Dove or Hawk? characterizing monetary regime switches during financial liberalization in India

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20 April 2011

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Characterizing Monetary Regime Switches During Financial Liberalization in India

April 2011

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Abstract

The last decade has seen a worldwide move by emerging markets to adopt explicit or implicit inflation targeting regimes. A notable and often discussed exception to this trend, of course, is China which follows pegged exchange rate regime supported by capital controls. Another major exception is India. It is not clear how to characterize the monetary regime or identify the nominal monetary anchor in India. Is central bank policy in India following a predictable rule that is heavily influenced by a quasi inflation target? To address this point, we investigate monetary policy regime change in India using a Markov switching model to estimate a time-varying Taylor-type rule for the Reserve Bank of India. We find that the conduct of monetary policy over the last two decades can be characterized by two regimes, which we term 'hawk' and 'dove.' In the first of these regimes, the central bank reveals a greater relative (though not absolute) weight on controlling inflation vis-à-vis narrowing the output gap. The central bank was in the "dove" regime about half of the sample period, during these episodes focusing more on the output gap and exchange rate targets to stimulate exports, rather than on moderating inflation. India is following its own direction in the conduct of monetary policy, seemingly not overly influenced by the emphasis on quasi-inflation targeting seen in many emerging markets.

This is a substantially revised version of a paper presented at the 6th NIPFP-DEA Research Meeting held in New Delhi, India, March 9-10, 2010. We are grateful to our discussant, Ila Patnaik, and to conference participants, for helpful comments that have led to substantial improvement in the paper. Of course, they are absolved of all responsibility for remaining shortcomings.

1. Introduction

A major switch in the conduct of monetary policy has occurred in many nations over the past two decades. Although taking different forms, the switch has been towards more systematic rules and less discretion in the conduct of monetary policy. Many central banks in emerging markets have adopted formal inflation targets, including Brazil, Chile, Colombia, Czech Republic, Korea, Hungary, Israel, Peru, Philippines, Poland, South Africa, Thailand and Turkey. Other central banks have adopted systematic rules that *de facto* describe the behavior of the central bank's operating instrument response—usually interbank interest rates-- to inflation, output gaps and the external environment. Rose (2007) argues that the move to IT regimes, either explicitly or implicitly (e.g. adopting systemic rules focusing on inflation), has created a new monetary system that is more stable and durable than its predecessors, especially exchange rate targeting and fixed exchange rates such as existed in the Bretton Woods system.

Theoretical studies that derive optimal monetary policy rules, and empirical studies that investigate their use in practice, are now commonplace in the literature (e.g. Taylor, 1993; Clarida, Gali, Gertler, 2000; Woodford, 2001). Taylor (1993) formulated a policy rule by which the U.S. Federal Reserve adjusts the policy rate in response to past inflation and the output gap (actual less potential output). He showed that this rule described Federal Reserve policy performance quite well from 1987 to 1992. Using a quadratic loss function for the welfare objective of the central bank, Woodford (2001) provided a formal normative justification for following a Taylor-type rule under certain conditions. Many studies subsequently applied and developed this class of policy rule to examine the behavior of central banks in industrialized countries (e.g., Clarida et al., 2000), and several have been applied to emerging and developing economies (e.g. Aizenman et al., 2008; Gonçalves and Salles, 2008). In fact, Gonçalves and Salles (2008) find that in a sample of 36 emerging market economies (13 of which implemented the IT regime), the IT adopters had greater drops in inflation and growth volatility compared to the non-adopters.

In light of the 2007-09 global financial crisis, it may be premature to make a final judgment on the desirability and durability of IT regimes and whether their widespread adoption has actually ushered in a new era of world monetary stability. It is noteworthy that the two most populous, largest and, arguably, dynamic emerging markets, China and India, have *not* adopted IT regimes and withstood the global financial crisis quite well. China follows a quasi-fixed exchange rate regime against the U.S. Dollar, accumulating massive international reserves and maintaining tight capital controls to keep the parity unchanged (e.g. Glick and Hutchison, 2009; Ouyang, et al., 2010). The monetary policy regime is less explicit and apparently more dynamic in India, with the authorities typically arguing that discretion is paramount in their policy decisions.[1]

The objective of our paper is to investigate the nature of monetary policy rules in India, a country that has undergone major domestic and international financial development and deregulation over the past two decades. These developments have changed the financial environment and external constraints (e.g. balance of payments, exchange rates and regime shifts) facing the central bank (Reserve Bank of India, RBI), and may have influenced its operating procedures and policy tradeoffs between output-inflation-exchange rate stabilization. These considerations, in turn, may have influenced the formulation of the monetary policy rule in India. In particular, money market deregulation took place in 1987. Prior to that time, the money market was highly regulated and the interest rate was essentially fixed.[2] Since 1987 there has been much greater flexibility in money market rates, and the RBI started using it as the primary operating instrument of monetary policy. To this end, we investigate the monetary policy rule in India and whether simple Taylor-like policy rules—perhaps changing over time to account for the varying economic environment – may be employed to systematically describe central bank actions. The RBI describes its policy actions in terms of discretion, and states that a multitude of factors are taken into consideration when deciding the course of monetary policy. The question is whether the seemingly discretionary policy followed by the RBI may be empirically described by a systemic rule that allows for occasional regime switches.

Therefore, our paper focuses on the monetary policy rule in India, and contributes to the literature by adopting a regime switching model along the lines of Hamilton (1989) to allow for multiple changes over time in central bank preferences between "Hawk" and "Dove" monetary regimes that in turn shift the central bank operating policy rule. Previous work for emerging markets has focused on a stable monetary policy rule (constant coefficients) over time or perhaps

[1] Since India and China are both in the Gonçalves and Salles (2008) sample of non-IT adopters, our analysis provides a useful complement to theirs for the Indian case, though our approach does not explicitly examine the kind of comparison they make.

[2] While arguments can be made for later starting dates, given the evolution of financial liberalization in India, and of the RBI's conduct of monetary policy, this particular liberalization episode seems to be the most appropriate beginning for our sample period.

a discrete shift from one rule to another in line with a change in the central bank leadership, institutional change or political change[3]. None has focused on regime switching in India. Our approach, by contrast, allows for the Indian central bank to operate in either of two regimes, and switch from one regime to another multiple times in response to changes in the economic conditions (e.g. inflation rate, output gap, and the exchange rate). For example, at times the central bank may be primarily concerned with inflation in a "Hawk" regime—perhaps because inflation is viewed as the primary threat to economic stability—while at other times the primary focus may be shifted to stimulating output ("Dove" regime). These shifts may occur predictably over the business cycle or at other times, not necessarily representing an institutional change but simply a complex policy rule that changes over time, shifting with a given probability in response to an evolving economic environment.

Our application of the regime switching model to Indian monetary policy is interesting in its own right. Much like the US Federal Reserve, the Reserve Bank of India (RBI) has seemingly responded to the state of the economy in an apparently discretionary and flexible manner. A former Deputy Governor of the RBI described their approach as follows, "Thus the overall objective has had to be approached in a flexible and time variant manner with a *continuous rebalancing of priority between growth and price stability*, depending on underlying macroeconomic and financial conditions." (Mohan, 2006b; italics our own). The question is whether the apparently discretionary and flexible approach of the RBI can systematically and empirically be described in practice by a Taylor-type rule, albeit with the possibility of regime switches. Based on description of the conduct of monetary policy by RBI officials, India appears to be a good candidate to be described by a regime switching model between hawk and dove regimes.

Seemingly, no study has undertaken this line of research for India. In particular, we are aware of only three studies that have investigated monetary policy rules for India, none of which have considered regime switching. In particular, Mohanty and Klau (2005) augment the Taylor rule to include changes in the real effective exchange rate. They use quarterly data from 1995 to 2002 for thirteen emerging economies including India. They find that for India, the estimated inflation coefficient is relatively low whereas the output gap and real exchange rate change are

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[3] Owyang and Ramey (2004), Assenmacher-Wesche (2005) and Frommel et al. (2004) consider regime-switching models for monetary policy rules for advanced economies. No study of which we are aware applies regime-switching models to monetary policy rules in developing or emerging market economies.

significant determinants of the short-term interest rate. Virmani (2004) estimates monetary policy reaction functions for the Indian economy, with the monetary base (termed in the literature as the McCallum Rule) and interest rate (Taylor Rule) as alternative operating targets. He finds that a backward-looking McCallum rule tracks the evolution of the monetary base over the sample period (1992Q3-2001Q4) reasonably well, suggesting that RBI acts as if it is targeting nominal income when conducting monetary policy. In addition, neither of these studies explores the Indian central bank's policy rule beyond the early 2000s. Hutchison et al. (2010) estimate more recent monetary policy rules for India. However, they only consider the possibility of limited structural breaks as opposed to systemic regime switches.

The next section discusses the evolution of monetary policy in India and related literature. We summarize some of the major changes that took place in this sphere. The third section discusses the methodology and data. We describe Woodford's version of the Taylor Rule, and how we adapt Hamilton's Markov switching method to the case of monetary policy rules. We describe the data (quarterly data from 1987 to 2008), and procedures used to derive potential output, in particular. The fourth section discusses the results: in particular, the Markov switching model identifies two distinct regimes, which we label 'hawk' and 'dove.' We begin with a model that focuses on domestic variables, then consider the role of the exchange rate in monetary policy making. The fifth section concludes by summarizing our results and interpretation.

2. Monetary Policy and Financial Liberalization in India

The Indian economy experienced several major structural changes in financial markets and fiscal financing over the sample period that have influenced the conduct of monetary policy. As has been highlighted in debates about the timing of Indian economic reform (Panagariya, 2008), there was no single "big bang" moment, especially with respect to the evolution of the financial sector, making it difficult to identify well-defined structural breaks in the Indian economy. Nonetheless, a number of key developments for monetary policy may be identified. Firstly, fiscal deficits are no longer automatically parked with public sector banks, or passively monetized by the RBI (Shah, 2008). Secondly, the liberalization of financial markets began in the late 1980s, moving towards a deeper financial sector and away from extreme financial repression (Shah, 2008). The process of financial liberalization accelerated following the balance of payments crisis in 1991.

Between 1991 and 1997, lending rates of commercial banks were deregulated, the issue of ad hoc treasury bills was phased out (thereby eliminating automatic monetization of the budget deficit), Statutory Liquidity Ratio (SLR) and Cash Reserve Ratio (CRR) rates were sharply reduced, and the RBI reactivated the refinance rate or bank rate (which is now used as a signaling rate to reflect the monetary policy stance). In 1994, India switched over to a mainly market-determined exchange rate system and instituted current account convertibility.

The RBI appeared to loosely target monetary growth between 1980 and 1998 and, from then onwards, followed a multiple indicator approach with discretion. Starting in 1998, the RBI undertook strong monetary policy measures (increasing interest rates and withdrawing liquidity by raising the CRR) to combat concerns about excessive liquidity and speculation in the foreign exchange market. The foreign exchange market was characterized by a high degree of volatility following the onset of the Asian financial crisis towards the end of 1997 and beginning of 1998. These emergency measures were gradually reversed once the threat had abated of the crisis spilling over to India.

The subsequent period, through the mid-2000s, saw the RBI continuing to refine its approach to macroeconomic management. With global and domestic inflation relatively low, the RBI set a band for target inflation of 4-5%, which was low by historical standards. It announced an intention to bring the CRR down, and move away from using the CRR as a policy instrument, focusing on interest rates instead (this intention was not realized, in practice). The RBI also continued to slowly ease capital controls, with implications for the functioning of domestic financial markets. Relaxations of capital controls included easing of requirements for and caps on foreign institutional investors (FIIs), streamlining of approval processes, and allowing FIIs to hedge exchange rate risk in currency forward markets. While domestic fixed income markets continued to be thin (as opposed to vibrant stock exchanges), especially for corporate bonds, a market for government securities did develop in this period.

A significant development in this period was an institutional innovation by the RBI to manage its own open-market operations. The new institution, termed the Liquidity Adjustment Facility (LAF) was introduced on June 5, 2000, and operates through repo and reverse repo auctions, thereby setting a corridor for the short-term interest rates, consistent with the policy objectives. The LAF therefore finally gave the RBI an explicit method for modulating short-term liquidity under varied financial market conditions, in order to influence call money rates. According to the RBI, the LAF has been operated "both as a tool for liquidity management and for interest rate signaling depending upon market conditions." Furthermore, the method of operation of the LAF has itself been evolving over time, in addition to variations in response to changing market conditions.

A final aspect of changing monetary management was the increase in capital inflows that began in the last decade. Capital inflows, if unchecked, increase the domestic money supply, resulting in a looser monetary policy than would otherwise be the case. Capital inflows also put pressure on the exchange rate to appreciate. The RBI engaged in sterilization of inflows and accumulation of foreign exchange reserves in this time frame. In this period, therefore, the RBI apparently had to deal with trilemma of maintaining an independent monetary policy in the face of international capital flows and a desire to manage the exchange rate. Accordingly, we will address international factors and the implications of increasing openness of the Indian economy in our empirical analysis of monetary policy in India.

This brief institutional discussion suggests that a regime-switching Taylor rule may be appropriate to uncover the underlying preferences of the RBI's decision-makers and particularly how they have evolved over time. Even given the seemingly discretionary nature of policy, as articulated in statements by the RBI, its revealed preferences may be well captured by a model of systematic, though time-varying, behavioral responses.

3. Methodology and Data

3.1 Theory and Estimation

The Woodford (2001) version of the Taylor Rule for an open economy expresses the policy instrument—the interbank interest rate—as a function of the output gap, inflation target, the exchange rate and lagged interest rate. With constant coefficients, this policy rule may be written as:

$$i_t = c + \alpha y_t + \beta \pi_t + \chi \Delta e_t + \delta i_{t-1} + \varepsilon_t \qquad (1)$$

where i_t is the nominal interest rate, π_t is the year-on-year inflation rate (assuming a constant inflation target so the target is subsumed in the constant term of the equation) and y_t is the output gap at time t (deviation of actual output, measured as the index of industrial production, from potential output), e_t denotes the log of exchange rate and Δ is the first difference operator. The expected signs of the estimated coefficients are: α, β, χ and $\delta > 0$. The rule indicates a relatively high interest rate when inflation is above its target, when the output is above its potential level, or when the central bank is attempting to limit exchange rate depreciation. The lagged interest rate is introduced to capture the inertia in optimal monetary policy, as specified by Woodford (2001). We use end of period quarterly data for all variables for the period 1987Q1-2008Q4.

Equation (1) is the standard model for the estimation of central bank policy functions. It assumes that the policy response to economic variables is stable over time. Some authors allow for a discrete shift in policy following a central bank reform or other institutional change. Our argument above, however, suggests that the central bank's preferences may change in a systematic and predictable way such that there are switches between periods when inflation is the primary concern of policy ("Hawk" regime) and when the output gap is the primary concern of policy ("Dove" regime). The distinction between Hawk and Dove regimes is common in the literature (see Owyang and Ramey, 2004 and Assenmacher-Wesche, 2005, for recent references). This implies that a regime switching model that allows the coefficients to shift between two states (s = 1, 2) would be a better representation of monetary policy than the alternative of a one-regime (constant coefficients) model.[4] In this circumstance, our estimation equation becomes:

$$i_t = c + \alpha_{st} y_t + \beta_{st} \pi_t + \chi \Delta e_t + \delta i_{t-1} + \varepsilon_t \qquad (2)$$

with S_t representing the state at time t, i.e. S_t =1.... k, where k is the number of states. Since we consider the switching to take place between 2 states ("Hawk" and "Dove" regimes), k = 2 in our case. In addition to switching the coefficients, we also allow the variance of the error term to switch simultaneously between the states, $\varepsilon_t \sim N(0, \sigma^2_{st})$.

Markov Switching Models (MSM), originally motivated by Goldfeld and Quandt (1960), have been popularized in business cycle and exchange rate analysis by Hamilton (1989) and Engel and Hamilton (1990). In our case, the model allows us to estimate how much weight the

[4] As noted earlier, one can allow for structural breaks in estimation, but the regime-switching approach allows for a somewhat different approach to changing policy responses – the maintained hypothesis is of two policy stances, between which the policy maker chooses depending on economic conditions.

RBI assigns to the relevant macroeconomic variables in two different regimes. In a MSM, switching between regimes does not occur deterministically but with a certain probability. In general terms, the evolution of the discrete, unobserved state-variable S_t is serially dependent upon S_{t-1}, $S_{t-2}, \ldots S_{t-r}$, in which case the process is referred to as an r^{th} order Markov switching process.

As noted above, we assume a two-state, first order Markov switching process for S_t, characterized by constant transition probabilities $p_{ij} = \Pr\{S_t = m | S_{t-1} = n\}$. In particular, let P denote the 2 x 2 transition probability matrix for our two-state Markov process such that:

$$P = \begin{bmatrix} p_{11} & p_{21} \\ p_{12} & p_{22} \end{bmatrix} \tag{3}$$

The estimation procedure classifies each observation as belonging to either regime. The regimes however, are not observed or specified ex-ante, but are estimated from the data.

To estimate the model, we consider the joint distribution of i_t and S_t conditional on past information:

$$f(i_t, S_t \mid \Psi_{t-1}) = f(i_t \mid S_t, \Psi_{t-1}) f(S_t \mid \Psi_{t-1}) \tag{4}$$

where Ψ_{t-1} denotes information at time t-1 and $f(i_t \mid S_t, \Psi_{t-1})$ is the conditional normal density function for the regime S_t=m. The likelihood function we estimate is a weighted average of the density functions for the two regimes, the weights being the probability of each regime:

$$\ln L = \sum_{t=1}^{T} \ln \left\{ \sum_{m=1}^{2} f(i_t \mid S_t, \Psi_{t-1}) \Pr(S_t = m \mid \Psi_{t-1}) \right\} \tag{5}$$

where the weighting term $\Pr(S_t = m \mid \Psi_{t-1})$ is the probability of being in each regime and is also referred to as the filtered probability. Given $\Pr(S_{t-1} = n \mid \Psi_{t-1})$, n = 1,2, at the beginning of time t the weighting terms $\Pr(S_t = m \mid \Psi_{t-1})$ are calculated as:

$$\Pr(S_t = m \mid \Psi_{t-1}) = \sum_{n=1}^{2} \Pr(S_t = m \mid S_{t-1} = n) \Pr(S_{t-1} = n \mid \Psi_{t-1}) \tag{6}$$

where $\Pr(S_t = m \mid S_{t-1} = n)$, m = 1, 2; n = 1, 2, are the transition probabilities (elements of matrix P above).[5] Once Ψ_t is observed at the end of time t, the probabilities are updated using the

[5] Equation (6) is useful in showing that while the transition probabilities are constant, the conditional probability of being in one regime or another depends on the history of the economy, summarized in the information available at that time, and therefore varies from period to period.

iterative filter, as discussed in Kim and Nelson (1999). The updated probabilities are calculated as follows:

$$\Pr(S_t = m \mid \Psi_t) = \frac{f(i_t \mid S_t = m, \Psi_{t-1}) \Pr(S_t = m \mid \Psi_{t-1})}{\sum_{m=1}^{2} f(i_t \mid S_t = m, \Psi_{t-1}) \Pr(S_t = m \mid \Psi_{t-1})} \quad (7)$$

where $f(i_t \mid S_t = m, \Psi_{t-1})$ is given by the probability density function of a normal distribution for regime $S_t = m$. Note that this is simply Bayesian updating of the probabilities of being in each state, given the information available then.

To start the filter at time t =1, we use the initial values obtained from an ordinary least squares regression. Once the coefficients of the model are estimated using an iterative maximum likelihood procedure and the transition probabilities are generated, we can use the algorithm in Kim and Nelson (1999) to derive the filtered probabilities for S_t using all the information up to time t i.e. $\Pr(S_t = m \mid \Psi_T)$ where t = 1, 2, …, T.[6]

3.2 Data

For the short-term policy rate, we use the overnight call money market rate.[7] This is the standard interest rate used to indicate the policy stance of the central bank.The Indian central bank follows a multiple instrument approach to influence the call money rate. An important issue, especially in India, is the measurement of the output gap. Unlike advanced countries, there are no official measures of potential output levels. Virmani (2004) compared estimated potential GDP derived from an unobserved components model with estimates derived from a Hodrick-Prescott (HP) filter, and found little difference. Accordingly we derive the output gap using the HP filter for measuring trend output and taking the residual of the HP filter.[8] To measure output, we use the Index of Industrial Production (IIP)[9]. Year-on-year inflation is measured using annual percentage change in the Wholesale Price Index (WPI). The WPI is the price level employed by the RBI to calculate "headline" inflation in India. All data are quarterly and the overall sample period is 1987q1 to 2008q4. We start our sample at 1987q1 because interest rate regulation

[6] The MSM model is estimated using the MS-Regress Matlab package for Markov Regime Switching Models, developed by Marcelo Perlin (2009).

[7] We use the call money market rate primarily because of availability of consistent data during our sample period.

[8] The HP filter output is sensitive to the endpoints, and we examine the robustness of our results to this issue: this point is taken up in the results section.

[9] We also estimated output gap using real GDP (from 1994 onwards, conditional on data availability) and the results were found to be very similar.

essentially fixed the money market rate prior to that time. With broad changes in the financial system in the late 1980s came money market deregulation and at that time it became the primary operating instrument of the central bank.

Prior to estimation, several data issues were dealt with. (i) Analysis of linear plots and the Hylleberg-Engle-Granger-Yoo test suggest that the quarterly IIP series has multiplicative seasonality. Hence it was de-seasonalized using the X-12 ARIMA procedure. (i) Unit root tests, i.e. Augmented Dickey-Fuller, Phillips-Perron, Elliott-Rothenberg-Stock and Kwiatkowski-Phillips-Schmidt-Shin test results suggest the presence of unit root in the exchange rate series in levels, but the first difference of the series is stationary. Accordingly, the first difference of the nominal exchange rate was used. (iii) Durbin Watson and Breusch-Godfrey tests suggest the presence of serial correlation and the Breusch-Pagan/Cook-Weisberg test shows the presence of heteroskedasticity in error terms. Hence the OLS regressions have been run with the Newey-West variance-covariance matrix, to correct for both autocorrelation and heteroskedasticity.

Finally, we discuss our treatment of the interest rate series. Some other studies have used an average of the interest rate over the preceding quarter (or whatever the length of the period), presumably to capture the average policy stance for that period. However, this is not completely logical, since it creates a dependent variable that is partially determined prior to the right-hand side observations. Using the end-of-quarter interest rate avoids this inconsistency. However, for 2007q4 there was an extreme spike in the interest rate that was recognized at the time as inadvertent, and not the result of a deliberate policy action. We have replaced this unrepresentative outlier by the average of interest rates in the weeks before and after that observation.

4. Empirical Results

4.1 Preliminaries

Figures 1-3 show the movements between the output gap and inflation (Figure 1), interest rate and inflation (Figure 2), and interest rate and output gap (Figure 3) in India over the 1987q1 to 2008q4 period. Table 1 shows the corresponding correlations between these series for the full sample (1987-2008), early sample (1987-1995) and later sample (1996-2008).

Figure 1 does not show a distinct pattern between the output gap (right-hand-side scale) and inflation (left-hand-side scale) during the full sample period (overall correlation = -0.02), although a weak positive (and statistically significant) correlation emerges in the later period (0.06). The "output-inflation tradeoff" is not clearly evident in simple co-movements in these variables, but the relationship may be masked by a variety of real and financial disturbances to the Indian economy as well as attributable to an activist monetary policy.

Figure 2 shows the evolution of the interest rate and inflation. The interest rate is the overnight money market rate. Trend inflation has declined in India over the sample period. Inflation averaged about 9 percent, with wide variation (standard deviation of 2.9 percent), over the 1987 to 1995 period, and fell to around 5 percent during 1996-2007 as well as being more stable (standard deviation of 2.1 percent) in the latter period. Inflation jumped in mid-2008 in response to the world-wide food and energy price boom, but declined to the previous level by the end of 2008. Similarly, interest rates were at much higher average level and more variable in the first sub-period compared with the second sub-period. Lower levels and more stability in inflation are associated with lower and more stable interest rates. Beyond simple averages, however, the figure also suggests that the money market interest rate moves sluggishly in response to swings in the inflation rate, especially in the late sample period. This suggests that the RBI, in setting interest rates, has generally been slow to respond to inflation movements, with an overall contemporaneous correlation of 0.35 for the full sample.

Figure 3 shows the output gap (left-hand-side) and the money market interest rate (right-hand-side). Overall, swings in the output gap are followed by similar changes in the interest rates (correlation 0.35) and this pattern is evident in both the early and latter sample periods. When the output gap is negative, interest rates tend to fall and vice versa. This correlation appears to be particularly strong in the early period (correlation 0.51), whereas in the late period the pattern is clearly evident during most cycles with two exceptions, and this is confirmed by the decline in the correlation coefficient after 1995. There also appears to be a range of (small) fluctuations in the output gap that does not elicit an interest rate policy response.

In sum, it appears that the RBI responds both to the output gap and inflation in setting policy interest rates. Interestingly, the correlations for both series with money market interest rates are almost identical over the full sample period (0.35) and both correlations decline after 1995, especially the contemporaneous linkage between interest rates and inflation.

Another variable that the RBI may sometimes target is the exchange rate. The RBI itself has argued that its focus has been only on controlling volatility of exchange rate movements, rather than targeting the level of the exchange rate. However, some analyses (e.g., Patnaik 2007) have suggested that there has been a systematic attempt at times to manage the level of the nominal Rupee-Dollar rate. In order to address this issue, we extend the basic Taylor Rule model with a model that also includes the exchange rate as a determinant of policy.

4.2 Constant Coefficient Estimates

The first column of coefficient estimates in Table 2 presents the results from estimating equation (2) assuming constant coefficients, and with the exchange rate omitted. The coefficients on the output gap, inflation and lagged interest rate are all significant at the 1% level and have signs predicted by theory. These estimates suggest that the RBI increases the overnight interest rate by 54 basis points in response to a one unit rise in the output gap (where positive increases in the output gap represent a rise in output relative to trend), and increases the interest rate by 33 basis points in response to a 100 basis point rise in inflation. The lagged interest rate coefficient of 0.40 suggests considerable inertia in policy, so the long-run effects are substantially greater than the impact effects (i.e. the long-run effect on the interest rate of a unit change in the output gap is 0.89 and of a 100 basis point increase in inflation is 0.55). The long-run inflation-response of 0.55 is considerably less than what Woodford (2001) suggests would in principle (greater than 1.0) be necessary to stabilize the economy.[10]

The constant term is also of interest. According to the formulation of Woodford (2001, equations 2.3 and 2.6), it captures the deviation of the baseline interest rate from the target values of the inflation rate and output gap, each weighted by the response coefficients embodied in the monetary policy rule. In an equilibrium rule, therefore, the constant term in the specification estimated in Table 2 should be zero. If a Taylor-type rule is being followed, therefore, we would expect the constant term to be zero.

[10] Taylor (1993) suggested that a policy rule with coefficients of 0.5 on the output gap and 0.5 on inflation (from target) was able to predict U.S. Federal Reserve interest rate policy responses. His formulation includes a base inflation term on the right hand side, so that his inflation coefficient is equivalent to a magnitude of 1.5 in the Woodford (2001) specification, which is used here. The lagged interest rate term is not in the original Taylor specification, but does not affect the comparison once the long run effect is computed.

4.3 Markov Switching Model

In estimating the Markov Switching Model, we explore several variants of the base specification. This is necessary because of the complexity of the underlying economic dynamics, of the possible policy rule followed by the RBI, and of the estimation method itself. The specific role played by the exchange rate in Indian monetary policy conduct adds to this complexity. It is only by comparing estimates from different specifications and identifying robust features across the different results, that one can be reasonably confident about the policy rule that is potentially discovered by the empirical analysis.

4.3.1 Output gap and inflation coefficient switching

The second column of coefficients in Table 2 presents the initial regime switching model estimates, where both the output gap and inflation coefficients are subject to change between the different policy regimes. The output gap (inflation) coefficient estimate for state 1 is denoted by α_1 (β_1) and state 2 is denoted by α_2 (β_2). The lagged interest rate coefficient is given by δ. The table also presents the probability p_{11} of staying in state 1 (state 2, p_{22}) if policy is already in state 1 (state 2). Unity minus this parameter gives the probability of switching from state 1 (state 2) to state 2 (state 1). The error variances of state 1 and state 2 are also presented, as are the expected duration of staying state 1 and state 2 and the total log likelihood.

The results show a clear distinction between two regimes of the RBI policy stance with respect to the coefficient of the output gap but not the inflation coefficient. The inflation coefficients in the two states are almost identical, while the output gap coefficient in the first state is less than half that of state 2. The state 2 output gap coefficient is quite close to the estimate for the constant coefficient model, and this is also true of the inflation coefficients in both states. The lower weight given to the output gap in state 1 characterizes this state as a Hawk regime, with a *relative* emphasis on inflation developments. State 2 is characterized as a Dove regime with the relative emphasis on the output gap Several other observations on the results in Table 2 are noteworthy. First, the coefficient of the lagged interest rate is substantially higher in the regime switching model than is the case of the constant coefficients estimates, reflecting more inertia.[11] This implies that the long run impacts are now estimated to be higher, except for the long run response to the output gap in state 1, since other short run coefficients are similar. In fact, the long-run inflation responses are estimated to be 1.19 and 1.25, in regimes 1 and 2, respectively, above the threshold of unity that marks a stabilizing monetary policy rule with respect to inflation. Of course, the model also suggests that this response is very slow to be fully realized. The long run output gap coefficients are 0.69 and 1.76, respectively.

Second, the estimates in Table 2 are consistent with the view of the former Deputy Governor of the RBI, since the expected lengths of the two regimes are quite short, being about 7 and 4 quarters respectively. The probabilities of staying in each state are not inordinately low, at 0.85 and 0.76 for states 1 and 2, respectively, but are low enough to lead to substantial switching between the two regimes. However, one significant difference between the two states is in the standard errors of the estimated regressions. The standard error for the Dove regime is about 14 times as high as that of the Hawk regime, implying that the former's overall variance is less well explained by the independent variables.

Finally, note that the constant term in the switching regression is reduced essentially to zero, in contrast to the positive and significant value in the constant coefficient regression. As we noted earlier, a zero constant term is consistent with an equilibrium monetary policy rule, and we can take this feature of the estimation as a point in favor of the MSM approach over a constant coefficient model.

It is also important to examine the predicted time frames of the two different regimes. This information is captured probabilistically by the filtered probabilities (equations (6) and (7)). Figure 4 displays the filtered probabilities corresponding to the results of the regime switching model of Table 2. While these probabilities have several peaks and troughs, our sense is that the output booms of the late 1980s, mid 1990s and early 2000s are all associated with high probabilities of state 1, the "Hawk" regime. The idea here is that monetary policy is relatively less concerned with the output gap in these boom times, though the absolute stance toward inflation remains roughly the same across the two states.

[11] The relative magnitude of the lagged interest rate coefficient in the MSM model versus the constant coefficients case is in line with intuition, since the latter estimates would tend to assign regime switching effects to faster responses.

4.3.2 Output gap switching

The results of the first specification of the MSM indicate that one can impose that constraint that the inflation coefficient does not switch across the two regimes. In other words, only the coefficient of the output gap switches. These estimates, still without any consideration of exchange rate policy responses, are presented in Table 3. The short run coefficients are now lower than the estimates in Table 2. However, the larger coefficient on the lagged interest rate term compensates for this change, and the long run coefficient estimates are very similar. The long-run output gap responses in states 1 and 2 are, respectively, 0.54 and 2.07, though the former is less precisely estimated than in the first specification. The estimated long-run inflation response, at 1.25, is essentially the same as the earlier state 2 long-run response estimate. The stability of the estimates reinforces the assumption that the restriction imposed here is valid.[12] The constant term in this case, and in subsequent MSM specifications stays at zero, supporting the robustness of the MSM approach as capturing equilibrium behavior.

The regression standard errors are much lower in Table 3 than in Table 2, but the relevant and striking difference is in the estimates of the transition probabilities. These are much higher than before, and as a result, the switching between regimes is highly attenuated. In fact, the expected duration of regime 2, the Dove regime, is as high as 10 years, and the graph of filtered probabilities for these estimates, in Figure 5, suggests that there are only two likely Dove periods, where the RBI was not giving much weight to the output gap – the two major booms of the late 1980s and the early 2000s. Given the dynamics of the Indian economy in the 1990s, we believe that this specification does not, therefore, fully capture the conduct of monetary policy over this period.[13] This leads us to turn to considering external factors and exchange rate policy, which is believed to have had major implications for the conduct of domestic monetary policy at various times over the sample period (Patnaik, 2007).

[12] We also estimated the MSM with only the inflation coefficient allowed to switch. The lagged interest coefficient and both inflation coefficients were almost identical to their counterparts in Table 3, as were most other features of the regression (standard errors, transition probabilities and average regime lengths. The output coefficient was insignificant, and the point estimate was close to the regime 1 point estimate in Table 3. This further supports the imposition of the constraint of no switching of the inflation coefficient.

[13] The estimates with only the inflation coefficient being allowed to switch, mentioned in the previous footnote, share this unsatisfactory feature.

4.3.3 Output gap switching with an exchange rate term

Following on the previous discussion, we include the change in the log of the nominal exchange rate into the MSM model, with only the output gap coefficient being allowed to switch. The results in Table 4 provide further evidence of robustness of the basic approach. The two regimes differ in their output gap coefficients, with regime 1 being where the output gap receives less weight from policymakers. The short run coefficients in Table 4 are now back to being close to their values in Table 2, but the lower lagged interest rate coefficient means that the long run responses are once again similar to those in Tables 2 and 3. The estimated long-run responses to the output gap are 0.55 (regime 1) and 1.69 (regime 2). The long-run inflation response is estimated at 1.14, only slightly lower than the previous estimates.

The estimates in Table 4 retain the lower regression standard errors of the second specification, but have the lower transition probabilities and expected regime durations of the first specification. The associated filtered probability graphs (Figure 6) provide a picture of monetary policy responses in the 1990s that are close to those derived for the first specification, with some switching between the Hawk and Dove regimes, which differ in their stance toward the output gap. It appears that the Hawk and Dove regimes are each in force for roughly half the sample period, with well-defined episodes for each.

Most importantly, the estimates in Table 4 have a positive and statistically significant coefficient for the exchange rate term, indicating that the RBI responded to exchange rate depreciations (appreciations) by increasing (decreasing) the interest rate. This is consistent with a nominal exchange rate target, or with an attempt to “smooth” or dampen exchange rate movements, and with other empirical analyses of RBI behavior (though not necessarily with the RBI’s own public position on its exchange rate stance). In many ways, therefore, the specification reported in Table 4 seems to be a reasonable, parsimonious description of the conduct of monetary policy in India over this period.

4.3.4 Exchange rate switching

Given that the exchange rate appears to be an important target variable for monetary policy, it is worth checking if it is also subject to regime switching. We examine two alternative specifications. A baseline specification allows only the exchange rate coefficient to switch, so as not to force changes in the stance toward the exchange rate to be tied to changes in the stance toward the output gap. Accordingly, Table 5 and Figure 7 present the results for the MSM model where only the exchange rate coefficient switches. However, Table 6 and Figure 8 also provide estimates where both the output gap and the exchange rate coefficients are allowed to switch between regimes.

The results with exchange rate switching demonstrate the robustness of the results in Table 4 (where only the coefficient of the output gap was allowed to switch). The coefficient of the inflation is stable across the three specifications, as is the coefficient of the lagged interest rate. The coefficients of the output gap in the two cases where switching is allowed on this dimension are also quite close (Tables 4 and 6). Furthermore, the filtered probability graphs are also similar across the three specifications, suggesting that the RBI adjusted its stance on several occasions in the 1990s, as well as during the booms of the late 1980s and early 2000s.

The regime-specific regression standard errors and constant terms are also very close across the three specifications that involve the exchange rate, as are the transition probabilities. In the case of joint switching of the output gap and exchange rate coefficients, the transition probabilities are slightly higher, resulting in somewhat longer expected durations of regimes in this case: about 14 quarters for regime 1 (almost double the other two cases) and about 8 quarters for regime 2 (versus about 6 in the other two cases). However, these longer expected durations are plausible, unlike the 10-11 year expected duration for regime 2 in Table 3.[14]

The exchange rate switching models therefore suggest that are results are robust, but also raise two additional, possibly related, puzzles. First, in both cases of exchange rate switching, the coefficient of the exchange rate in regime 2 is negative. This means that a depreciation in the nominal exchange rate (a positive difference in the variable as defined) is being met with a decrease in the interest rate, which would tend to accentuate the depreciation, rather than acting to stabilize the exchange rate (as would be the case with a positive coefficient). Second, in the case where both the coefficients of the output gap and the exchange rate are allowed to switch together, what can be the rationale for this pairing? In the case of the output gap and inflation, the idea that high inflation and high output go together is intuitively understandable in terms of

[14] In an earlier draft of this paper, we estimated and presented an MSM model with the output gap and inflation coefficients both being allowed to switch, but with the exchange rate included (unlike Table 2). In that case also, only the two output booms toward the beginning and end of our sample period were identified as likely Hawk regimes, with the entire decade in between as the Dove regime. The exchange rate coefficient was not significant, and the inflation coefficients in both regimes were similar, though marginally insignificant in regime 2. These observations suggest that either underdetermining the switching model (Table 3 here) or over determining it (the case of our previous draft) leads to a misspecification that shows up in failing to capture regime switches adequately.

the business cycle, but here that obvious connection does not exist. Since the first puzzle is common across both final specifications, and there is strong evidence that switching of the output gap coefficient is appropriate, it makes sense to focus on the results of Table 6, where regime 2 has the interpretation as the Dove regime with respect to the output gap, and the gap is more negative (output is weak). In this case, a possible interpretation of our results is that the negative coefficient of the exchange rate represents an attempt at stimulating exports in a weak economy, rather than exchange rate targeting or inflation control. This is a conjecture that would require further investigation, but seems consistent with how exchange rate policy is viewed in the Indian media, or by Indian industry associations, for example.

Aside from the issue of whether the policy stance toward the exchange rate switches, the sequence of estimations we have presented does support the importance of the exchange rate in monetary policy (something that has not always emerged clearly in other estimates of Taylor-type rules for India without allowing for switching). Even more clearly, the evidence points strongly toward a consistent inflation stance, mildly positive in its control effects, but with a substantially varying concern with respect to the output gap.[15]

5. Conclusion

This paper investigates the conduct of monetary policy in India by estimating policy rules that may switch over time depending on the economic environment. The broader context is to explore the monetary policy regime of a large, dynamic, emerging market that apparently eschews the popular policy rule of explicit or implicit inflation targeting. Our primary question then is whether Indian monetary policy, usually described by RBI policymakers as highly discretionary, may in fact be described by simple policy rules as has been the case for many central banks. That is, is the RBI more systematic in policy implementation than it claims and may its policy be accurately described by quasi-IT or Taylor rule? Our specific methodological approach is estimation of Taylor-type (1993) rules along the lines of Woodford (2001), but allowing for switches in the preferences of the central bank over time using a regime switching model (Hamilton, 1989).

[15] We also investigated allowing the coefficients of all three variables to switch between regimes, but the model was not well-estimated in that instance. In any case, all the other evidence indicates a lack of switching in the inflation stance.

Overall, our results suggest that RBI policy may be characterized by a regime switching model, with switches in regimes that are naturally characterized as Hawk and Dove regimes, over the 1987-2008 period. Based on the likelihoods of the two policy stances, the Dove regime appears to have been in force (at least 50 percent likelihood) about half of the entire period, comprising four (possibly five) well-defined episodes. The model estimates suggest that the RBI focuses relatively more on the output gap during the Dove regime, with attention to inflation being essentially the same across the Hawk and Dove regimes. We also found strong evidence that external considerations, represented here by movements in the exchange rate, systemically influenced RBI policy. This policy seems to have taken the standard form of responding to exchange rate depreciation (appreciation) by raising (lowering) the interest rate. However, there is also a possibility that the RBI took steps to stimulate exports when the economy was relatively weak (regime 2).

In the context of the worldwide attention to inflation targeting approaches by central banks, we can also assert that no evidence of an exclusive concentration on inflation, or of inflation targeting was found in our analysis of Indian data. India, along with China, has not followed the trend of many emerging markets in adopting IT or quasi-IT monetary regimes. It is not the nominal anchor guiding monetary policy in India. The output gap seems to play an important role, and while inflation enters as a determinant of policy, our estimates also indicates a great deal of policy discretion followed by the RBI, as articulated by the central bank's own senior officials.

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Table 1: Correlations

	1987q1-2008q4	1987q1-1995q4	1996q1-2008q4
Output gap-Inflation	-0.0246	-0.0373	0.0625
Output gap-Interest rate	0.3541***	0.5140***	0.3525**
Inflation-Interest rate	0.3530***	0.2821*	0.0329

Note: *** (**) (*) denotes significance at the 1%, 5% and 10% level, respectively.

Table 2: Constant Coefficients and Regime Switching (Output Gap and Inflation)

Parameters	Constant Coefficients	Switching Coefficients
α_1	0.5373*** (0.1898)	0.2213* (0.1177)
α_2		0.5606*** (0.1000)
β_1	0.3421*** (0.1097)	0.3786*** (0.0405)
β_2		0.4002*** (0.0710)
δ	0.4042*** (0.0860)	0.6811*** (0.0404)
p_{11}		0.85
p_{22}		0.76
σ^2_1		2.8420*** (0.5055)
σ^2_2		40.4376*** (7.9018)
Constant	3.3261*** (0.8731)	0.0000 (0.0002)
Expected Duration of Regime 1		6.87
Expected Duration of Regime 2		4.18
Final Log Likelihood		-225.3404

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 3: Regime Switching (Output Gap Only)

Parameters	Switching Coefficients
α_1	0.1024 (0.0924)
α_2	0.3913*** (0.0587)
β	0.2354*** (0.0978)
δ	0.8110*** (0.0970)
p_{11}	0.90
p_{22}	0.98
σ^2_1	0.5563 (0.3736)
σ^2_2	20.9685*** (5.4980)
Constant	0.0000 (0.0002)
Expected Duration of Regime 1	10.36
Expected Duration of Regime 2	43.06
Final Log Likelihood	-222.1531

Note: Standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4: Regime Switching (Output Gap Only) with Exchange Rate

Parameters	Switching Coefficients
α_1	0.1890** (0.0782)
α_2	0.5760*** (0.0902)
β	0.3894*** (0.0404)
χ	7.4694** (3.3821)
δ	0.6589*** (0.0374)
p_{11}	0.86
p_{22}	0.84
σ^2_1	2.4452*** (0.4283)
σ^2_2	29.7200*** (2.0682)
Constant	0.0000 (0.0008)
Expected Duration of Regime 1	7.35
Expected Duration of Regime 2	6.32
Final Log Likelihood	-224.4692

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 5: Regime Switching (Exchange Rate Only)

Parameters	Switching Coefficients
α	0.2726*** (0.0819)
β	0.3861*** (0.0426)
χ_1	10.5081** (4.7422)
χ_2	-16.6013*** (5.1837)
δ	0.6718*** (0.0365)
p_{11}	0.87
p_{22}	0.84
σ^2_1	2.6090*** (0.4148)
σ^2_2	29.3076*** (2.5337)
Constant	0.0000 (0.0001)
Expected Duration of Regime 1	7.79
Expected Duration of Regime 2	6.26
Final Log Likelihood	-224.1054

Table 6: Regime Switching (Output Gap and Exchange Rate)

Parameters	Switching Coefficients
α_1	0.2212*** (0.0645)
α_2	0.5399*** (0.1527)
β	0.3810*** (0.0389)
χ_1	11.7969** (5.0357)
χ_2	-15.3889** (6.2878)
δ	0.6680** (0.0312)
p_{11}	0.93
p_{22}	0.88
σ^2_1	2.6367*** (0.4298)
σ^2_2	28.6072*** (2.8689)
Constant	0.0000 (0.0001)
Expected Duration of Regime 1	13.86
Expected Duration of Regime 2	8.36
Final Log Likelihood	-224.2626

Figure 1: Output Gap and Inflation (WPI)

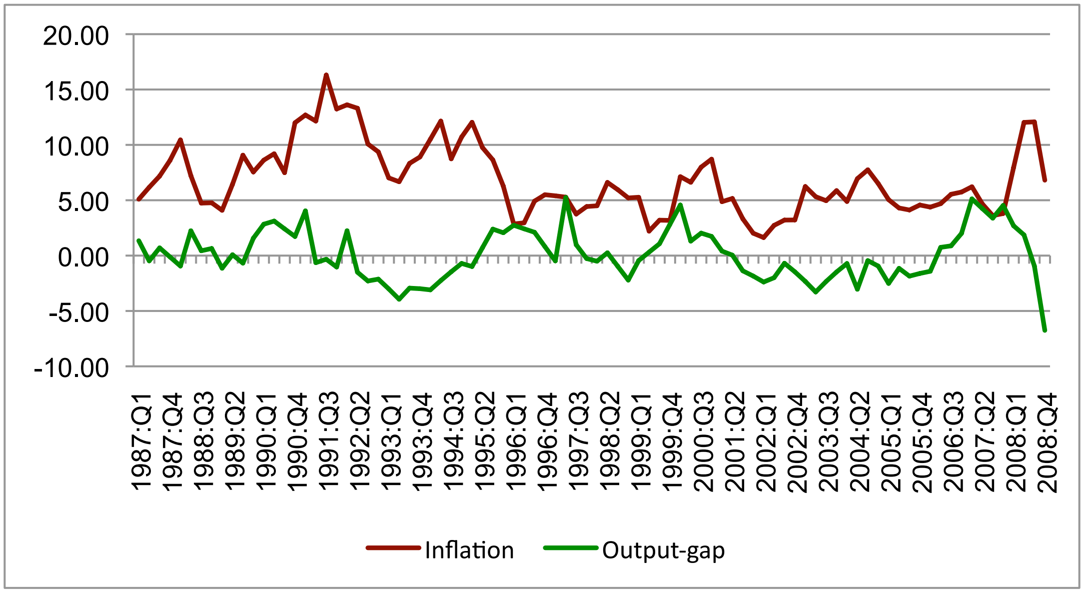

Figure 2: Interest Rate and Inflation (WPI)

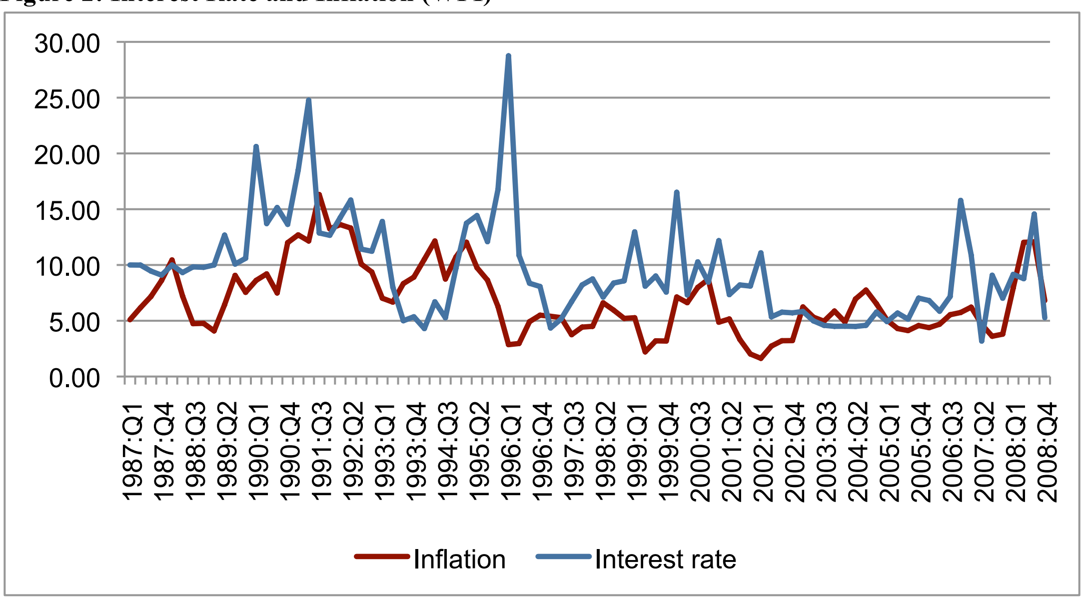

Figure 3: Interest Rate and the Output Gap

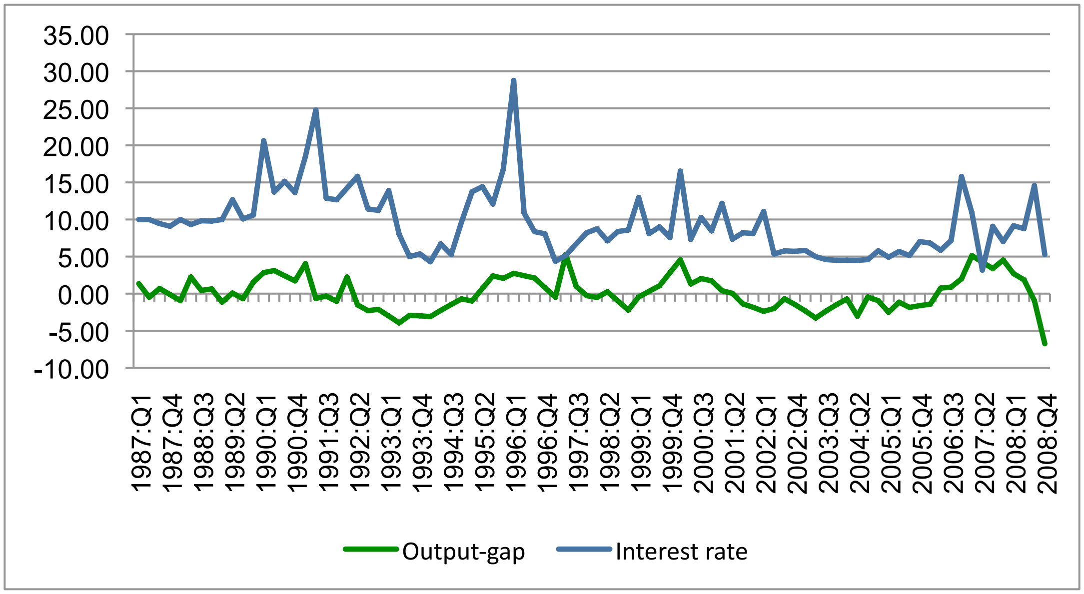

Figure 4: Estimated Regime Probabilities, Regime Switching (Output Gap and Inflation)

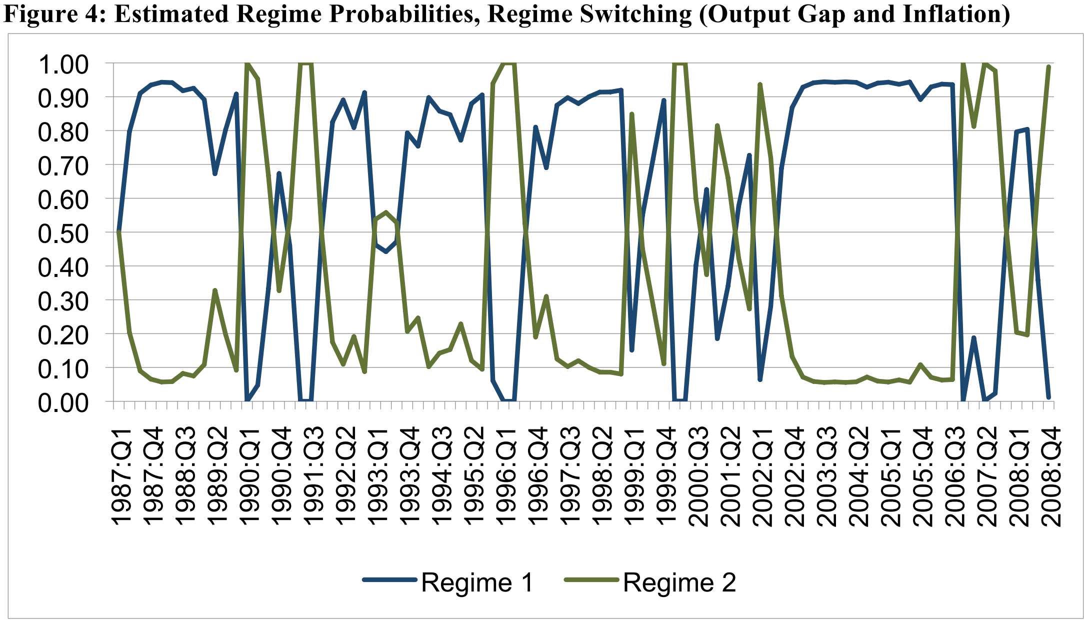

Figure 5: Estimated Regime Probabilities, Regime Switching (Output Gap Only)

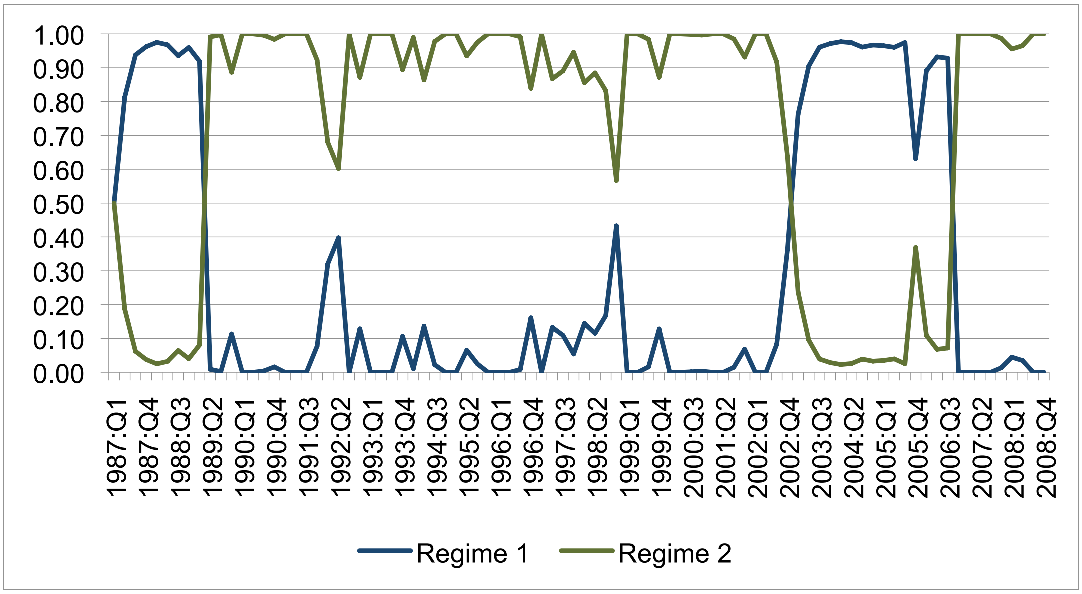

Figure 6: Estimated Regime Probabilities, Regime Switching (Output Gap Only) with Exchange Rate

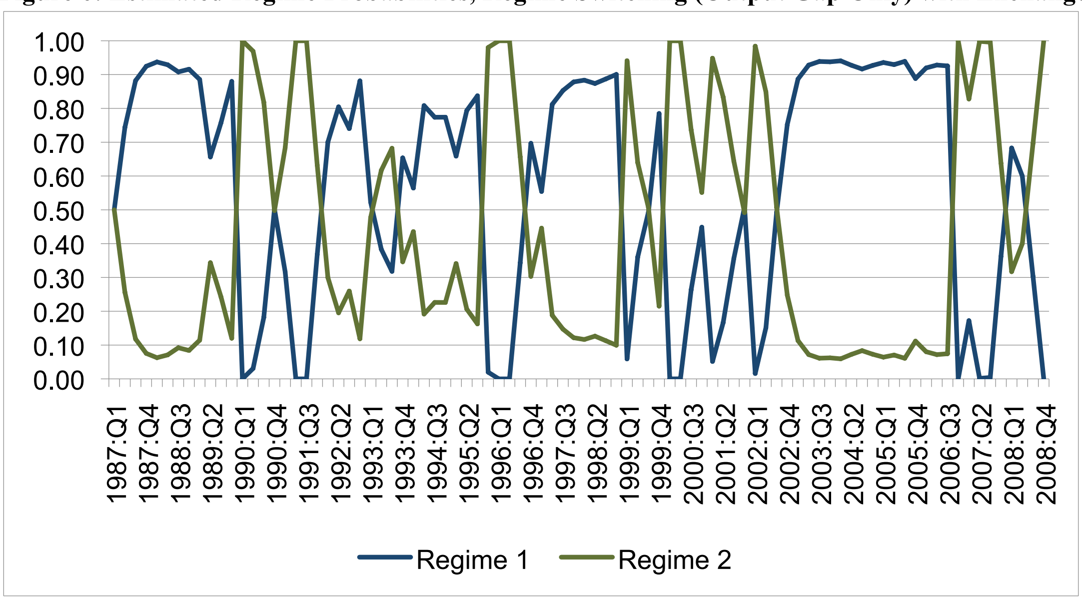

Figure 7: Estimated Regime Probabilities, Regime Switching (Exchange Rate Only)

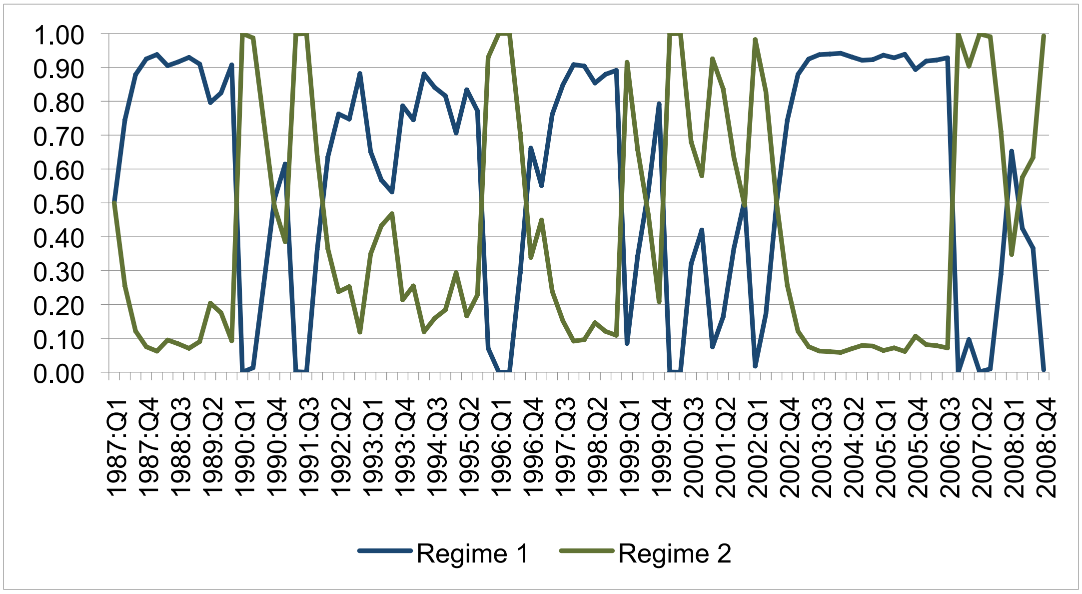

Figure 8: Estimated Regime Probabilities, Regime Switching (Output Gap and Exchange Rate)