in the depreciation regime (the threshold here is again close to 2.0), though only the first lag of the dependent variable is significant, with much lower coefficient; the DEPRATE has a significant coefficient.

Figure 10: Regime shift with DEPRATE



Thus we note that the first two regimes appear almost identical to each other, and are very similar to the low DEPRATE regime shown by the L1 model. The high depreciation regime, on the other hand, is similar to the corresponding regime in the L1 model with even the transition point and transition speed parameters having almost similar values. The model diagnostics corroborate this: the L1 model has much lower values of the information criteria. Thus, we choose L1 over L3 and conclude that there are two distinct regimes, separated by depreciation rate of 2% per month. In the low depreciation regime the interest rates show high degree of inertia, and no other variable is significant. In the high depreciation regime, depreciation exerts a significant influence on policy, but there is a tendency of reversal of these changes over time. The plot showing the regimes (Fig. 10) suggests that there have been only a few short periods during the period of the study which fall in the high depreciation regime. These can be identified with (a) the East Asian Crisis (b) the Global Financial Crisis and (c) The Taper Tantrum of the Fed during the summer of 2013.Further, the transition between regimes is fairly smooth: the RBI does not immediately start placing a high weightage on depreciation rate as it depreciates, its behavior is marked by gradual changes in response, with some signs of change in behavior once the rate of depreciation crosses 1.5%.

5.4 Models with INFGAP

The other indicator for which we find significant evidence of nonlinear behavior is INFGAP, and for this we are able to estimate an L3 function only. The results show that in the low inflation regime (INFGAP less than -6%, i.e., actual inflation less than -1%), the depreciation rate is significant, in addition to the lags of the dependent variable. In the middle inflation regime (inflation more than -1% but less than 5%) both the lags of the dependent variable turn highly significant with a coefficient value above 0.9. Also, INFGAP is now significant at 5%. The p-value of GDPGAP is also close to 0.10. However, in the high inflation regime it is only the lags of the dependent variable which are significant. Thus, one can conclude that in the middle inflation regime there is response to both inflation and output gap, in the high inflation regime the policy rates exhibit high degree of inertia. This model has much lower values of the information criteria as compared to the two models with DEPRATE.

These models suggest that the reaction function of RBI is affected by both INFGAP and DEPRATE. The estimated models indicate some misspecification in the form of unexplained dynamics. The way forward would be to estimate a model with multiple reaction functions, one in each of the two variables.

6. Conclusions

Monetary policy making has undergone a sea change during the last three decades. At the same time, there have been several extreme macroeconomic events forcing central banks to shift the focus of monetary policy. In this light, an attempt has been made, in this paper, to study the reaction function of the monetary policy of the Reserve Bank of India, while allowing for possible regime-shifts. The plots based on rolling regression clearly show regime-shift and this is supported by tests for smooth-transition regime-switching. Estimated nonlinear models further support these findings. The results show that during low-inflation regime the monetary policy tends to focus on exchange rate. Another model shows that during the periods of high depreciation the focus of monetary policy shifts to exchange rate. The results indicate a need for more sophisticated models encompassing regime-switching governed by both exchange rate and inflation.

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Appendix A

Figure 9: Transition Function with DEPRATE

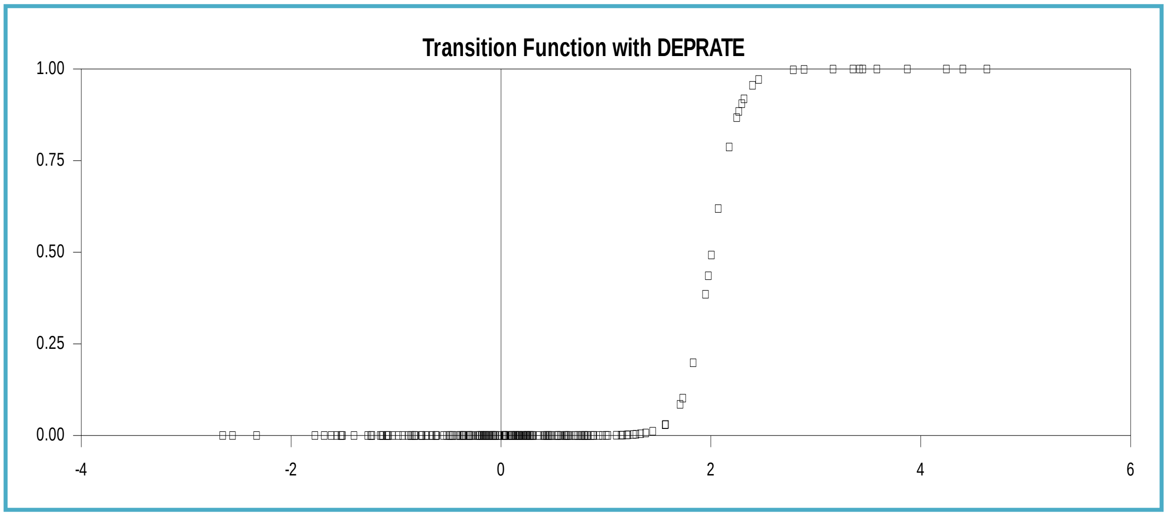


Figure 11: Transition Functions with INFGAP

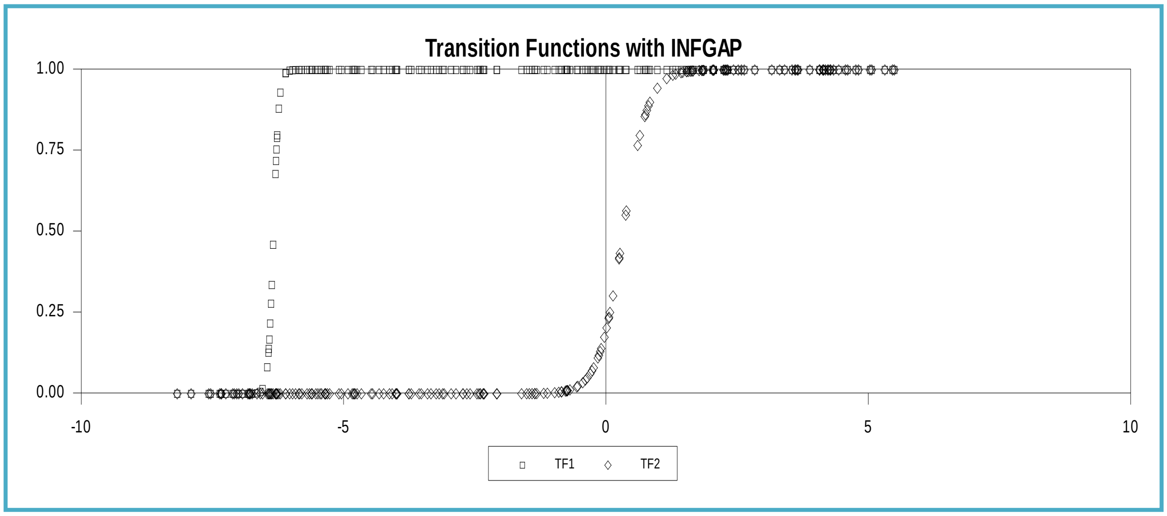
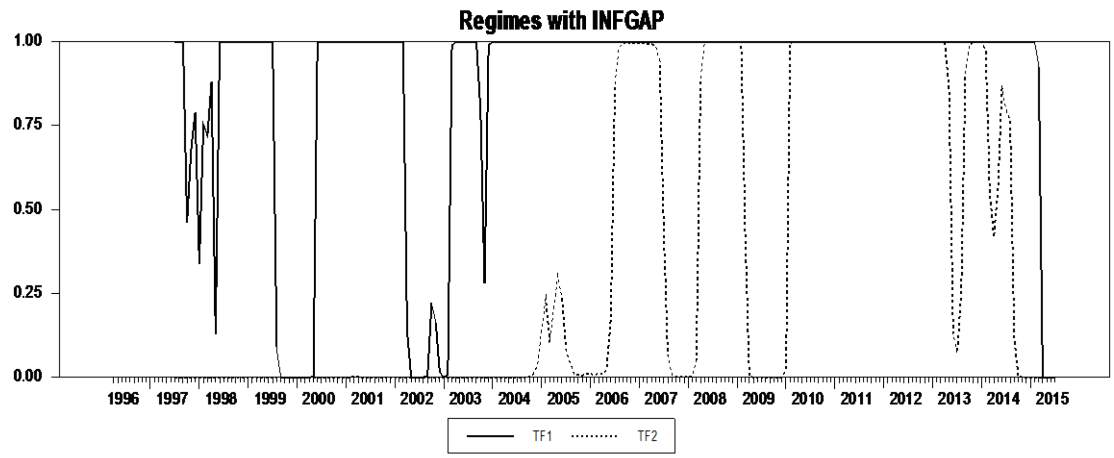


Figure 12: Regimes with INFGAP



Appendix B

Table 2: Results from L2 model with DEPRATE

Variable	Coef	Std Error	T-Stat	Signif
		Low DEPRATE regime		
INPT	0.616	0.216	2.856	0.005
INT(-1)	0.495	0.075	6.586	0.000
INT(-2)	0.417	0.072	5.760	0.000
INFGAP(-1)	0.022	0.015	1.443	0.151
GDPGAP(-1)	0.039	0.027	1.442	0.151
		High DEPRATE regime		
INPT	8.367	1.434	5.836	0.000
INT(-1)	0.732	0.109	6.691	0.000
INT(-2)	-0.793	0.167	-4.758	0.000
GDPGAP(-1)	0.091	0.075	1.217	0.225
DEPRATE(-1)	0.277	0.081	3.407	0.001
		Transition Parameters		
GAM1				9.207
MU1				2.008
		Model Diagnostics		
RSS				118.414
AIC				1026.579
SIC				1066.744
Autocorrelation[7]				0.000

[7]P-value for test for first order autocorrelation.

Table 3: Results from L3 model in DEPRATE

Variable	Coeff.	Std. error	T-Stat	Signif.
		Low DEPRATE regime		
INPT	0.493	0.440	1.121	0.264
INT(-1)	0.915	0.068	13.360	0.000
INFGAP(-1)	0.026	0.037	0.692	0.490
GDPGAP(-1)	0.016	0.042	0.391	0.696
		Middle DEPRATE regime		
INPT	0.892	0.322	2.775	0.006
INT(-1)	0.483	0.095	5.088	0.000
INT(-2)	0.401	0.087	4.591	0.000
INFGAP(-1)	0.024	0.021	1.114	0.267
GDPGAP(-1)	0.059	0.044	1.359	0.176
		High DEPRATE regime		
INPT	3.401	1.032	3.294	0.001
INT(-1)	0.560	0.110	5.098	0.000
GDPGAP(-1)	0.068	0.081	0.847	0.398
DEPRATE(-1)	0.215	0.086	2.486	0.014
		Transition parameters		
GAM1				20.710
MU1				-0.257
GAM2				9.880
MU2				2.014
		Diagnostic Statistics		
RSS				128.897
AIC				1044.675
SIC				1101.413
Autocorrelation				0.000

Table 4: Results from L3 model in INFGAP

Variable	Coeff	Std error	T-Stat	Signif
		Low INFGAP regime		
INPT	1.846	0.939	1.966	0.051
INT(-1)	0.345	0.212	1.626	0.106
INT(-2)	0.403	0.200	2.016	0.045
GDPGAP(-1)	0.035	0.096	0.360	0.719
DEPRATE(-1)	1.868	0.521	3.588	0.000
		Middle INFGAP regime		
INPT	0.558	0.262	2.130	0.034
INT(-1)	0.656	0.086	7.597	0.000
INT(-2)	0.291	0.088	3.309	0.001
INFGAP(-1)	0.077	0.036	2.107	0.036
GDPGAP(-1)	0.062	0.039	1.610	0.109
		High INFGAP regime		
INPT	1.007	0.493	2.040	0.043
INT(-1)	0.659	0.118	5.579	0.000
INT(-2)	0.187	0.113	1.657	0.099
INFGAP(-1)	0.040	0.065	0.613	0.540
GDPGAP(-1)	0.034	0.036	0.944	0.346
		Transition parameters		
GAM1				75.942
MU1				-6.347
GAM2				16.408
MU2				0.317
		Diagnostic Statistics		
RSS				99.360
AIC				994.539
SIC				1057.953
Autocorrelation				0.038

MORE FROM THE AUTHORS

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