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Asymmetric effects of unanticipated monetary shocks on stock prices: Emerging market evidence

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ABSTRACT

This study investigates the asymmetric effects of unanticipated monetary shocks on stock prices in India over the period 1994M4–2018M11. We find that the evolution of stock prices is state-dependent across different monetary policy processes. Unanticipated monetary shocks appear to have significantly asymmetrically lagged effects on stock prices, namely: (i) the positive effect of negative unanticipated shocks in bull markets; and (ii) the negative effect of positive unanticipated shocks in bear markets. Our findings imply that monetary policy-markers should attend to these situations for the future of money-supply policies to diminish the degree of uncertainty about the money supply in adjusting stock prices.

1. Introduction

The relationship between monetary policy and the real economy has been well developed in the specialized literature. Lucas (1972), Barro (1978), and Frydman and Rappoport (1987) indicated that if anticipated monetary policy is neutral, only unanticipated monetary shocks are probably to entirely impact real output. Interestingly, the literature argues that the impacts of unanticipated monetary shocks can be asymmetric on real economic activities. This is attributed to the following factors: (*i*) the business cycle's different stages (Galí, 2015; Iacoviello, 2005); (*ii*) the contraction versus the expansion in the conduct of monetary policy (Jiang, 2018; Shiu-Sheng, 2007); and (*iii*) the different levels of monetary policy effect on real economic activities. In the same vein, regarding financial markets, several studies found that the relationship between the monetary policy process and stock market prices is also asymmetric (Ravn, 2014; Ülke and Berument, 2016). Most studies on the relationship between monetary policy and stock market employed such estimation techniques as event analysis (Val et al., 2018), VAR models (Fausch and Sigonius, 2018; Singh and Nadkarni, 2018), DSGE models (Ravn, 2014), and Markov Switching models (Ivrendi and Guloglu, 2012).

Concerning the special case of India (Bank, 2018), the conduct of Indian monetary policy has been increasingly changed since the 1990s (Mohan and Ray, 2019). More specifically, Reserve Bank of India (RBI) allowed the convertibility of current account and market-based exchange rate system in 1994. RBI set up the goal of annual monetary growth from 1980 to

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1998 and also moved towards active interest policy measures to conduct Indian's monetary policy in 1999. Targeting inflation regime was integrated into the Indian monetary policy framework in 2013. Empirically, some studies showed that the interest rate is the strongest monetary transmission channel in India (Aleem, 2010; Hutchison et al., 2010; Khundrakpam, 2017). However, the relationship between monetary policy and the real economy in India needs further investigating. Hutchison et al. (2010) showed that Indian rate policy is sensitive to the output gap, while Aleem (2010) indicated that unanticipated monetary shocks in India are significantly driven by the Fed's monetary policy. Regarding the Indian financial sector, Kumari and Mahakud (2015) found that the volatility of the stock market is affected by the money supply and interest rate. As in Narayan (2009), the author showed that the rupee shocks caused asymmetric effects on the stock market. Recently, Kolluri et al. (2015) have revealed that there exists the co-integration between India's stocks with the bond and stock markets of the US, the UK, Japan, China, and emerging equity markets. Also, Prabu et al. (2016) have found that the Fed's monetary policy significantly affects the Indian stock market. Unfortunately, most previous studies have ignored the impacts of negative and positive unanticipated monetary policy shocks on the Indian stock market.

This study performs an empirical analysis to examine the asymmetric effects of negative and positive unanticipated shocks of monetary policy on stock prices in India. Econometrically, based on available monthly data in India over the 1994M4–2018M11 period, we conduct a two-step procedure to establish a plausible empirical model for estimating the asymmetric effects of monetary policy on stock prices in India. In the first step, based on Taylor's rule we model monetary policy process in which interest policy is used as a proxy of monetary policy. To deliver robust results, we present three models for monetary policy process: (*i*) the first is employed on the simple version of the Taylor rule (Taylor, 1993); (*ii*) the second is an augmented version of the Taylor rule for emerging countries as suggested by Mohanty and Klau (2005); and (*iii*) the third includes the structural break of the monetary policy process in India. The optimal version is selected by the Akaike Information Criterion (AIC). To the best of our knowledge, this is the only study that uses Taylor' rule for extracting negative and positive unanticipated monetary shocks for the case of India. In the second step, by extracting unanticipated monetary shocks, we calculate negative and positive unanticipated monetary shocks based on the method of Cover (1992). The Markov Switching dynamic regression (MSDR) model is employed to estimate the asymmetric effects of unanticipated monetary policy shocks on stock prices in India. The MSDR model allows the quick evolution of heterogeneous time series in different states (Ailliot and Monbet, 2012; Cheng, 2016). Besides, attention is directed especially to time-varying parameters in the MSDR model to capture the dynamic relationship between monetary policy shocks and stock prices.

The next section presents the overall methodology and empirical data employed in this study. Section 3 reports and discusses the results. The final section concludes the study with a policy discussion.

2. Methodology and data

First, we define the monetary policy process in India with the method adopted as in Hutchison et al. (2010). Second, following Cover (1992), we identify positive and negative unanticipated monetary policy shocks from extracting residuals of estimating monetary policy process. Third, these shocks are added to the MSDR model for estimating their impacts on the stock prices in India.

2.1. Taylor rule and monetary policy process for India

Following Hutchison et al. (2010), India's monetary policy process can be estimated based on the simple Taylor rule. The best fit model is selected in terms of AIC at the minimum. The Taylor rule is given:

$$\Delta i_t = \delta_0 + \delta_1 i_{t-1} + \delta_2 \pi_t + \delta_3 y_t + \delta_4 exc_t + \varepsilon_t \tag{1}$$

In Eq. (1) , t is the time; ε_t *is* residuals $\sim iid(0, \delta^2)$; i is the interest rate of RBI as a proxy of India's monetary policy; π is inflation; y is output gap calculated by the difference between actual output and potential output; *exc* is exchanges rate. A rise in the exchange rate involves depreciation and vice versa. Parameters δ_2, δ_3, and δ_4 are estimated coefficients reflecting the elasticity of interest policy to the output gap, inflation, and exchanges rate, respectively.

Eq. (1) is estimated using OLS. The residuals series extracted from Eq. (1) are considered a proxy of the unanticipated "shock" of the monetary policy process. To measure the asymmetric effects of negative and positive unanticipated shocks, we create two series of monetary policy shocks. The series of negative monetary shocks is extracted from the monetary policy shock in terms of min (*shock, zero*). The series of positive monetary shocks is extracted from the monetary policy shock in terms of max (*shock, zero*).

Following Cover (1992), positive monetary shocks (*RESDP*) are calculated by:

$$RESDP_t = \frac{1}{2} * [|shock_t| + shock_t] \tag{2a}$$

And negative monetary shocks (*RESDN*) are given by:

$$RESDN_t = -\frac{1}{2} * [|shock_t| - shock_t] \tag{2b}$$

RESDP is associated with an unexpected increase in the interest rate of RBI, while *RESDN* is related to an unexpected decrease in the interest rate of RBI. As such, changes in *RESDN* and *RESDP* are apt to affect the prices and prices of financial assets. Notably, the impacts of *RESDN* and *RESDP* can be asymmetric on stock prices. That is, an increase in *RESDN* leads to an increase in stock prices, and in contrast, an increase in *RESDP* induces a reduction in stock prices.

2.2. Research model

In this study, we use a composite index for the overall Indian stock market and employ Markov Switching dynamic regression (MSDR) model to estimate the dynamics of stock prices in India. The MSDR model allows a fast adjustment after the Markov process changes state. Theoretically, the dynamic characteristics of the stock market are related to two basic features: asymmetry and unobserved factors. The asymmetry indicates that market stock behaviours are different between the bull market and bear market. Unobserved variables, such as random factors, affect the dynamics of stock prices.

The MSDR model proposed by Hamilton (1989) defines this asymmetry aspect by allowing for nonlinear switching between different states and switching mechanism conditioned by the unobserved state variable , s_t, involving a first-order Markov process , $s_{t-1}, s_{t-2}, \ldots, s_{t-k}$. The probabilities of the state of s_t are dependent on the past state of s_{t-1}: $P_r\,(s_t = j|s_{t-1} = i) = p_{ij}$ with $j \in (1, \ldots, k)$. If probabilities are closer to one, a Markov process is more persistent. Considering a two-state process , $s_t \epsilon (1, 2)$, switching probabilities from state one to state two can be expressed as:

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

where $p_{11} + p_{12} = 1$ *and* $p_{21} + p_{22} = 1$

$$p_{11} = P_r[s_t = 1|s_{t-1} = 1] \text{ and } p_{12} = P_r[s_t = 2|s_{t-1} = 1] \tag{3b}$$

$$p_{22} = P_r[s_t = 2|s_{t-1} = 2] \text{ and } p_{21} = P_r[s_t = 1|s_{t-1} = 2] \tag{3c}$$

MS models are estimated by adopting maximum likelihood techniques in which conditional density is defined as: $y_i = f\,(y_t|s_t = i, y_{t-1}; \theta)$ *with* $i = 1, 2, ..k$, and the marginal density of y_t is specified: $f\,(y_t|\theta) = \sum_{i=1}^{k} f(y_t|s_t = 1, y_{t-1}, \theta) P_r(s_t = 1; \theta)$. The likelihood function to estimate the probabilities is given as follows:

$$P_r\,(s_t = 1|y_t; \theta) = \frac{f(y_t|s_t = 1, y_{t-1}; \theta) P_r(s_t = 1; \theta)}{f(y_t|y_{t-1}; \theta)} \tag{4}$$

To capture a dynamic relationship between stock prices and unanticipated monetary shocks, the time-varying monetary shocks are added to the MSDR model of stock prices. The MSDR model of stock prices is given:

$$STOCKg_t = \mu_{s,t} + \alpha_{s,t}(RESP_t, RESDN_t) + \epsilon_{s,t} \tag{5}$$

In Eq. (5) , $s_t \in (1, 2)$ is the time state, t; $\mu_{s,t}$ is the intercept terms in states:

$$\mu_{s,t} = \mu_1 \text{ if } s_t = 1 \tag{6a}$$

$$\mu_{s,t} = \mu_2 \text{ if } s_t = 2 \tag{6b}$$

Stock prices can be transferred from state 1 to state 2 with the mean, $\mu_{s,t}$ and variance, $\delta^2_{s,t}$. *RESDP* and *RESDN* are positive and negative unanticipated monetary shocks. These variables all are exogenous with state-dependent coefficients, $\alpha_{s,t}$. Unanticipated monetary shocks through interest rate movements reflect changes in values of rational expectations, which tend to impact the returns and prices of financial assets (Assefa et al., 2017). As such, the hypothesis is that an increase in RESDP (*i.e.* increased interest rate) could give rise to a decrease in stock prices (negative effect). In contrast, an increase in RESDN (*i.e.* reduced interest rate) could lead to an increase in stock prices (positive effect).

Eq. (5) is calculated using maximum likelihood (ML). In the ML framework, residuals analysis and specification tests can be directly used to select the best fit model (Cheng, 2016). Also, we use monthly data to investigate the asymmetric effects of unanticipated monetary shocks on stock prices. As such, the MSDR model is appropriate to capture quick shifts in the stock prices process. As in Hamilton and Lin (1996), these authors revealed that stock volatility process and ARCH term cannot be estimated with quarterly data. Previously, Glosten et al. (1993) indicated that the GARCH-M model seems to be not persistent for monthly conditional stock volatility. Therefore, the variable of monthly conditional stock volatility is not included in our model of stock prices.

2.3. Empirical data

The study uses monthly data for India in the 1994M4–2018M11 period from Federal Reserve Bank of St. Louis (https://fred.stlouisfed.org), including stock prices (*STOCKg*) measured by stock prices growth rate (previous period), industrial production index (*IP*), consumer price index for all goods (*CPI*), Rupee nominal exchange rate against the United States dollar (*EXC*), India's Central Bank rate (*IR*), Fed interest rate (*FED)*, and global oil prices (*OIL*). Inflation (*INF*) is measured as the first difference of the log of the consumer price index. We observe that most Indian monetary market rates, such as interbank rate and discount rate, are the same as the Central Bank rate of RBI. As such, we use the Central Bank rate of RBI as a proxy of India 'monetary policy. All these variables are seasonally adjusted by the X-12 procedure. Output gap (*OG*) is the difference between nominal *IP* and potential *IP*. To estimate the potential *IP*, we use the function of Hodrick and Prescott (*HP*) filter with the smoothing parameter $\lambda = 1\,269\,000$ for monthly data. Fig. 1 depicts the trend of *OG* index in India in the 1994M1–2018M11 period.

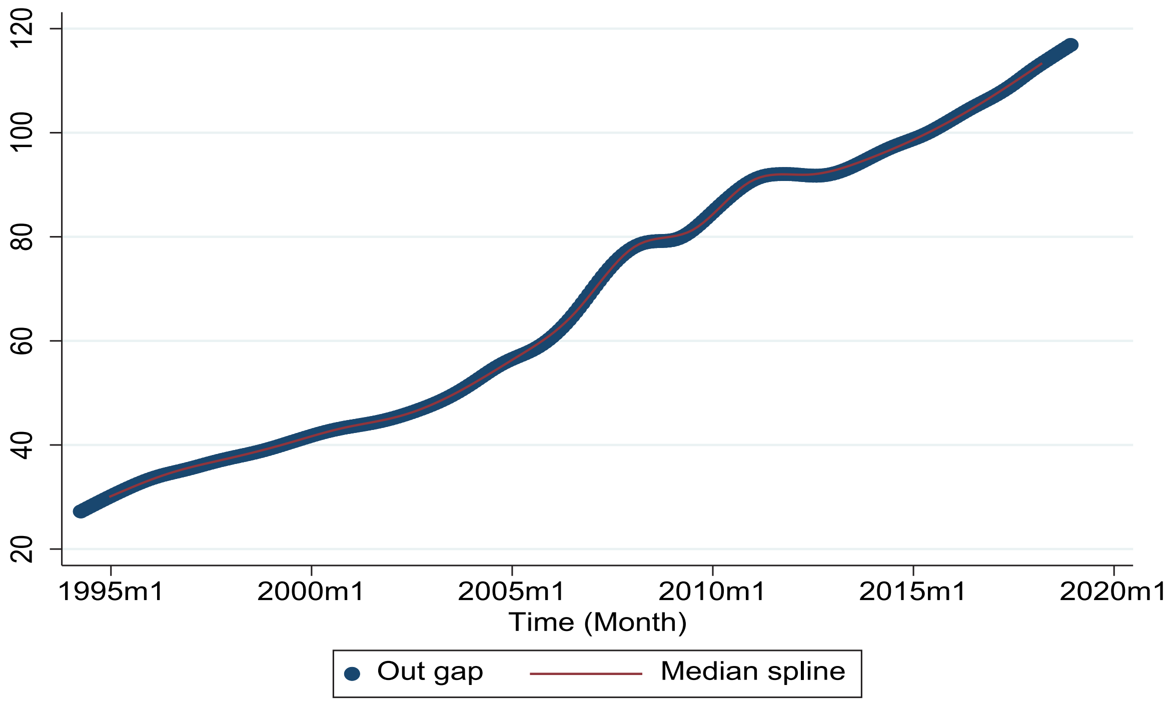

Fig. 1. Tendency of output gap index in India over the 1994M1–2018M11 period.

Table 1
Statistics and definition of variables.

Variable	Definition	Obs	Mean	SD	Min	Max
IP	Industrial production index in India, Index 2015 = 100, seasonally adjusted	297	68.202	27.217	26.963	119.241
OG	Output gap is calculated by the difference between nominal IP and potential IP in India	297	68.202	27.182	27.238	116.857
IR	The interest rate of Reserve Bank of India as a proxy of the monetary policy of Reserve Bank of India (%), seasonally adjusted	296	7.745	2.032	5.922	12.311
CPI	Consumer price index in India, Index 2015 = 100, seasonally adjusted	297	58.650	28.082	22.554	115.395
INF	Inflation in India calculated by the difference of the log of consumer price index in India	296	0.552	0.622	−1.259	4.082
STOCKg	Stock prices growth rate (previous period) in India (%)	297	0.930	5.879	−24.055	22.075
EXC	Indian Rupees to One U.S. Dollar, seasonally adjusted	297	48.366	10.323	30.942	73.394
FED	Effect FED funds rate (%), seasonally adjusted	297	2.582	2.286	0.067	6.642
OIL	Global oil prices: U.S. Dollars per Barrel, seasonally adjusted	297	51.957	29.581	11.718	124.969

Descriptive statistics of variables are presented in Table 1. The tendency of the Central Bank rate and primary rate in India over the 1994M4–2018M11 period is depicted in Fig. 2. India' Central Bank rate shows a downward tendency. Fig. 3 shows that the trend of the Central bank rate and stock prices growth rate in India is the opposite. The Central bank rate decreases steadily in the 1994–2007 period, while the stock prices growth rate rises slightly in the same period. Likewise, the Central bank rate decreases gradually in the 2012–2018 period, but the stock prices growth rate rises strongly in the same period.

Other variables, namely output gap growth (*OG*), Exchange rate (*EXC*), and global oil price (*OIL*), are estimated in logarithm form to reduce heteroscedasticity. Testing skewness and kurtosis show that all variables are rejected to be a normal distribution at the 1% significance level (see Table 2). Besides, the time-series properties of variables are detected by the unit root test using the augmented Dickey–Fuller (ADF) and the Dickey–Fuller generalized least (DF-GLS),

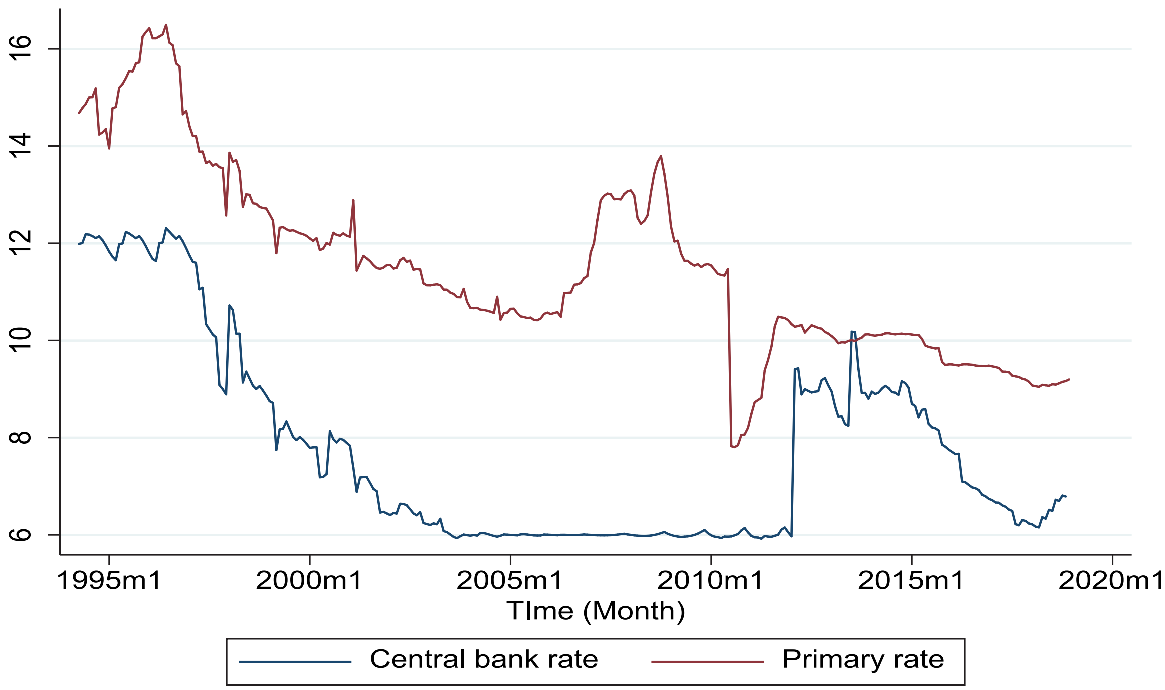

Fig. 2. Tendency of Central Bank rate and primary rate in India over the 1994M4–2018M11 period.

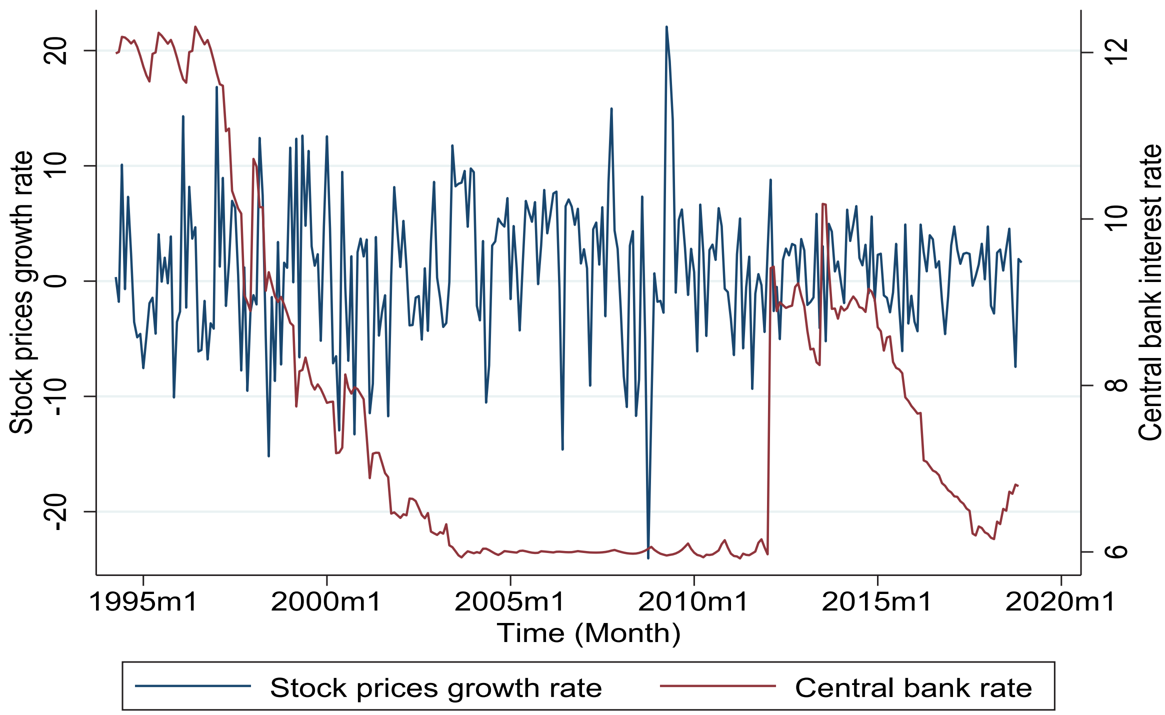

Fig. 3. Tendency of Central Bank rate and stock prices growth rate in India over the 1994M4–2018M11 period.

respectively. The results are presented in Table 3. Variables *OG*, *INF*, and *STOCKg* are stationary in *I(0)* process for both ADF and DF-GLS tests, whereas *IR*, *EXC*, *FED*, *and OIL* are stationary in *I(1)* process.

In addition, the Wald test for unknown structural break date is reported in Table 4. Variable *OG* has a structural breakpoint in 2006M2, relating to the 2008 financial crisis. India's inflation and the Central bank rate are structurally

Table 2
Test for normal distribution.

Variable	Obs	Pr(Skewness)	Pr(Kurtosis)	Prob>chi2
LnOG	297	0.139	0.000***	0.000***
IR	296	0.000***	0.000***	0.000***
INF	296	0.000***	0.000***	0.000***
STOCKg	296	0.000***	0.000***	0.000***
FED	297	0.041**	0.000***	0.000***
LnOIL	297	0.179	0.000***	0.000***
LnEXC	297	0.404	0.013**	0.037**

Note: (***), (**), and (*) denote significance at 1%, 5% and 10%, respectively.

Table 3
Unit root test for variables.

Variables	ADF		DF-GLS	
	Without trend	Trend	Without trend	Trend
LnOG	−7.680***	−7.680***	−5.464***(Lag 1)	−5.464***(Lag 1)
IR	−1.187	−1.187	−1.187 (Lag 1)	−1.187 (Lag 1)
INF	−12.503***	−12.503***	−10.392*** (Lag 1)	−10.392***(Lag 1)
STOCKg	−10.162***	−10.162***	−13.562*** (Lag 1)	−13.555***(Lag 1)
FED	−0.712	−0.602	−1.862 (Lag 1)	−1.862 (Lag 1)
LnOIL	−1.682	−1.714* (Lag 3)	−1.680 (Lag 1)	−1.680 (Lag 1)
LnEXC	−0.679	−1.325* (Lag 7)	−1.828 (Lag 1)	−1.828 (Lag 1)
Difference				
ΔIR	−17.375***	−17.376***	−13.175*** (Lag 1)	−13.175*** (Lag 1)
ΔLnEXC	−12.430***	−12.430***	−10.656*** (Lag 1)	−10.656*** (Lag 1)
ΔFED	−8.356***	−8.354***	−3.978***(Lag 1)	−3.978***(Lag 1)
ΔLnOIL	−13.643***	−13.659***	−7.091***(Lag 1)	−7.091***(Lag 1)

Notes: (***), (**) and (*) denote significance at 1%, 5% and 10%.
Critical values of ADF test:

- Without trend: −3.456 (1%), −2.878 (5%) and −2.570 (10%).
- Trend: −2.339 (1%), −1.650 (5%), and −1.284 (10%).

Critical values of DF-GLS test:

- Without trend, Lag (1): −2.58 (1%), −2.007 (5%) and −1.690 (10%).
- Trend, Lag (1): −3.480 (1%), −2.904 (5%), and −2.616 (10%).

Table 4
Structure break test (Wald).

Variable	Break time	Wald test (p)
Structure break test with variables		
LnOG	2006m3	0.000***
ΔIR	2001m11	0.000***
INF	1998m12	0.000**
STOCKg	2003m6	0.302
ΔLnEXC	2012m4	0.000***
The structure break test with regression: $\Delta IR_t = \beta_0 + \beta_1 IR_{t-1} + \beta_2 INF_t + \beta_2 LnOG_t + \beta_3 \Delta LnEXC_t + \varepsilon_t$		
	2012m2	0.000***

Note: The sample is in the period of 1994m4–2018m11. (***), (**) denote significance at 1%, 5% levels.

broken in 1998M12 and 2001M11, respectively, relating to the Asian 1997 financial crisis. Based on Taylor rule, the regression of monetary policy is estimated by OLS with variables *IR*, *INF*, *OG*, and *EXC*. As a result, India's monetary policy has a structural breakpoint in 2012M2, relating to high inflation in India in the 2010–2013 period. The dummy variable of monetary policy's structural breakpoint is added to Eq. (1) to examine the monetary process.

3. Empirical results

3.1. Estimates for unanticipated monetary shocks

Following Hutchison et al. (2010), we estimate monetary policy rule for India based on Taylor rule. Model 1 is estimated based on simple Taylor rule without exchange rate (Taylor, 1993). Model 2 is calculated with the exchange rate. as suggested by Mohanty and Klau (2005). Added to Model 3 is second lagged exchange rate, whereas the dummy variable

Table 5
Taylor rule for monetary policy in India (Dependent variable ΔIR).

Variable	(1)	(2)	(3)	(4)
IR(−1)	−0.022**	−0.020*	−0.026**	−0.068***
	[0.011]	[0.011]	[0.011]	[0.017]
LnOG	−0.000	0.000	−0.000	−0.003***
	[0.001]	[0.001]	[0.001]	[0.001]
INF	0.072**	0.075**	0.076***	0.095***
	[0.029]	[0.029]	[0.029]	[0.029]
$\Delta LnEXC$		−0.013		
		[0.012]		
$\Delta LnEXC(-2)$			0.024**	0.026**
			[0.012]	[0.012]
D2012				0.284***
				[0.092]
Cons	0.115	0.088	0.156	1.763***
	[0.262]	[0.263]	[0.262]	[0.582]
Obs	295	295	293	293
R2 adjusted	0.035	0.041	0.051	0.081
AIC	146.421	147.588	**144.849**	**137.349**
LM test for (ARCH)	0.839	0.844	0.854	0.815
Durbin–Watson d-statistic	2.068	2.052	2.064	1.983
Breusch–Godfrey LM test for autocorrelation (1)	0.549	0.649	0.573	0.889

Note: (***), (**), (*) denote significance at 1%, 5%, and 10% level. Standard error in parentheses.
Model 4 is favoured because it has a smaller AIC value.

of 2012M2 structure break is introduced to Model 4. The results are presented in Table 5. Specification tests, including R squared and AIC, show that Model 4 is favoured over the other models. The result of Model 4 shows that output gap, inflation, and exchange rate are statistically significant at the 1% and 5% levels, respectively. This suggests that Indian monetary policy is quick to react with changes in output gap, inflation, and exchange rate. Furthermore, the 2012M2 structural breakpoint related to high inflation significantly influences Indian monetary policy process.

Considering Model 4, residuals series is extracted to obtain unanticipated monetary shocks. Fig. 4 depicts the trend of negative unanticipated monetary shocks (*RESDN*) and positive unanticipated monetary shocks (*RESDP*) in India. It seems that changes in *RESDN* are stronger than those in *RESDP* in the periods of 1998–2001 and 2012–2015.

3.2. Dynamics of stock prices

To know whether India's stock prices are state-dependent, we first estimate the dynamics of India's stock prices by the MSDR model. We select MSAR (Markov Switching Autoregressive model) estimations as a reference.[1] The results are presented in Table 6. Regarding MSDR models, Model 1 is estimated with constants only. Model 2 considers the first lag of stock prices growth rate, *STOCKg (−1)* as a time-invariant variable. Built into Model 3 is *STOCKg (−1)* as a time-varying variable. Regarding the MSDR Models 1–2, the Wald test statistic shows $\mu_1 = \mu_2 = \delta_1^2 = \delta_2^2$ (rejected at the 1% level), suggesting that Indian stock prices are dependent on states. Based on the Schwarz Bayesian information criterion (SBIC) value, Models 1–2 can be duly employed. Therefore, we first select Model 1 to estimate the switching dynamics of stock prices across the monetary policy process, and then Model 2 is used to check robustness. The MSDR Model 1 is specified as follows:

$$STOCKg_t = \mu_{s,t} + \epsilon_{s,t} \tag{7}$$

The results of the MSDR Model 1 show the evolution of stock prices with dependent states: (*i*) state 1 with the mean $\mu_1 = 1.008\%$ and the variance$\delta_1^2 = 6.901$ (high stock prices/bull market); (*ii*) state 2 with the mean $\mu_2 = 0.798\%$ and the variance, $\delta_2^2 = 3.459$ (low stock prices/bear market). These variables all are statistically significant. The estimated probability of being state 1 (p_{11}) is 99.60%, and the probability of being state 2 (p_{22}) is 99.60%, suggesting that each state is persistent. It is worth noting that state 1 is more volatile than state 2 because it has a higher variance value. Fig. 5 presents the probability of being state 1 with upward movements in bull markets but downward movements in bear markets.

[1] The MSAR model is not favoured over the MSDR models 1–2 because it has the Schwarz Bayesian information criterion (SBIC) value for this model, 6.410, is higher that SBIC for the MSDR models 1–2.

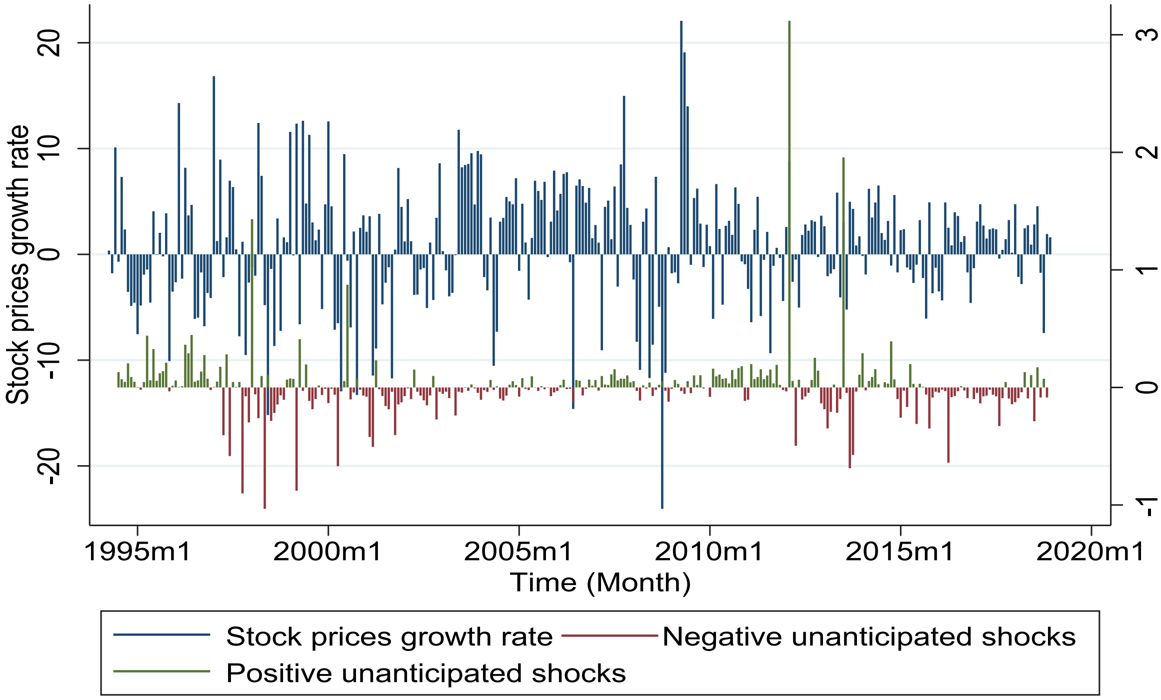

Fig. 4. Unanticipated monetary shocks and stock prices growth rate in India over the 1994M4–2018M11 period.

Table 6
Switching estimates for stock prices in India: MSDR and MSAR (Dependent variable: *STOCKg*).

Variable	MSDR model			MSAR model
	(1)	(2)	(3)	AR(1)
STOCKg(−1)		0.180*** [0.058]		
$\varnothing_1$			0.565*** [0.156]	1.608*** [0.021]
$\varnothing_2$			0.002 [0.115]	0.192*** [0.056]
μ_1	1.008** [0.507]	0.829* [0.493]	−1.455 [1.026]	−15.333*** [0.461]
μ_2	0.798** [0.339]	0.655* [0.350]	2.150*** [0.817]	0.769** [0.300]
δ_1^2	6.901*** [0.371]	6.680*** [0.368]	5.554*** [0.645]	3.055*** [0.171]
δ_2^2	3.459*** [0.246]	3.488*** [0.261]	5.040*** [0.451]	5.373*** [0.227]
p_{11}	0.996 [0.004]	0.996 [0.004]	0.234 [0.184]	0.222 [0.159]
p_{21}	0.004 [0.006]	0.005 [0.006]	0.612 [0.436]	0.021 [0.009]
Obs	297	297	296	295
Log likelihood	−923.994	−916.513	−932.804	−925.944
SIBC	6.332	6.330	6.456	6.410
Wald test $\mu_1 = \mu_2 = \delta_1^2 = \delta_2^2$	0.000***	0.000***	0.578	0.000***

Note: (***), (**), (*) denote significance at 1%, 5%, and 10% level. Standard error in parentheses.
MSDR Model 1: $STOCKg_t = \mu_{s,t} + \epsilon_{s,t}$; MSDR Model 2: $STOCKg_t = \mu_{s,t} + \alpha_t STOCKg_{t-1} + \epsilon_{s,t}$; MSDR Model 3: $STOCKg_t = \mu_{s,t} + \varnothing_{s,t} STOCKg_{t-1} + \epsilon_{s,t}$; MSAR (1) model: $STOCKg_t = \mu_{s,t} + \varnothing_{s,t}(STOCKg_{t-1} - \mu_{t-1}) + \epsilon_{s,t}$; The MSDR Models 1–2 can be more proper over others because they have smaller the Schwarz Bayesian information criterion (SBIC) values.

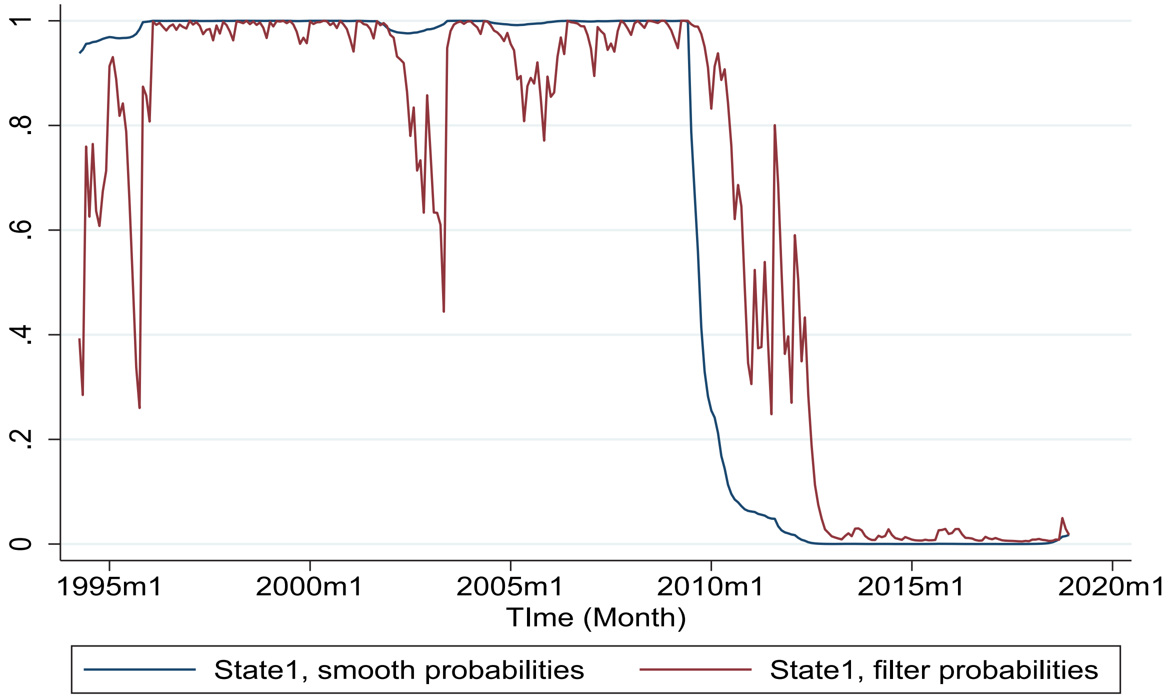

Fig. 5. The dynamics of stock prices for India in the 1994M4–2018M11 period: Probabilities for bull markets in MSDR model.

3.3. Effects of unanticipated monetary shocks

To know whether the impacts of *RESDN* and *RESDP* on stock prices are symmetric or asymmetric, we take account of: (*i*) whether there exists the difference between the effects of negative and positive unanticipated monetary shocks on stock prices; and (*ii*) whether negative (positive) shocks are positive (negative) on stock prices.

3.3.1. No lagged shocks

First, we assume that current unanticipated monetary shocks affect stock prices. As described in Eq. (5), *RESDN* and *RESDP* are incorporated into the model as varying-time parameters to test the asymmetric effects of unanticipated monetary shocks on the stock prices in bull and bear markets. The maximum likelihood estimation results are presented in Table 7. Model 3 is estimated only with negative unanticipated shocks (*RESDN*), and Model 4 only with positive unanticipated shocks (*RESDP*). Added to Model 5 are both *RESDN* and *RESDP*.

As presented in Table 7, Model 5 captures the intercept and the variance of the common factor and time-varying parameters (unanticipated shocks) to follow Markov switching between two states. When adding unanticipated shocks (*RESDN* and *RESDP*), the results of Eq. (7) are different from those of Eq. (5) . State 1 is now low stock prices (bear markets) and has a mean price of 0.081%. State 2 is now high stock prices (bull markets) and has a mean price of 10.271%. However, the probability of being state 1 (p_{11}) is 97.40%, and the probability of being state 2 (p_{22}) is 72.50%. Consequently, the expected average duration of state 1 (39.744 months) is longer than that of state 2 (3.629 months). Interestingly, the estimation result shows only the coefficient on *RESDP* is negative and significant in state 2. The hypothesis that the coefficient on *RESDN* in state 1 is equal to that in state 2 is not rejected at the significance level of 1%. In contrast, the coefficient on *RESDP* in state 1 is assumed to be equal to that in state 2 is rejected at the significance level of 1%. The interpretation of this result is twofold. First, the effects of current unanticipated monetary shocks are different on stock prices. Second, India's stock market is asymmetrically responsive to current positive unanticipated monetary shocks in bull markets. This gives rise to a conclusion that a current tightening monetary policy of increasing interest rate has a negative effect on stock prices only during the period of bull markets. Fig. 6 presents the probability of being bear markets (state 1) with the common factor that shows upward movements in bear markets but downward movements in bull markets.

3.3.2. Lagged shocks

Second, we assume that lagged unanticipated monetary shocks affect stock prices. As such, Eq. (5) is computed as:

$$STOCKg_t = \mu_{s,t} + \delta_{s,t}(\sum_{i=1}^{n} RESDN_{t-i}, \sum_{i=1}^{n} RESDP_{t-i}) + \epsilon_{s,t} \tag{8}$$

Table 7
The effects of unanticipated shocks on stock prices in India (MSDR model) (Dependent variable: *STOCKg*).

Variables	(4)	(5)	(6)
State 1			
RESDN	1.428		0.095
	[3.376]		[2.406]
RESDP		1.896	1.894
		[1.293]	[1.309]
State 2			
RESDN	−3.189		−1.637
	[2.585]		[6.531]
RESDP		−39.955***	−39.213***
		[13.130]	[13.557]
μ_1	0.139*	0.081	0.081
	[0.082]	[0.402]	[0.459]
μ_2	0.510	10.480***	10.271***
	[0.416]	[2.204]	[2.389]
δ_1^2	6.937***	5.391***	5.319***
	[0.387]	[0.256]	[0.256]
δ_2^2	3.466***	4.987***	4.984***
	[0.251]	[0.990]	[0.977]
p_{11}	0.996***	0.975***	0.974***
	[0.005]	[0.017]	[0.017]
p_{21}	0.005	0.277	0.275
	[0.007]	[0.137]	[0.122]
Obs	293	293	293
Log likelihood	−911.373	−925.895	−925.863
SBIC	6.376	6.475	6.513
Expected duration (Month)			
State 1			39.744
State 2			3.629

Note: (***), (**), (*) denote significance at 1%, 5%, and 10% level. Standard error in parentheses.
Model 4 is estimated with current negative unanticipated shocks (RESDN).
Model 5 is estimated with current positive unanticipated shocks (RESDP).
Model 6 is estimated with current positive and negative unanticipated shocks (RESDN, RESDP).

In Eq. (8), n is the order of lagged *RESDN* and *RESDP* ($n = 1,\ldots, N$). The model with optimal lags is selected with lower Schwarz Bayesian information criterion (SBIC).

We estimate Eq. (8) with one, three, and five lagged shocks, respectively (the results are reported in *A1* of Appendix). The model is not concave from six lags onwards. The Wald test statistic shows $\mu_1 = \mu_2 = \delta_1^2 = \delta_2^2$, which is not rejected for models with one and five lagged shocks. In addition, the hypothesis that the coefficients on *RESDN* sum in state 1 are jointly equal to those in state 2 is not rejected at the significance level of 1%. Likewise, the coefficients on *RESDP* sum in state 1 are assumed to be jointly equal to those in state 2, which is also not rejected at the significance level of 1%. This means that the models with one and five-month lag fail to provide evidence that the evolution of stock prices from unanticipated monetary shocks is dependent on states. Regarding the model with three-month lag, the Wald test statistic shows $\mu_1 = \mu_2 = \delta_1^2 = \delta_2^2$, which is rejected at 1% significance level. In the same vein, the hypothesis that the coefficients on *RESDN* sum (*RESDP sum*) in state 1 are equal to those in state 2 is rejected at the significance level of 1%. This suggests that the model with three lagged shocks is favoured in analysing the Markov switching effects of unanticipated monetary shocks on stock prices.

Following the procedure suggested by Papke and Wooldridge (2005), the cumulative effects of *RESDN* and *RESDP* in Eqs. (2a) and (2b) are calculated:

$$\widehat{\delta'_{RESDN}} = \sum_{i=1}^{n} \delta_{s,t} RESDN_{t-i} \tag{9a}$$

$$\widehat{\delta'_{RESDP}} = \sum_{i=1}^{n} \delta_{s,t} RESDP_{t-i} \tag{9b}$$

The Wald test is employed to identify the value and significance of $\widehat{\alpha'_{RESDN}}$ and $\widehat{\alpha'_{RESDN}}$. According to Papke and Wooldridge (2005), the cumulative effects of *RESDN* and *RESDP* are also long-run effects. The results of estimating the cumulative effects of *RESDN* and *RESDP* with three-month lag are reported in Table 8. Model 1 is estimated only with three lagged shocks. Model 2 includes Fed rate (*FED*) and global oil price (*OIL*) as time-varying variables affecting Indian stock prices

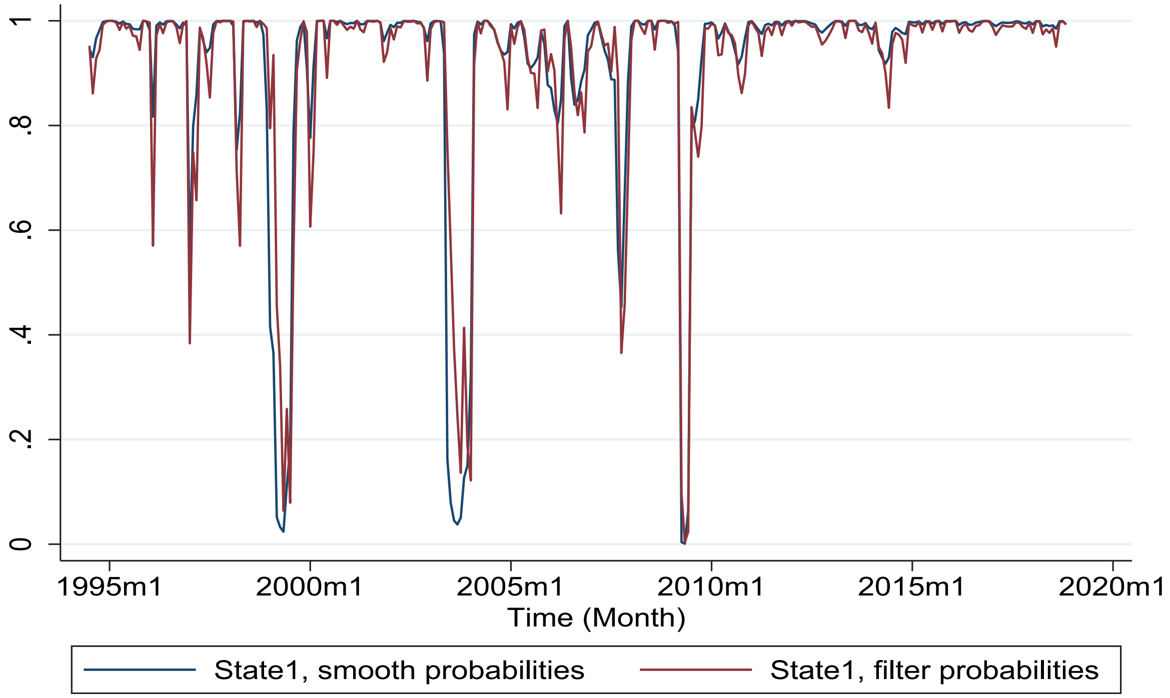

Fig. 6. The effects of current unanticipated shocks on stock prices for India over the 1994M4–2018M11 period in MSDR model: Probabilities of staying bear markets in MSDR model.

as in previous studies (Aleem, 2010; Nath Sahu et al., 2014). Model 2 is specified as follows:

$$STOCKg_t = \mu_{s,t} + \delta_{s,t}\left(\sum_{i=1}^{n} RESDN_{t-i}, \sum_{i=1}^{n} RESDP_{t-i}\right) + \beta_{s,t}(FED, OIL) + \epsilon_{s,t} \tag{10}$$

where *FED* and *OIL* are exogenous with state-dependent coefficients, $\beta_{s,t}$.

In Table 8, the accumulated effects of *RESDN* and *RESDP* in Model 1 are very consistent with those in Model 2. Model 2 is favoured over Model 1 because it has a lower SIBC value. Model 2 shows that the intercept and the common factor of time-varying are significant. State 1 is low stock prices (bear markets) with a mean price of −1.787%. State 2 is high stock prices (bull markets) with a mean price of 2.061%. The probability of being state 1 (p_{11}) is 89%, and the probability of being state 2 (p_{22}) is 97.8%. As a result, the expected average duration of bull markets (23.46 months) is longer than that of bear markets (5.25 months).

Notably, the cumulative effect of *RESDP* is negative and significant on stock prices in bear markets (State 1), while that of *RESDN* is positive and significant in bull markets (State 2). This suggests that Indian stock market is significantly and asymmetrically responsive to three lagged unanticipated monetary shocks. This brings about a conclusion that a tightening monetary policy of increasing interest rate after three-month lag has a negative effect on stock prices during the period of bear markets. In an asymmetric manner, an expansionary monetary policy on reducing interest rate after three-month lag has a positive effect on stock prices during the period of bull markets. In addition, the accumulated effect magnitude of *RESDP* (|7.704%|) in bear markets is smaller than that of *RESDN* (|9.308%|) on stock prices in bull markets. This shows that the influence of negative unanticipated monetary shocks of reducing interest rate on stock prices in bull markets is likely to be stronger than that of positive unanticipated monetary shocks of increasing interest rate on stock prices in bear markets. Our results are in line with the study of Guo et al. (2013), which indicated that the effects of Chinese monetary policy shocks from interest rate are significantly asymmetric on the stock market in different states. Interestingly, our finding is different from the study of Khundrakpam (2017), showing that impacts of monetary policy shocks are symmetric on investment activities in India.

Model 2 shows that the effects of Fed rate and oil price on stock prices are dependent on states. Global oil price strongly and persistently affects Indian stock prices in line with (Nath Sahu et al., 2014). An increase in Fed rate reduces stock prices in bear markets, but it raises stock prices in bull markets. This suggests that the increased Fed rate would reduce stock prices in the US. Therefore, it is likely to result in more capital flows from the US stock market to Indian stock market in bull markets. However, during the period of Indian bear markets, the increased Fed rate could not attract more flows from the US stock market to Indian stock market due to lower stock returns in India.

Table 8
The accumulated effects of unanticipated shocks on stock prices in India (MSDR) (Dependent variable: *STOCKg*).

Variables	With three lagged shocks	
	(1)	(2)
State 1		
$\sum_{i=1}^{n} RESDN_{t-i}$	−5.692	−5.526
	[12.019]	[6.442]
$\sum_{i=1}^{n} RESDP_{t-i}$	−10.807**	−7.704*
	[5.396]	[4.037]
OIL		21.954***
		[6.180]
FED		−9.342***
		[2.856]
State 2		
$\sum_{i=1}^{n} RESDN_{t-i}$	17.222**	9.308**
	[6.652]	[4.479]
$\sum_{i=1}^{n} RESDP_{t-i}$	3.661	0.936
	[6.571]	[3.061]
OIL		19.476***
		[4.460]
FED		6.972***
		[2.106]
μ_1	0.458	−1.787**
	[1.496]	[0.753]
μ_2	2.597***	2.061***
	[0.833]	[0.529]
δ_1^2	3.618***	2.121***
	[0.314]	[0.290]
δ_2^2	6.670***	5.410***
	[0.621]	[0.256]
p_{11}	0.935***	0.890***
	[0.004]	[0.079]
p_{21}	0.057	0.042
	[0.041]	[0.022]
Obs	290	290
Log likelihood	−903.340	−884.112
SBIC	6.660	6.605
Wald test: $\mu_1 = \mu_2 = \delta_1^2 = \delta_2^2$	0.000***	0.000***
Wald test: $\sum RESDN$(State 1) $= \sum RESDN$ (state 2)	0.000***	0.019**
Wald test: $\sum RESDP$(State 1) $= \sum RESDP$ (state 2)	0.000***	0.048**
Expected duration (Month)		
State 1	15.491	5.250
State 2	17.282	23.460

Note: (***), (**), (*) denote significance at 1%, 5%, and 10% level. Standard error in parentheses.
Model 1 is estimated without FED and OIL.
Model 2 is estimated with FED and OIL.

Fig. 7 shows the dynamics between three lagged unanticipated monetary shocks and stock prices growth in India. The probability of being bear markets (state 1) with upward movements in bear markets but downward movements in bull markets. Bear markets appear in the periods of 1996–2004 and 2008–2013 relating to the 1997 Asian financial crisis and the 2008 global financial crisis. The Indian stock prices have a tendency to gradually move toward bull markets in the 2013–2018 period. During this period, the Indian Central Bank implemented inflation targeting to bring its monetary policy into effect.

3.3.3. Robustness check

For robustness check, we estimate the dynamics between unanticipated monetary shocks and stock prices by applying the dynamic model for stock prices as follows (see Model 2 in Table 6):

$$STOCKg_t = \mu_{s,t} + \sum_{j=1}^{k} \alpha_{t,j} STOCKg_{t-j} + \delta_{s,t} \left(\sum_{i=1}^{n} RESDN_{t-i}, \sum_{i=1}^{n} RESDP_{t-i} \right) + \beta_{s,t}(FED, OIL) + \epsilon_{s,t} \quad (11)$$

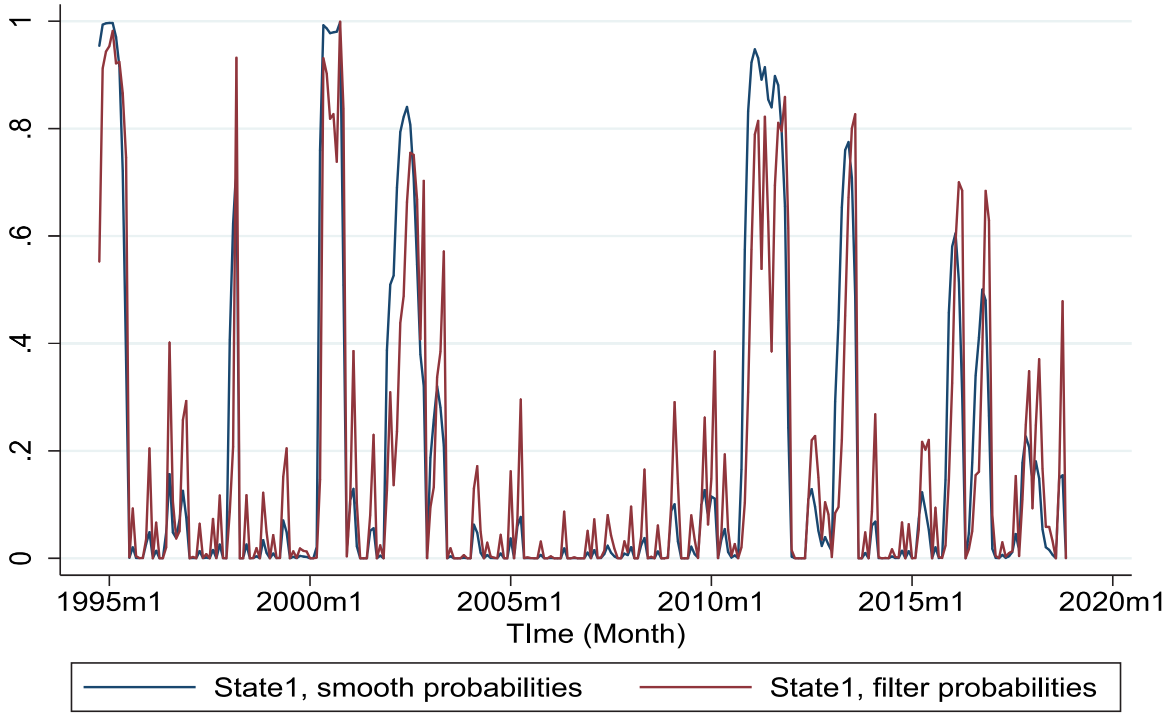

Fig. 7. The impacts of three lagged unanticipated shocks on stock prices for India over the 1994M4–2018M11 period in MSDR model: Probabilities of staying bear markets in MSDR model.

where *j* is the lag order of *STOCKg* with j = 1…k. The cumulative effects of *RESDN* and *RESDP* in Eq. (11) are given as follows:

$$\widehat{\delta'_{RESDN}} = \frac{\sum_{i=1}^{n} \delta_{s,t} RESDN_{t-i}}{1 - \sum_{j=1}^{k} \alpha_{t,j} STOCKg_{t-j}} \tag{12a}$$

$$\widehat{\delta'_{RESDP}} = \frac{\sum_{i=1}^{n} \delta_{s,t} RESDP_{t-i}}{1 - \sum_{j=1}^{k} \alpha_{t,j} STOCKg_{t-j}} \tag{12b}$$

Given the estimation of Eq. (11), Table A.2 in Appendix reports the accumulated effects of unanticipated monetary shocks on stock prices with three lagged unanticipated monetary shocks. Observations show that in Models 2–3, first, the effects of unanticipated monetary shocks are different from the states of stock prices index. Second, stock prices index is symmetrically lagged responsive to one lagged unanticipated monetary shocks. That is, the influence of one lagged negative unanticipated shocks of reducing interest rate is positive on stock prices index in bear markets. In contrast, the influence of one lagged positive unanticipated shocks of increasing interest rate is negative on stock prices index in bull markets.

4. Conclusions

The debate on the relationship between unanticipated monetary policy and stock market is becoming progressively more critical to investors and policymakers. It is a fact that India is in progress of its economic transition. The study contributes to the literature by shedding light on the effects of Indian stock prices on unanticipated shocks in monetary policy. By using monthly data for the 1994M4–2018M11 period and applying the extended MSDR model to time-varying unanticipated monetary shocks, our findings are interesting for the following reasons:

First, based on Taylor rule, we estimate the equation of monetary policy for the case of India. The results show that Indian monetary policy is quickly and significantly responsive to changes in output gap, inflation, and exchange rate. Then, unanticipated monetary shocks are drawn from the residuals of the equation of monetary policy.

Second, the dynamics of Indian stock prices are found to reflect two states: state 1 with high stock growth rate (or bull markets) and state 2 with low stock growth rate (or bear markets). Interestingly, each state is persistent. However, considering unanticipated monetary shocks, observations show that the evolution of stock prices is also dependent on states, but this is different when the model is estimated without monetary shocks. That is, state 1 now reveals low stock

Table A.1
Switching estimates for time varying unanticipated shocks on stock prices growth rate in India (MSDR).

Variable	(n = 1)		(n = 3)		(n = 5)	
	State 1	State 2	State 1	State 2	State 1	State 2
RESDN	−1.175 [3.418]	5.753* [3.360]	−4.813 [4.234]	2.548 [3.414]	1.843 [6.860]	−0.010 [2.701]
RESDN(−1)	9.800*** [3.202]	−1.965 [3.769]	−2.112 [5.571]	12.047*** [3.615]	13.204*** [4.901]	5.518 [5.292]
RESDN (2)			−0.665 [4.045]	−2.073 [3.324]	−16.056*** [5.892]	4.219 [3.267]
RESDN (3)			1.897 [4.021]	4.700 [3.593]	−0.017 [6.074]	5.835* [3.143]
RESDN (4)					−0.070 [5.881]	−1.751 [2.478]
RESDN (5)					−8.847* [5.100]	3.994 [2.692]
RESDP	3.274** [1.540]	0.026* [0.015]	2.427* [1.296]	1.667 [2.946]	4.315 [3.454]	0.975 [1.307]
RESDP (−1)	−0.723 [1.652]	−0.020* [0.012]	−1.333 [1.402]	−3.106 [2.909]	−0.879 [3.386]	−2.903** [1.340]
RESDP (−2)			−0.677 [1.378]	3.309 [5.008]	6.762* [3.628]	−1.036 [1.408]
RESDP (−3)			−11.224*** [3.990]	1.791 [1.902]	−7.322 [5.142]	−0.412 [1.622]
RESDP (−4)					−0.351 [3.616]	−0.170 [1.399]
RESDP (−5)					2.107 [3.960]	−0.209 [1.904]
μ	−1.746 [1.238]	4.360*** [1.121]	0.458 0.458	2.597*** 2.597***	−4.445** [1.985]	4.180*** [0.779]
δ	5.126 [0.431]	4.731 [0.358]	3.618*** [0.314]	6.670*** [0.621]	4.728*** [0.541]	4.577*** [0.322]
p	0.789 [0.082]	0.180 [0.081]	0.935*** [0.004]	0.057 [0.041]	0.658*** [0.123]	0.146 [0.065]
Obs	292		290		288	
Log likelihood	−918.328		−903.340		−899.489	
SBIC	6.562		6.660		6.836	
Wald test $\mu_1 = \mu_2 = \delta_1^2 = \delta_2^2$	0.453		0.000***		0.790	
Wald test $\sum RESDN$(State 1) = $\sum RESDN$ (State 2)	0.519		0.000***		0.441	
Wald test $\sum RESDP$(State 1) = $\sum RESDP$ (State 2)	0.418		0.000***		0.532	

Note: (***), (**), (*) denote significance at 1%, 5%, and 10% level. Standard error in parentheses.
n denotes lags of monetary shocks.

growth rate (or bear markets), whereas state 2 shows high stock growth rate (or bull markets). Our findings indicate that bear markets are associated with economic recessions or financial crises, suggesting that the stock market is closely related to the economy's business cycle.

Third, we find that Indian stock prices are immediately and negatively responsive to the current positive unanticipated monetary shocks in bull markets. More interestingly, our findings indicate that the impacts of unanticipated monetary shocks on stock prices are asymmetric on Indian stock prices across different monetary policy processes with three-month lag. That is, a tightening monetary policy with three-month lag through an increase in the Indian Central Bank's interest rate has a negative lagged effect on stock prices. In contrast, an expansionary monetary policy with three-month lag through a reduction in the Indian Central Bank's interest rate has a positive lagged effect on stock prices. More importantly, negative unanticipated monetary shocks have a larger lagged effect on stock prices than positive unanticipated monetary shocks, which is in line with the study of Cover (1992).

The results are significant for both theoretical implications and policy decision making. Regarding theory, the results provide additional evidence to support theoretical frameworks, which is key to anticipating asymmetric effects of positive and negative unanticipated monetary shocks on stock prices. With regard to policy decision making, our findings imply that monetary policymakers should have greater awareness of adverse circumstances involving the course of formulating money supply policies, especially to diminish the uncertainty levels of the money supply in adjusting stock prices. Indeed, current negative monetary shocks (i.e unexpected increases in the money supply or the Central Bank's interest rate cut) have no immediate effects on stock prices. Nonetheless, current positive monetary shocks associated with unexpected

Table A.2
Check robustness with the dynamic model for stock prices (*STOCKg*).

Variables	With three lagged shocks					
	(1)		(2)		(3)	
	State1	State 2	State1	State 2	State1	State 2
STOCKg (−1)	0.206*** [0.073]		0.270*** [0.065]		0.238*** [0.054]	
STOCKg (−2)			−0.107** [0.052]		−0.099* [0.052]	
STOCKg (−3)					0.092* [0.050]	
$\sum_{i=1}^{n} RESDN_{t-i}$	−18.871 [12.458]	13.853** [6.634]	−13.028 [6.702]	10.799** [5.228]	−2.950 [5.899]	11.235* [5.899]
$\sum_{i=1}^{n} RESDP_{t-i}$	1.042 [8.891]	−4.014 [3.524]	−12.023*** [4.353]	0.670 [3.531]	−22.373** [6.950]	2.147 [3.827]
FED	6.602** [2.729]	−3.633 [3.158]	−7.568** [3.525]	5.308** [2.062]	−11.094*** [3.109]	4.860** [2.111]
OIL	27.799*** [9.861]	14.485*** [4.694]	28.402*** [4.770]	15.646*** [4.563]	0.345 [0.842]	15.378*** [4.713]
μ	−4.025* [2.166]	3.407*** [0.831]	−1.574 [1.006]	1.708** [0.394]	0.358** [0.124]	1.531*** [0.525]
δ^2	3.791*** [0.619]	4.328*** [0.308]	1.744*** [0.394]	5.243*** [0.246]	1.991*** [0.280]	5.397*** [0.263]
ρ	0.462 [0.152]	0.273 [0.114]	0.737 [0.101]	0.051 [0.023]	0.845 [0.064]	0.038 [0.017]
Obs	290		290		290	
Log likelihood	−883.425		−877.821		−876.258	
SBIC	6.620		6.606		6.610	
Wald test $\mu_1 = \mu_2 = \delta_1^2 = \delta_2^2$	0.000***		0.000***		0.000***	
Wald test $\sum RESDN$(State 1) = $\sum RESDN$ (State 2)	0.039**		0.000***		0.000***	
Wald test $\sum RESDP$(State 1) = $\sum RESDP$ (State 2)	0.053*		0.003**		0.000***	

Note: (***), (**), (*) denote significance at 1%, 5%, and 10% level. Standard error in parentheses.

decreases in the money supply (or the Central Bank's interest rate increase) lead to reduced stock prices. Moreover, we find that uncertainty about the money supply has an asymmetrically lagged effect on stock prices. This implies that policy-makers can attend to the average growth rate of stock prices to minimize unexpected changes in their money supply policy.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

See Tables A.1 and A.2.

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