DOI: 10.1111/jmcb.13144

AEIMIT LAKDAWALA
RAJESWARI SENGUPTA

Measuring Monetary Policy Shocks in Emerging Economies: Evidence from India

In this paper, we provide a template for constructing monetary policy shocks for emerging economies. Our approach synthesizes financial data with a narrative analysis of central bank communication and related media coverage. We create a publicly available time-series database of policy dates and shocks for the Reserve Bank of India (RBI). Our shocks suggest that financial markets infer information about the future path of policy rate from RBI communication. Bond and stock markets react strongly to these monetary shocks but exhibit heterogeneity across governor regimes. Finally, we use the shocks as external instruments to identify the impact on macroeconomic variables.

JEL codes: E44, E52, E58, G10
Keywords: monetary policy, Reserve Bank of India, event study, monetary transmission, central bank communication, structural VAR

IN THE ADVANCED ECONOMIES, THERE IS a large literature that uses high-frequency financial market data around monetary policy announcements to estimate the causal effects of monetary policy (see Altavilla et al. (2019) and Swanson (2021) for prominent recent examples). However, we know little about whether this framework is appropriate for emerging economies. In this paper, using the Indian economy as a case study, we provide a road map for measuring monetary shocks in an emerging country setting. Specifically, we buttress high-frequency financial market

We are grateful for the valuable feedback of Anusha Chari, Chetan Ghate, Viral Acharya, Ravindra Dholakia, Ashima Goyal, Harsh Vardhan, Ila Patnaik, and Ajay Shah. We also thank seminar participants at the Reserve Bank of India, International Monetary Fund, Presidency University, Calcutta, Delhi School of Economics Winter School Conference 2021, the 16th and 17th Annual ISI Conferences on Economic Growth and Development, LEAP seminar, Singapore Economic Review Conference 2022, "Emerging Markets Back in the Spotlight: Risks and Policy Options Conference" in Pretoria, South Africa, IIT-Bombay and Econometric Society Conference 2022, and the 4th Annual Economics and Finance Conference at Ahmedabad University for helpful comments and suggestions. Prashant Parab and Sonali Goel provided excellent assistance with the data.

AEIMIT LAKDAWALA *is an assistant professor of economics, Wake Forest University* (*E-mail*: lakdawa@wfu.edu). RAJESWARI SENGUPTA *is an associate professor of economics, Indira Gandhi Institute of Development Research* (*E-mail*: rajeswari@igidr.ac.in).

Received December 17, 2021; and accepted in revised form October 20, 2022.

data with a narrative analysis of official central bank statements and corresponding media discussion. This narrative analysis is especially useful when financial market depth is a concern and helps identify time periods when high-frequency data might be unreliable. In the process, we create a publicly available time-series database of monetary policy dates and shocks based on announcements by the Reserve Bank of India (RBI). We then use the shocks to study the transmission of monetary policy to financial markets and macro-economic variables.

For the first part of our approach, we use data on Overnight Index Swap (OIS) rates to construct high-frequency monetary shocks around RBI announcement dates. Below, we provide a detailed discussion of how OIS rates help to overcome three limitations of the existing literature on monetary transmission in emerging economies. We find that OIS rates move markedly more on RBI announcement days and that there are two distinct dimensions of information revealed on these days. Markets revise their expectations about future policy rates in response to RBI communication in addition to (and independent of) the RBI decision to set the short-term policy rate. To capture these two separate effects, we construct "target factor" and "path factor" shocks following the work of Gürkaynak, Sack, and Swanson (2005).

The second part of our approach involves a narrative analysis where we attempt to answer the following question: How reliable are OIS rates (and thus our two factors) at capturing revisions of market expectations in response to RBI decisions? To better understand this, we examine official monetary policy statements of the RBI. We combine this with an analysis of the reaction of the Indian financial media to the announcements. Focusing on dates associated with prominent changes in our factors, we find that, overall, our factors capture surprises that are consistent with our reading of the RBI decisions, the language used in the statements, and the corresponding media discussion.

There is one clear exception to this. Around the period of the Global Financial Crisis in 2007–09, the target factor shocks (driven by the 1-month OIS rates) exhibit large movements on RBI announcement days that are difficult to square with the corresponding RBI statements or media reaction. We think one possibility that might explain this could be the presence of heightened liquidity premia in the OIS markets during the Global Financial Crisis. We make sure to check that our results on monetary transmission are not driven by this period.

Outside of this period, there are some clear instances where surprise changes (and nonchanges) of the RBI's policy rate are captured by corresponding target factor shocks. A prominent example of this is the November 2016 meeting of the Monetary Policy Committee (MPC) in the immediate aftermath of the Demonetization announcement where the government withdrew from circulation close to 85% of the currency by demonetizing currency notes of higher denominations. For the path factor, there are a handful of instances when the RBI statement gave explicit guidance about the future stance of monetary policy, for instance, the use of the phrase ".. *further hikes may not be warranted*" in the October 2011 meeting. However, most of the other monetary policy statements are not so direct about the

future policy stance. Overall, our results suggest that "forward guidance" from the RBI is not typically explicit about the future path of the policy rate as is often the case for the Federal Reserve or the European Central Bank. Instead, Indian financial markets extract information from somewhat opaque RBI communication that talks about future rates through the lens of evolving macro-economic and financial conditions.

Having constructed the monetary shocks we next study the transmission of RBI actions and communication to the financial markets and the real economy. We start with an event study response of key financial variables on RBI announcement days. We find that there is a systematic relationship of government bond yields and stock prices (but not the exchange rate) with surprise news about the policy rate. Positive (contractionary) realizations of both target and path factor shocks raise bond yields and lower stock prices but have no discernible impact on the exchange rate.

We also study the transmission of the monetary policy shocks to macro-economic variables using a structural vector autoregression (SVAR) model. We find that after a contractionary shock, prices fall, as expected, but output goes up. The counterintuitive output response is similar to results found in the existing literature on Indian monetary policy transmission (see, e.g., Mishra, Montiel, and Sengupta 2016).[1] One factor that may hamper the effectiveness of monetary transmission to the real economy in India is fiscal dominance of monetary policy, as discussed by Gupta and Sengupta (2016) and Acharya (2020).

Our paper is related to the recent work of Kamber and Mohanty (2018) who study monetary transmission in China using OIS rates. Our results suggest that using longer horizon interest rates may help understand the full effect of central bank actions in emerging economies. Our work also adds to the literature studying the monetary transmission mechanism in India, some examples being Sahoo and Bhattacharyya (2012), Das (2015), Sensarma and Bhattacharyya (2016), Montiel, Mishra, and Sengupta (2016), and Ghosh, Narayanan, and Garg (2021). The narrative analysis here is complementary to the textual analysis of RBI statements undertaken in Mathur and Sengupta (2019).

While monetary shocks and corresponding announcement dates are readily available for developed countries, this is not the case for the RBI for our full sample.[2] We hope that making our list of dates together with our measures of monetary policy shocks available publicly will aid future research on Indian monetary policy.[3]

1. In general, results on the transmission from the policy rates to output and inflation are largely ambiguous in the studies that have estimated the VAR model in the Indian context (see, e.g., Aleem 2010, Mohanty 2012, Khundrakpam and Jain 2012, Paramanik and Kamaiah 2014, among others).

2. Since the MPC regime in 2016, RBI meeting dates and accompanying statements have been released to the public on regularly scheduled dates and are available on the RBI's website. Before this, however, RBI's announcements were relatively irregular and not always announced in advance.

3. These can be accessed from authors' website at https://aeimit.weebly.com/data.htmlor https://sites.google.com/view/rasesite/public-goods/data-on-monetary-policy-shocks-in-india?authuser=0.

1. MONETARY POLICY FRAMEWORK IN INDIA

The monetary policy framework in India has evolved substantially over the last couple of decades. From the late 1990s till 2015, the RBI's monetary policy decisions were governed by a "multiple indicator approach" (MIA; Dua 2020), wherein the RBI would look at a host of macro-economic factors in order to decide monetary policy, and also use a multiplicity of policy instruments. There was also no well-defined quantitative target.

In 2016, India officially adopted inflation targeting (IT) and price stability was defined as the main objective of the RBI's monetary policy. The gradual move toward IT began the previous year when Governor Raghuram Rajan signed the Monetary Policy Framework Agreement with the Ministry of Finance, formally specifying that India would adopt IT. Under IT, RBI has to achieve a medium-term CPI (consumer price index) inflation target of 4% with a symmetric 2% band around it. The primary policy instrument is now the repo rate. A six-member MPC was set up chaired, by the RBI Governor, in order to take monetary policy decisions under this new regime.[4]

The sample period in our analysis running from September 2003 to December 2020 covers the tenures of five RBI Governors, namely, Y.V. Reddy, D. Subbarao, Raghuram Rajan, Urjit Patel, and Shaktikanta Das. The last two regimes coincide with the period of MPC/IT whereas the MIA period overlaps with the tenures of Governors Reddy and Subbarao. The tenure of Governor Rajan can be thought of as a transition phase.

During the MIA period, the RBI publicly communicated its decisions partly through official statements published on its website on the dates of monetary policy announcements, and partly through unscheduled circulars. While circulars were entirely unexpected, the release of statements was relatively more predictable and, by and large, followed specific periodic intervals for a Governor regime in the pre-IT period. In the IT regime, an annual calendar of monetary policy meetings is published on the RBI website at the start of the year. Table 1 provides a Governor-wise summary of the monetary policy statements and circulars during our sample period. Also, the monetary policy statements were usually longer and more verbose during the MIA period, compared to the tenure of Governor Rajan and the IT period (Mathur and Sengupta 2019) when the statements became shorter, and more focused on issues of price stability and growth.

2. CONSTRUCTING MONETARY SHOCKS

To identify the effect of monetary policy, one cannot directly use changes in the monetary policy instrument (e.g., the short-term interest rate). The endogenous

4. The MPC consisting of three external members and three members from the RBI, including the Governor, held its first meeting in October, 2016.

TABLE 1

MONETARY POLICY COMMUNICATION INSTRUMENTS OF THE RBI, 2003–PRESENT (SEPTEMBER 2022)

Governor	Term	Instruments of communication	Statement intervals
Dr. Y.V. Reddy	November 3, 2003 to September 5, 2008	Statements (16); Circulars (7); Press releases (5)	3, 4, 6 months
Dr. D. Subbarao	September 5, 2008 to June 17, 2013	Statements (20); Circulars (13)	3 months
		Midquarter reviews/Press releases (12)	
Dr. Raghuram Rajan	September 4, 2013 to September 4, 2016	Statements (19); Circulars (1)	2, 3 months
		Midquarter reviews/Press releases (2)	
Dr. Urjit Patel (MPC)	September 4, 2016 to December 5, 2018	Statements (14)	2 months
Shaktikanta Das (MPC)	February 7, 2019 to Present	Statements (22); Circulars (1)	2 months

NOTE: The tenure of Governor Reddy began from September 2003 but we report here from November 2003 onward as that is the start date of our sample period. The tenures of Governors Urjit Patel and Shaktikanta Das overlap with the period of formal inflation targeting. The current Governor Shaktikanta Das has till date (till September 2022) presided over 22 monetary policy statements of the Monetary Policy Committee (MPC).

reaction of the central bank's policy instrument to economic conditions leads to the classic simultaneous equation bias. This problem can be overcome by isolating exogenous variation in the policy instrument. There is a large literature that uses high-frequency changes in derivatives (most commonly interest rate futures) to measure monetary policy shocks (see Kuttner 2001, for an early example). However, interest rate futures are not actively traded in the Indian financial markets. In this section, we provide details on how rates on OIS can be used to capture monetary policy surprises and document their transmission in Section 4. In Section 4, we also show that monetary transmission is broadly similar if we instead use T-bill rates (3-month and 1-year) to construct monetary shocks.

OIS contracts are derivatives in which parties exchange fixed and floating interest rate payments. The floating rate payments are typically tied to the overnight interbank rate which is a good proxy for the central bank's monetary policy instrument. For India, the Mumbai Interbank Offer Rate (MIBOR) is the relevant floating rate for the OIS rates that we study.

Lloyd (2021) shows that OIS rates accurately measure interest rate expectations for various countries. Moreover, he argues that OIS rates are likely to have relatively low counterparty risk and liquidity premia. In recent work, OIS rates have been used to study monetary shocks of the ECB (Altavilla et al. 2019) and China (Kamber and Mohanty 2018). In the Indian context, a recent report by the RBI (Rituraj and Kumar 2021) shows that OIS rates are indeed a reliable way to measure the market's expectation about the future path of the repo rate.

While the repo rate is now the primary policy tool, the RBI has relied on a combination of a few different policy tools in the past. During our sample from 2003 to 2020, the prominent other ones are the cash reserve ratio (CRR), the reverse repo rate,

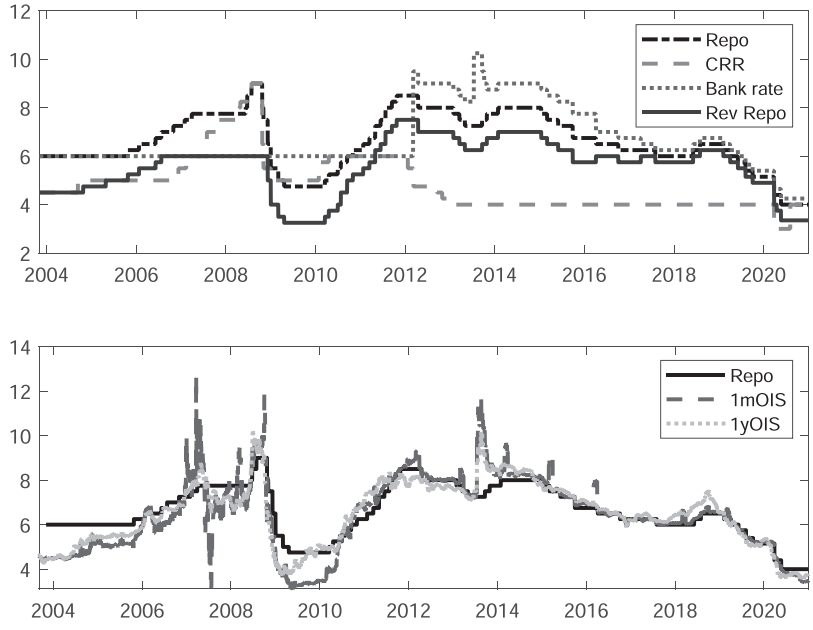

Fig 1. Policy Tools of the RBI and OIS Rates.

NOTES: The top panel shows the different interest rates used by the Reserve Bank of India, namely, repo rate, cash reserve ratio, bank rate, and reverse repo rate. The bottom panel shows the repo rate together with the 1-month and 1-year OIS rates.

and the bank rate.[5] In Figure 1, the top panel plots the four monetary policy tools. The repo and reverse repo rate were changed by the RBI throughout the sample, but this is not true of the other rates.[6] The bank rate is kept fixed at 6% from the beginning of our sample in 2003–12, while the CRR is kept fixed at 4% from early 2013 up until the start of the pandemic in 2020. Overall, when multiple policy tools are changed at the same time, they are typically done in the same direction.

The bottom panel of Figure 1 plots the repo rate together with the 1-month and 1-year OIS rates. We omit the other OIS rates here to make the graph readable. This figure shows that OIS rates are a reasonable proxy for capturing the general trend

5. CRR is the minimum cash balance that a scheduled commercial bank is required to maintain with the RBI as a certain percentage of its net demand and time liabilities (NDTL). Bank rate is the rate at which the RBI is ready to buy or rediscount bills of exchange or other commercial papers. It acts as the penal rate charged on banks for shortfalls in meeting their reserve requirements (CRR and statutory liquidity ratio). In 2011, RBI instituted the marginal standing facility (MSF). The MSF rate, which has so far been changed only on a handful of occasions is the interest rate at which the RBI provides money to those commercial banks who are facing acute shortage of liquidity.

6. The repo rate is the rate at which the RBI provides overnight liquidity to the banks against the collateral of government securities, whereas the reverse repo rate is the interest rate at which the RBI absorbs liquidity, on an overnight basis, from banks against the collateral of eligible government securities.

in movement of the policy interest rates in India. In this paper, we are interested in estimating the causal impact of RBI's monetary policy actions and thus we focus our analysis on RBI announcement days. The RBI announcement dates in our sample correspond to dates when information was revealed about changes (or nonchanges) in the repo rate, the reverse repo rate, the bank rate, and the CRR. These announcements were made using either statements or circulars or press releases.

We analyze a total of 115 RBI announcement dates, excluding a total of five RBI announcements. We drop four circulars in October 2008 which were right after the bankruptcy of Lehman Brothers and related financial turmoil (Oct-6, Oct-10, Oct-15, and Oct-20). We also drop the May-18, 2004 meeting that is right after the announcement of the Union government election results. These announcement dates do not include dates when the RBI released information about its open market operations (OMO). The purpose of these purchase or sale operations is primarily to stabilize the liquidity in the market and hence, these announcements are unrelated to information about the future path of the policy rate. We leave the analysis of these OMO dates for future research.

We use the daily change in OIS rates on these RBI announcement days to construct our measure of monetary policy shocks. One approach to characterize monetary policy shocks is to use the change in the shortest maturity rates to capture unexpected changes (or nonchanges) to the policy rate target. For example, Bernanke and Kuttner (2005) do this for U.S. data using the current month's fed funds futures rate. Das, Surti, and Tomar (2020) and Mathur and Sengupta (2019) use the 1-month OIS rate to calculate monetary surprises for India. However, this approach ignores any information revealed by the central bank about the future path of the policy rate. Based on this idea, there is a large body of literature that uses longer maturity futures and OIS rates to capture forward guidance (see Gürkaynak, Sack, and Swanson 2005, for an early influential paper).

Do higher maturity interest rates respond to information in RBI announcements over and above surprise changes in the policy rate target? We show in the next subsection that the answer is an emphatic yes. Before proceeding to this, we would like to emphasize the importance of using OIS rates to isolate the unexpected component of policy rate changes. For the handful of studies that use high-frequency data to estimate monetary policy transmission in India, the focus has typically been on analyzing responses to changes in the policy repo rate, without effectively accounting for the monetary policy surprises.

2.1 OIS Rate Changes on RBI Announcement Days

To capture surprises to the policy rate target and any surprises to the expected path of the policy rate, we analyze change in OIS rates of various maturities on RBI announcement days. We focus on five OIS rates of maturities 1,3,6,9-month and 1-year.[7]

7. The data sources for all the variables used in our analysis have been outlined in Table A.1.

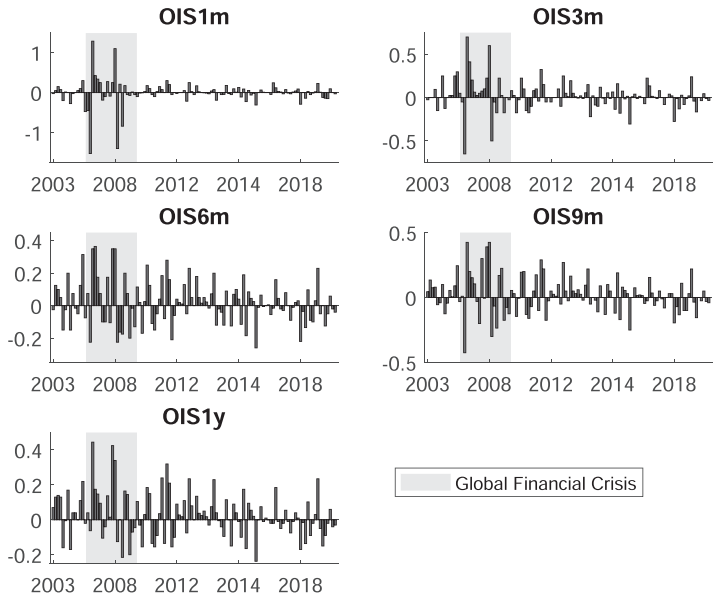

Fig 2. Change in OIS Rates on RBI Announcement Days.

NOTES: The figure shows the 1-day change in various OIS rates of different maturities on RBI announcement days.

TABLE 2

SUMMARY STATISTICS OF OIS RATE CHANGES

	RBI statement days			All other days		
	Mean	Std-dev	Obs	Mean	Std-dev	Obs
OIS 1m	−0.001	0.298	115	0.000	0.163	4399
OIS 3m	0.019	0.167	115	0.000	0.095	4399
OIS 6m	0.017	0.134	115	0.000	0.075	4399
OIS 9m	0.019	0.140	115	0.000	0.073	4399
OIS 1y	0.025	0.128	115	−0.001	0.056	4399

NOTE: Summary statistics for daily change in OIS rates on RBI announcement days and all other days. The sample runs from September 2003 to December 2020.

We start by plotting the change in each of the five OIS rates on RBI announcement days in Figure 2. The gray shaded region shows the period from January 2007 to December 2009 reflecting the Global Financial Crisis and the figure shows that OIS rate changes are clearly more volatile in this period, especially for shorter maturities. In Sections 3 and 4, we discuss this period in more detail and show that our main results are robust to excluding these dates, but for now they are included in our sample.

The top panel of Table 2 shows summary statistics of daily change in OIS rates for RBI announcement days and all other days. OIS rates of all maturities move

substantially more (roughly twice as much) on RBI announcement days, as can be seen from the standard deviations. This is reassuring and is a first indication that OIS markets are indeed reacting to the information revealed by the RBI. In Appendix Table OA.1, we show summary statistics for OIS rate changes broken down by individual governor regimes. The table confirms that the pattern of OIS rates moving more on RBI announcement days is pervasive and occurs for all governors in our sample.

Appendix Table OA.1 also helps understand if there have been changes in the size of the shocks over time, perhaps due to greater transparency or change in the monetary policy operating regime with the shift to MPC and IT. The top panel of the table shows the change in the 1-month and 1-year OIS rates by governor regimes. The standard deviation decreases with each successive governor regime from Reddy to MPC, suggesting that the size of surprises has gone down over time. However, there are two issues that complicate this interpretation.

First, the level of the interest rate has changed substantially over the sample period and has been on a downward path since 2012. Higher level of the interest rate will mechanically lead to larger surprises in the OIS rates. To account for this, we calculate the percent change in daily OIS rates rather than just the change.

Second, as we discuss in Section 3 the Global Financial Crisis was a period with large shocks to the OIS rates. To account for this, we drop the period from January 2007 to December 2009. These results presented in the online appendix show that there is no longer any evidence of decline in size of shocks over time. The standard deviation is lowest under Governor Rajan but not substantially lower. Interestingly, since the official implementation of IT lines up with the start of the MPC regime, the table also shows that there is no evidence of IT changing the size of monetary surprises. This is true even if we start the IT regime in early 2015 under Governor Rajan when it was first announced.

Based on these results, we think it is more helpful to think about regime shifts of RBI policy in terms of changes in governor regimes rather than pre-IT versus post-IT regimes.

2.2 Factor Analysis of OIS Rate Changes

Surprise news about the repo rate (and the other short-term rate policy instrument used by the RBI) is directly reflected in higher volatility of the short end of the OIS rate curve on RBI announcement days. These surprises should also result in higher volatility in medium-term OIS rates, based on the term structure relationship. This can be seen from the substantial amount of correlation across the maturities in the changes in OIS rates on RBI announcement days. For example, the correlation of the change in the 1-month OIS with the change in 3-month OIS is 0.85 and with the change in 1-year OIS rate is 0.61.

A natural question is how much independent variation is there in medium-term OIS rates relative to shorter ones. In other words, is there some form of "forward guidance" or "news" revealed by the RBI about future policy rates that moves medium-term rates independently of short-end rates? To tackle this question, we conduct a factor

TABLE 3

SHARE OF VARIANCE OF OIS RATE CHANGES EXPLAINED BY PRINCIPAL COMPONENTS

First PC	85.1
Second PC	11.7
Third PC	1.9
Fourth PC	0.7
Fifth PC	0.6

NOTE: The table shows the share of variance explained of changes in the five OIS rates (1,3,6,9-month and 1-year) on RBI announcement days by the principal components. The sample has 107 observations from September 2003 to December 2020.

TABLE 4

SHARE OF VARIANCE OF INDIVIDUAL OIS RATE CHANGES EXPLAINED BY TARGET AND PATH FACTOR

OIS rates	Target factor	Path factor	Unexplained
1-month	0.976	0.000	0.024
3-month	0.817	0.112	0.071
6-month	0.456	0.499	0.045
9-month	0.573	0.378	0.049
1-year	0.366	0.594	0.040

NOTE: The table shows the share of variance explained of changes in individual OIS rates on RBI announcement days by the target and path factor. The sample has 107 observations from September 2003 to December 2020.

analysis. Specifically, we use five OIS rates: 1,3,6,9-month and 1-year and perform a principal component analysis of these OIS rate changes

Table 3 shows that the first principal component explains 85% and the second one explains 12% more of the variation in the five OIS rate changes. Together, the first two principal components explain almost 97% of the variation and suggest that there are two "dimensions" of variation in the OIS rate changes on RBI announcement days. In other words, the first two principal components capture most of the information being revealed by the RBI on announcement days. But these principal components are both correlated with short and long end of the OIS rate curve and thus prevent us from attaching any economic meaning. To provide a structural interpretation, we follow the approach of Gürkaynak, Sack, and Swanson (2005) and transform these two principal components into the so-called "target" and "path" factors.

The target factor is intended to capture surprise changes to the central bank's short-term policy rate target. The path factor is intended to capture surprise changes to forward guidance, or any surprise news that makes markets change their expected path for future policy rates. These two factors are constructed to be orthogonal to one another, just like the principal components. This means that the path factor captures news about future rates that is uncorrelated to surprise changes to the contemporaneous policy target rate. This is performed using a factor rotating methodology and in Appendix B we provide details on how these are computed.

Table 4 shows the share of the variance of each individual OIS rate change that is explained by the target and path factors. The target factor explains 98% of variance

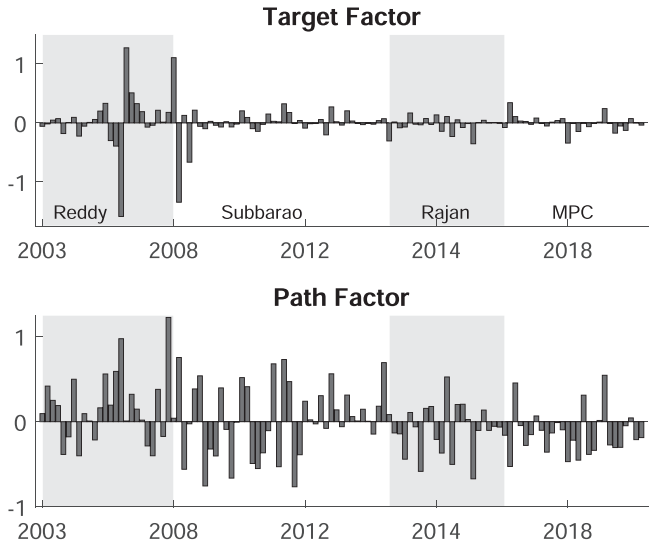

Fig 3. Target and Path Factors.

NOTES: The figure shows the target and path factors constructed from 1-day change in various OIS rates of different maturities on RBI announcement days. See Section 3.2 for details.

in the 1-month OIS rate while the path factor explains 0% (by construction). As the maturity increases notice that the target factor explains less and the path factor explains more of the variation. For the 1-year OIS rate, the path factor explains about two-thirds while the target only explains a third. The important implication is that RBI announcements are moving medium-term rates independent of their effect on short rates.

To provide even more intuition about the target and path factors, in Figure A.1 we show scatter plots that makes the following relationship clear: the target factor is highly correlated (0.98) with the changes in the 1-month OIS rate. The path factor is highly correlated (0.97) with the residual from regressing the 1-year OIS rate on the 1-month OIS rate.

In Figure 3, we plot the target and path factors, with shadings to demarcate the governor regimes. We normalize the factors in the following way. The target factor is scaled to have a unit effect on the 1-month OIS rate. The path factor is scaled to have the same effect that the target factor does on the 1-year OIS rate. The target factor has large positive and negative realizations during the regimes of Governors Reddy and Subbarao coinciding with the Global Financial Crisis, followed by much smaller realizations for the rest of the sample. The path factor on the other hand shows uniformity in the size of the realizations across most of the sample with just slightly elevated values around the Global Financial Crisis. In the next subsection, we provide an attempt at interpreting the big realizations of the two shocks by conducting

a narrative analysis where we bring in evidence from RBI statements and the related media discussion.

An alternative to the two-factor approach taken here is to use just the first principal component, as done recently in Nakamura and Steinsson (2018). The correlation between the first principal component and the target factor is greater than 0.9, while correlation with the path factor is only around 0.3. Thus, in terms of the Indian financial market response, the first principal component approach would be more akin to just using the target factor. Relatedly, in Section 4, we discuss that there are two main issues why our two-factor approach is preferable. First, using only one factor means losing out on substantial explanatory power in the high-frequency response of asset prices, especially bond yields. Second, it leads to a weak instrument problem in a proxy SVAR framework and makes the one-factor approach unsuitable for studying the impact on macro-economic variables as well. In the event that some researchers want to use a single variable to capture monetary shocks for India, we have made this series of the first principal component publicly available.[8]

Is there any evidence of asymmetry in the measure of monetary shocks? The principal component analysis that we perform normalizes the two shocks to have mean zero and thus makes it difficult to answer that question. But we can look at the raw OIS rate changes to get an idea. In the online appendix, we investigate the number of "expansionary" and number of "contractionary" RBI announcements based on whether the sign of the change is negative or positive and do not find much evidence of asymmetry.

However, there seems to be more asymmetry when we look within governor regimes. For Governors Reddy and Subbarao, there are notably more contractionary surprises (relative to expansionary) but under the MPC, there are more expansionary surprises. In Section 4, we explore if the transmission to financial markets depends on whether there is an expansionary or contractionary surprise.

In the next section, we conduct a narrative analysis where we examine the RBI meeting dates with the biggest changes in the target and path factors and try to relate the language in the statement released by the RBI and related media discussion to the estimated target and path factors.

3. NARRATIVE ANALYSIS

Our approach in this paper relies on using OIS rates to capture how the markets interpret the RBI's decisions about the policy rate target and any signals about the path of the future policy rate. A narrative analysis serves as an external validation exercise for our approach and also helps shed light on the nature of the communication used by the RBI. Specifically, we read through the official RBI statements

8. See link: https://aeimit.weebly.com/data.html.

and the corresponding discussion of the RBI announcement in *The Economic Times* newspaper, a leading English financial daily considered to be a trusted source for economic and financial news in India. Our analysis reveals that typically there is a clear and intuitive link between the target/path factor shocks and RBI decisions, communication, and related media coverage.

However, there is one stark exception to this rule. Target factor shocks around the Global Financial Crisis imply market surprises that are too large to be reconciled with RBI actions or description of market's reaction in the media.[9] Thus, for our main narrative analysis in this section we ignore the period from January 2007 to December 2009. We focus on the top two realizations of the target and path factor for each governor regime and list these dates in Tables 5 and 6 together with a description of the key takeaway for that date from our analysis.

For the discussion of the top target factor dates (shown in Table 5), we rely more on media commentary to interpret the shocks associated with the policy rate changes because what matters here is what the RBI *did* instead of what the RBI *said*. Other than the period noted above, we find that when the newspaper articles highlight a surprise change (or nonchange) by the RBI, it aligns well with the direction and size of the surprise as measured by the target factor shock.

A noteworthy date is December 7, 2016, the largest target factor of the IT regime. This meeting came right after the Demonetization announcement of November 8, 2016 when more than 85% of currency was withdrawn from circulation by the Indian government. The markets were almost certain that the RBI would cut rates but the MPC kept rates unchanged citing inflationary pressures. This took the markets by surprise and is reflected in a contractionary monetary policy shock with a large positive realization of the target factor.

To help us understand how the market reacts to the communication from the RBI, we look at the notable path factor dates. In some of these instances, the media reaction seems focused on a particular phrase in the RBI statement in order to gauge the future direction of monetary policy. As shown in Table 6, one such instance is the October 25, 2011 statement under Governor Subbarao's tenure. The repo rate was raised by 25 basis points. Consistent with the media discussion, this move was entirely expected and we get a target factor of essentially zero. However, the statement discussed a downward revision of future inflation and had the sentence … if the inflation trajectory conforms to projections, further rate hikes may not be warranted (RBI monetary policy statement, October 25, 2011). The media articles all prominently mention this particular phrase when reporting the dovish stance of the RBI. The substantially negative path factor captures this expansionary shock, and indeed it is the largest in magnitude in our entire sample.

9. In Table A.2, we list some of the dates from the Global Financial Crisis period when the target factor realizations were excessively high, reflecting the high volatility in the underlying OIS rates during this period. For example, on March 30, 2007, RBI raised the repo rate by 25 basis points whereas the target factor is valued −1.59, suggesting that markets expected the RBI to raise the policy rate by almost 2%. Expectations for such a massive increase in policy rates would have surely been discussed in the financial media, but we find no such mention.

TABLE 5

Top Target Factors: A Narrative Analysis

Date	Regime	Target factor	Path factor	Description
Dec. 11, 2006	Reddy	0.33	0.56	Repo rate unchanged at 7.25%, CRR increased from 5% to 5.5% with an unscheduled circular. Market was not expecting CRR change: "In a surprise move, RBI announced a hike in the Cash Reserve Ratio" (ET, *Call rates likely to hold firm, 11 Dec, 2006*).
Apr. 18, 2006	Reddy	−0.22	−0.40	Repo rate unchanged at 6.5%. Market was expecting RBI to raise rates: "And a large section of the market thinks that given a choice, he will go ahead with rate hikes" (ET, *Reddy unlikely to go soft on interest rates, 17 Apr, 2006*).
Jul. 26, 2011	Subbarao	0.32	0.73	Repo rate increased from 7.5% to 8%, more than market expectation: "All 15 market participants polled by ET over the weekend were unanimous the central bank would raise repo rate by 25 basis points" (ET, *RBI set to raise key rates by 25 basis points today, 26 Jul, 2011*).
Jun. 18, 2012	Subbarao	0.27	0.56	Repo rate unchanged at 8%, market expected a decrease: "Markets expected the RBI to cut rates to boost growth…" (ET, *Banks to underperform markets in short term on RBI move, 19 Jun, 2012*).
Sept. 29, 2015	Rajan	−0.35	−0.67	Repo rate lowered from 7.25% to 6.75%. Media report: "The 50 basis point cut in the repo rate was higher than the market expectation of 25 basis points…" (ET, *Analysts, economists react with surprise, elation, 30 Sep, 2015*).
Sept. 20, 2013	Rajan	−0.31	0.08	Repo rate raised from 7.25% to 7.5% but marginal standing facility (MSF) rate lowered to 9.5% from 10.25%. Market were conflicted, with some expecting lower MSF but no change in repo (ET, *RBI governor Raghuram Rajan may keep interest rates intact, 20 Sep, 2013*).
Dec. 7, 2016	MPC	0.34	−0.53	Repo rate unchanged at 6.25%, surprising markets: "The RBI decision shocked the market as everybody thought a 25 basis point rate cut was a certainty" (ET, *RBI keeps rates unchanged, projects momentum loss for economy, 8 Dec, 2016*).
Oct. 5, 2018	MPC	−0.34	−0.47	Repo rate unchanged at 6.5%. Media report: "Last week, an ET survey conducted among 25 participants predicted a quarter percentage points rate increase…" (ET, *Bond market cheers RBI decision, rupee slides, 6 Oct, 2018*).

Note: The table shows the top two target factors from each of the three RBI Governor regimes during the MIA phase, and also from the Inflation Targeting regime during which monetary policy decisions are taken by a six-member MPC.

Another example of the market reacting to what the RBI said in its statement is June 3, 2014, the second highest path factor realization during Governor Rajan's tenure. RBI left the repo rate unchanged at 8% and the monetary policy statement mentioned: If the economy stays on this course, further policy tightening will not be warranted. On the other hand, if disinflation, adjusting for base effects, is faster than currently anticipated, it will provide headroom for an easing of the policy stance (RBI monetary policy statement, June 3, 2014). The large negative realization of the path factor implies that the markets expected that because the policy rate had been left unchanged in this meeting, the RBI would lower the repo rate by even more in the next year compared to what the markets had anticipated prior to the meeting. Indeed, the RBI brought the repo rate down from 8% to 7.75% at its January 15, 2015 meeting.

TABLE 6

Top Path Factors: A Narrative Analysis

Date	Regime	Target factor	Path factor	Description
Dec. 11, 2006	Reddy	0.33	0.56	Repo rate unchanged at 7.25%, CRR increased from 5% to 5.5% with an unscheduled circular. The RBI had tightened monetary policy in the previous two announcements. With RBI holding the repo rate constant in this particular circular, markets responded to announcement by expecting a rate hike soon. Indeed, on January 31, 2007 RBI raised the repo rate from 7.25% to 7.5%.
Jan. 24, 2006	Reddy	0.09	0.50	Repo rate increased from 6.25% to 6.5%. RBI statement: "Indications of pick up in aggregate demand are getting stronger…It is important to respond in a timely and even pre-emptive manner to these developments to ensure that generalised inflation spirals do not develop…" Market reaction focused on stronger economy (ET, *Reddy gets bullish, revises GDP to 7.5-8% Jan 25, 2006*).
Oct. 25, 2011	Subbarao	−0.01	−0.76	Repo rate raised from 8.25% to 8.5% but the RBI said in its statement:"..inflation rate will decline significantly in December and continue on that trajectory…" and "… if the inflation trajectory conforms to projections, further rate hikes may not be warranted." Media focused on revised inflation outlook and especially the phrase "further rate hikes may not be warranted" (ET, *RBI hikes rates again, may take a break now, 26 Oct, 2011*).
Jul. 26, 2011	Subbarao	0.32	0.73	Repo rate increased from 7.5% to 8%. RBI said in its statement: "Considering the overall growth and inflation scenario, there is a need to persevere with the anti-inflationary stance." Media reaction focused on hawkish tone (ET, *RBI raises key policy rates by 50 bps; loans to get costlier, 27 July, 2011*).
Sept. 29, 2015	Rajan	−0.35	−0.67	Repo rate lowered from 7.25% to 6.75%. With inflation in check, media discussion focused on concerns about lower growth: "RBI sees underlying growth trends as subdued enough to require more aggressive stimulus" (ET, *Analysts, economists react with surprise, elation, 30 Sep, 2015*).
Jun. 3, 2014	Rajan	−0.03	−0.58	Repo rate unchanged at 8%. RBI statement gave dovish outlook: "If the economy stays on this course, further policy tightening will not be warranted. On the other hand, if disinflation, adjusting for base effects, is faster than currently anticipated, it will provide headroom for an easing of the policy stance."
Dec. 5, 2019	MPC	0.24	0.55	Repo rate unchanged at 5.15%. Media latched onto inflation focus of RBI "… inflation control is the prime objective of money policy" (ET, *Shocking' pause? No, RBI is just awaiting signals from FM's Budget, 6 Dec, 2019*).
Dec. 7, 2016	MPC	0.34	−0.53	Repo rate unchanged at 6.25%. Markets were surprised by no change but media discussion also focused on downward revision of growth forecasts. From RBI statement: "The outlook for GVA growth for 2016-17 has turned uncertain after the unexpected loss of momentum by 50 basis points in Q2" (ET, *RBI keeps rates unchanged, projects momentum loss for economy, 8 Dec, 2016*).

Note: The table shows the top two path factors from each of the three RBI Governor regimes during the MIA phase, and also from the Inflation Targeting regime during which monetary policy decisions are taken by a six-member MPC.

However, most of the other monetary policy statements are not so direct about the future policy stance. Our narrative analysis shows that once we exclude the volatile crisis period, there are clear instances where surprise movements in the policy rate got captured by our estimated target factors. For the path factor while there are a few instances when the RBI's monetary policy statements contained explicit forward guidance about the future path of interest rates, by and large, the markets *deciphered* information from the RBI's communication about the future macro-economic outlook.

4. TRANSMISSION OF MONETARY SHOCKS

In this section, we explore the transmission of the two kinds of monetary policy shocks to the economy. First, in Section 4.1 we document the high-frequency response of financial market prices to the two monetary shocks as captured by the target and path factors. Next, in Section 4.2 we study the response of output and inflation with a monthly SVAR using the monetary shocks as instruments for identification.

4.1 High-Frequency Transmission to Financial Markets

We study the response of government bond yields, stock returns, and currency returns to the target and path factors using an event study approach. We focus on a daily window around RBI announcements. The regression takes the following form:

$$\Delta s_t = \alpha + \beta_1 target_t + \beta_2 path_t + \varepsilon_t, \tag{1}$$

where Δs_t is the change/return in the asset price measured based on closing price on day of RBI announcement relative to the previous trading day's closing price. We use data on the 5- and 10-year government bond yields, the returns on the benchmark Nifty 50 index listed on the National Stock Exchange (NSE) and the returns on the INR\USD exchange rate. The bond yield, the stock market, and exchange rate data are from Reuters Datastream and the OIS data are from Blooomberg.

The sample has 115 observations from September 2003 to December 2020.[10] For each asset price, we report two columns. In the first column, we run the regression excluding the path factor (i.e., setting β_2 to zero). In the second column, we add the path factor to the regression. This exercise will allow us to easily see the contribution of each type of monetary shock in explaining the variation in the asset price change. Since the two factors are orthogonal by construction, coefficients from including both factors in the regression will be exactly the same as putting one factor individually in the regression.[11] Moreover, while the contribution of target factor to the R^2 is

10. The exchange rate regression has only 111 observations.

11. This can be seen by noticing that the coefficient on the target factor does not change across the two columns. Also we do not present results for regressions with only the path factor for space considerations.

TABLE 7

RESPONSE OF ASSET PRICES TO MONETARY SHOCKS

	5y-yield		10y-yield		Nifty		INR/USD	
Target factor	0.15***	0.15***	0.07*	0.07***	−3.28**	−3.28**	0.24	0.24
	[2.98]	[5.60]	[1.70]	[3.13]	[−2.05]	[−2.11]	[1.03]	[1.04]
Path factor		0.19***		0.19***		−1.53**		−0.02
		[10.63]		[11.12]		[−2.14]		[−0.11]
Constant	0.00	0.00	0.01	0.01	−0.29	−0.29	−0.04	−0.04
	[0.08]	[0.10]	[1.16]	[1.60]	[−1.23]	[−1.27]	[−0.85]	[−0.85]
Obs.	115	115	115	115	115	115	111	111
R^2	0.15	0.53	0.03	0.49	0.13	0.17	0.02	0.02

NOTE: The table shows RBI announcement day regressions of government bond yields (5- and 10-year), Nifty 50 return, and INR-USD exchange rate on target and path factors. For each asset price, the first column shows a regression with just a constant and the target factor. The second column adds the path factor. The sample has 115 observations (111 for the exchange rate) from September 2003 to December 2020. *t*-Statistics based on White heteroskedasticity-robust standard errors are reported in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

apparent in the first column, the contribution of the path factor to the R^2 is the difference between the R^2 of the two columns.

Recall that the target factor is scaled to have a unit effect on the 1-month OIS rate and the path factor is scaled to have the same effect that the target factor has on the 1-year OIS rate. For ease of interpretation in the online appendix, we regress the five OIS rates on the target and path factors and show that the coefficient of both the target factor and path factor in the 1-year OIS rate regression is 0.26. In other words, a 100-basis-point increase in the target and path factors corresponds to a 26-basis-point increase in the 1-year OIS rate. Table 7 reports the results from estimation of equation (1) with *t*-statistics in parentheses that are calculated using White heteroskedasticity-robust standard errors.

The target and path factors both have a statistically significant and positive effect on 5- and 10-year government bond yields. The path factor has a bigger effect on the 10-year yield relative to the target factor: the coefficient is more than twice as large. A path factor shock that increases the 1-year OIS by 26 basis points leads to a 19-basis-point increase in the 10-year government bond yield, but there is only a 7-basis-point increase in response to a target factor shock. Thus, long-term bond yields respond substantially more to information revealed in RBI statements about the future path of monetary policy rather than to surprise changes in the short-term policy rates. The R^2 from the two columns corroborates that the path factor contributes substantially more in explaining movements in the bond yields. Adding the path factor increases the R^2 from 0.03 to 0.49 for the 10-year yield.

As an alternative to using OIS rates, we also construct monetary shocks using data on Indian government T-bills. Due to the limited data availability of Indian government T-bills, we measure the alternate target factor as the change in the 3-month T-bill rate and the path factor as the residual from regressing the 1-year T-bill rate on the 3-month T-bill rate. Table A.3 shows the transmission to stock, bond, and foreign

exchange markets using these alternative measures. It is apparent that the results are very similar to our baseline results in Table 7.

There is significant heterogeneity in the bond market response across governor regimes. In Table A.4, we show the bond market response separately by governor regimes, grouping Urjit Patel and Shaktikanta Das into the "MPC" regime.[12] Under Governors Reddy and Subbarao, the bond yield response to both target and path factors is similar to the full-sample response reported in Table 7. However, under Governor Rajan and the MPC, the responses are drastically different from the full sample and from each other. Under Governor Rajan, the target factor has no effect (i.e., small and statistically insignificant effect) and explains essentially 0% of the variation in the 10-year yield. But the 10-year yield response to the path factor is substantially larger (five times as much relative to the overall sample effect) and explains all of the 0.62 R^2.

Notably, this pattern completely reverses under the MPC regime. The 10-year yield response to the target factor is 10 times larger than the overall sample effect and the path factor becomes insignificant. These results suggest that bond markets were only paying attention to RBI statements and communication under the Rajan regime, and were not reacting to surprise changes in the repo rate. However, under the MPC the bond market stopped responding completely to information revealed in the statement, instead responding to only surprise changes (and nonchanges) in the repo rate.

Both target and path factors also cause a statistically significant impact on the stock market in the full sample. Unlike the bond market, the stock market responds more to the target factor than to the path factor in the overall sample. Stock prices fall by 3.3% in response to a target factor shock but only by 1.5% in response to a path factor shock.[13] The bulk of the explanatory power is attributed to target factor (0.13 from target factor and only 0.04 from path factor).

One reason for the lower responsiveness of stock prices to the path factor could be related to the so-called "information effect." The idea is that monetary announcements convey information about the current and future stance of monetary policy but also about the central bank's internal macro-economic forecasts. This revelation of information about macro fundamentals comes from specific language used in the statement and thus is more likely to be captured by the path factor and not the target factor.[14] For stock prices, the information effect works in the opposite direction of a

12. We club together the last two governors into an MPC regime due to the relatively fewer observations available in each governor's regime. There are potentially important differences in implementation of monetary policy across the two regimes, for example, the narrowing of the corridor between the repo and reverse repo rate under Urijit Patel and the growing use of the reverse repo rate as the effective reference rate in the Shaktikanta Das regime.

13. The size of the effect is roughly similar to the response of Indian stock prices to U.S. monetary policy shocks (see, e.g., Lakdawala 2021).

14. For a detailed discussion of how forward guidance by the central bank can have information effects, see Campbell et al. (2012). For an example of recent work on the relationship between stock prices and central bank information effects, see Lakdawala and Schaffer (2019).

conventional monetary shock. For example, if the RBI signals that they are going to raise rates because the economy is growing faster than the markets had been expecting, then the news of higher rates would lower stock prices through higher discount rates. But the news about higher growth would raise stock prices due to higher expected cash flow. Note that the information effect works in the same direction as the conventional monetary shock effect for bond yields.

There is again substantial variation in stock response across governors regimes with shifting importance of target and path factors, there results are presented in Table A.5. Under Governors Reddy and Rajan, the stock market responds primarily to the path factor but under Subbarao the target factor is the bigger driving force. Under MPC, the stock market does not respond significantly to either target or path factor and the R^2 from the regression is essentially zero. The information effect is a potential candidate for explaining the heterogenous response across governors. In this paper, we do not directly investigate the role of the information effect in driving the financial market's response to RBI announcements but it appears to be a promising area for future research.

The foreign exchange market does not react systematically to either target or path factor in the overall sample. The exchange rate is defined as Indian rupees per U.S. dollar, so an increase represents a depreciation of the Indian rupee. The coefficients imply a depreciation in response to the target factor but an appreciation in response to the path factor, but neither effect is statistically significant. One potential reason for this might be that the RBI actively intervenes in the foreign exchange market on a regular basis to stabilize the exchange rate, as documented in Patnaik and Sengupta (2021). As a result, it may be difficult to capture the response of the exchange rate to monetary policy announcements.

As discussed in Section 2, the changes in OIS rates around the Global Financial Crisis of 2007–09 appear to be less reliable than the rest of the sample. In the online appendix, we confirm that the results are similar to the baseline case if we drop all RBI dates from January 2007 to December 2009. For our baseline regressions, asset price responses are measured with a daily window around RBI announcements. One concern with this approach is that the financial markets may not be getting enough time to digest all the information revealed in the RBI announcement, especially the ones that come later in the day. In the online appendix, we show that our results are very similar using a 2-day window.

An alternative to the two-factor approach taken here is to just use the first principal component (a more parsimonious way to capture monetary policy shocks). To compare this with our approach, in the online appendix we regress the asset price changes/returns on the first principal component of OIS rate changes. The qualitative pattern of the effect on asset prices is similar but we find that the first principal component explains far less of the variation in asset prices. For example, the 10-year yield regression R^2 is 0.49 with two factors but only 0.14 with one. Thus, we think it is important to use two factors to better characterize the full effect of RBI actions and communication on financial markets.

Finally, we explore any potential asymmetric effects of the monetary policy shocks. We categorize RBI announcement dates as "expansionary" or "contractionary" based on the sign of the change in the 1-year OIS rate. We separately run the event study regression of equation (1) for these two sets of dates. We exclude the dates that resulted in no change in the 1-year OIS rate and report the results in the online appendix. For bond yields, there is no evidence of asymmetric effects but there is some suggestive evidence that stock market responds more to contractionary shocks.

Overall, we find strong high-frequency evidence that the financial markets are responding systematically to the information revealed by the RBI on announcement days as captured through our monetary shocks. In the next section, we explore the lower frequency response of macro variables to the monetary shocks.

4.2 Transmission to Real Economy

We use an SVAR to estimate the dynamic impact of monetary policy on output and inflation. The monetary shocks are used as external instruments (or proxies) to identify the causal effect of RBI's actions.

Consider the SVAR where y_t is an $n \times 1$ vector of macro-economic variables and α_i are $n \times n$ parameter matrices

$$Ay_t = \alpha_1 y_{t-1} + \ldots + \alpha_p y_{t-p} + \varepsilon_t. \tag{2}$$

The components of the error terms ε_t are assumed to be uncorrelated with each other and interpreted as structural shocks. We premultiply by A^{-1} to get the reduced-form VAR

$$y_t = \delta_1 y_{t-1} + \ldots + \delta_p y_{t-p} + u_t, \tag{3}$$

where $u_t = B\varepsilon_t$ and $A^{-1} = B$. Also note that $E[u_t u_t'] = E[BB'] = \Sigma$. This reduced-form VAR can be estimated in a straightforward manner. However, identification of the impulse responses to the structural shocks requires an estimate of the matrix $B = A^{-1}$, which requires further restrictions. In this paper, we will follow the external instruments procedure outlined and developed by Stock and Watson (2002) and Mertens and Ravn (2013) and used recently in an Indian context by Lakdawala and Singh (2019)

The key requirement is to find an instrument that is correlated with the monetary policy shock but uncorrelated with the other structural shocks. Denote the policy shock as ε_t^p and the nonpolicy shocks as ε_t^q. For a given instrument Z_t, these two conditions are written as

$$E[Z_t \varepsilon_t^{p'}] = \phi, \tag{4}$$

$$E[Z_t \varepsilon_t^{q'}] = 0. \tag{5}$$

The baseline VAR is a simple four-variable monthly VAR with a measure of output, prices, exchange rate, and an indicator that captures the stance of monetary policy. We

use the monthly average of the 1-year OIS rate for this purpose, following the work of Gertler and Karadi (2015). The idea is to have this variable capture shocks to both changes in the target policy rate and any "forward guidance." Economic activity is measured using the index of industrial production and inflation is measured using the CPI. The exchange rate is the monthly average of the INR \USD exchange rate. We use 12 lags in the estimation. To use our target and path factors or OIS rate changes in general—which have been constructed on RBI meeting days—they need to be converted to a monthly frequency. We follow the simple procedure of summing any shocks that happen within the month. We have also tried an alternative methodology that adjusts for the fact that RBI meetings fall on different days in the month, with similar results.

One issue with using the external instruments identification strategy is the weak instruments problem. To explore the strength of the factors as instruments, we present the results from the first-stage regressions in the online appendix. The table shows the regression of the reduced-from residual from the OIS 1-year rate equation of the four-variable VAR on the target and path factors, the first principal component of the five OIS rates and the individual OIS rates as well. The estimates show that neither the individual OIS rate changes nor the first principal component would serve as effective instruments in the VAR, as they are all insignificantly related to the residual. Some of them even have the wrong sign, changes in the 1- and 3-month OIS rate and first principal component are negatively associated to the 1-year residual. The second row shows that the target factor also is negatively related to the residual and its effect is insignificant.

Only the path factor is significantly related to the 1-year residual. The F-statistic is around 7, which is close the recommendation of 10 that is usually used in the applied literature. Moreover, the R^2 for the path factor is also substantially higher than all the other cases. Thus, in our estimation we use the path factor as the instrument to identify the structural impulse responses in the VAR.

Figure 4 plots the impulse response to a one-unit contractionary shock to the 1-year OIS rate. After rising on impact, the 1-year rate falls back toward zero after about a year. CPI falls on impact. The effect is marginally significant and reverts back to zero after a few months. The Indian rupee appreciates on impact and effect last for about a year. Contrary to the expected effects of a contractionary monetary policy shock, output rises on impact. While the estimated impulse response of output is not significant on impact, it is significant around the 6-month mark. While this result is surprising from the perspective of conventional macro-economic theory, it is consistent with prior evidence on Indian monetary transmission using VAR models (Mishra, Montiel, and Sengupta 2016).

We compare our identification approach to the commonly used Cholesky (or recursive) identification scheme. In Figure A.2, we show the impulse responses for the baseline VAR identified using the Cholesky identification. The ordering of the variables is (i) Index of Industrial Production (IIP), (ii) CPI, (iii)1y OIS, and (iv) INR\USD. Industrial production and CPI are thus not allowed to react

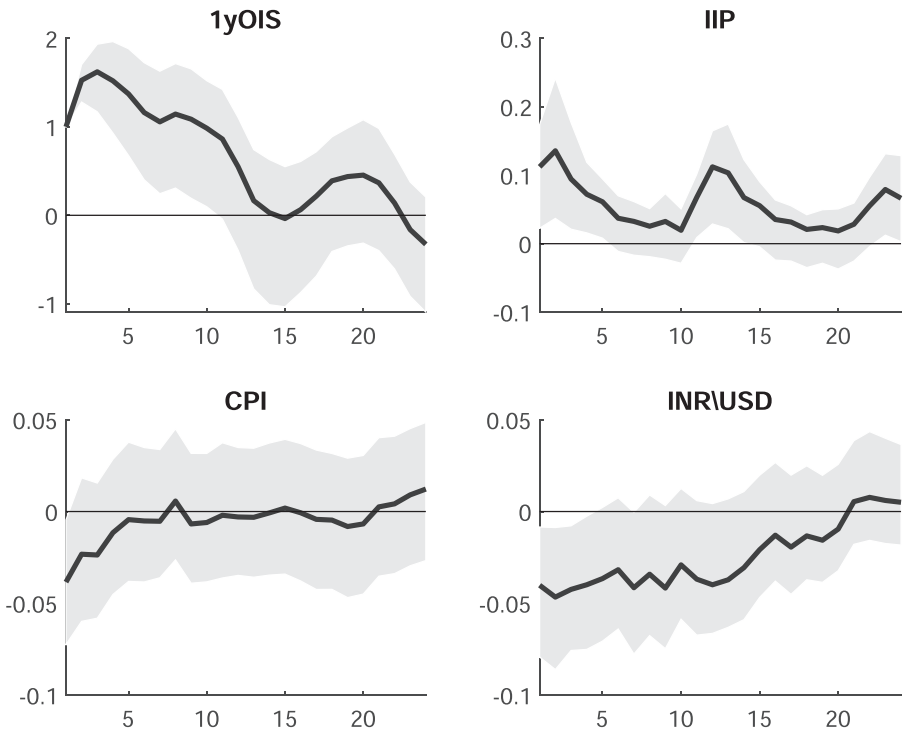

Fig 4. Impulse Response to a Monetary Policy Shock.

NOTES: Impulse responses to a 100-basis-point shock to the 1-year OIS rate identified using the external instruments/proxyVAR methodology, with the path factor used as the instrument. The sample runs from September 2003 to December 2020. The shaded gray areas represent bootstraped 90% confidence intervals.

contemporaneously to the monetary policy shock, as is common in this literature. But our external instrument identification shows that output goes up while CPI falls on impact. Moreover, while the Cholesky identification allows for the exchange rate to respond contemporaneously, the estimated impact is close to zero, compared to the appreciation in the external instruments framework. Overall, using the Cholesky identification would appear to mischaracterize the response of the economy to a monetary policy shock.

We also explore the effect of monetary policy shocks on bond and equity markets using the VAR. To do so, we add them to the baseline VAR and plot the impulse responses in Figure A.3. On impact, the 10-year yield rises around 70 basis points and the response stays statistically significant for about a year. Stock prices fall on impact but steadily rise over the next months.

Overall, we see that while the monetary shock has the expected impact on financial market variables and even inflation, the effect on output is at odds with standard macro-economic theory. What could be driving this result? As has been documented

in the literature, the monetary transmission mechanism is weak in India and results from the literature are often inconclusive (e.g., Aleem 2010, Mohanty 2012, Mishra, Montiel, and Sengupta 2016). One intriguing explanation for the positive response of output to a contractionary monetary shock could be related to the information effect discussed above, whereby a contractionary shock is related to good news about the economy.[15] Thus, if agents revise their expectations and decisions in response to the good news then that could contribute to higher economic activity.

Alternatively, it could be the more prosaic issue that the index of industrial production is not accurately capturing economic activity in India. We use this index as it is the only readily available indicator of economic activity at a monthly frequency. Investigating the appropriateness of using index of industrial production as an accurate proxy for broader economic activity in detail remains an important but open question. Another potentially important factor that might help explain the lack of an effective monetary transmission is fiscal dominance of monetary policy, as documented by Gupta and Sengupta (2016) and described at length in Acharya (2020).

5. CONCLUSION

We have constructed a new measure of monetary policy shocks for India using data on OIS rates. We complement this with a narrative analysis to highlight when these shocks are reliable at capturing the surprise component of RBI's decisions. The surprise component involves both unexpected (non) changes to the policy rate and guidance—typically not explicit—about the future direction of the policy rate. These shocks can be readily used to investigate the monetary transmission mechanism in India. We use these shocks in a high-frequency event study framework to identify the response of financial markets and find that stock and bond markets respond substantially. We also use the shocks as external instruments in a monthly SVAR and find that while prices fall in response to a contractionary shock output actually rises.

We think that our strategy of combining high-frequency financial market data together with a careful reading of the policy statements and media discussion provides a template for investigating the monetary transmission mechanism more broadly in emerging countries. We have also made the Indian monetary shocks data publicly available to researchers with the hope that our work in this paper dovetails into a more widespread effort in understanding the monetary transmission mechanism in India. For example, a more detailed investigation of the effect of monetary shocks on broader interest rates in the economy, including rates in interbank markets and longer-term interest rates directly affecting firms and households is an important area for future research.

15. For evidence of central bank information effects in an SVAR setting, see Lakdawala (2019) and Jarociński and Karadi (2020).

APPENDIX A: LIST OF VARIABLES

TABLE A.1

SOURCES OF VARIABLES USED IN THE ANALYSIS

Variable	Data source
OIS rates	Bloomberg database
Repo rate	Reserve Bank of India (RBI) Database on Indian Economy
Nifty50 index	National Stock Exchange (NSE)
GSec yields	Bloomberg database
INR-USD	Economic Outlook database, Centre for Monitoring Indian Economy (CMIE)
IIP	CMIE Economic Outlook database
CPI inflation	CMIE Economic Outlook database
TBill rates	Bloomberg database

NOTE: The sample period for all variables used in our analysis and reported here runs from September 2003 to December 2020. OIS rates are for maturities 1m, 3m, 6m, 9m, and 1 year. Treasury bill (TBill) rates are for maturities 3m and 1 year. Government security (GSec) yields are of maturities 5 y and 10 years. INR-USD is the nominal Rupee-Dollar exchange rate. IIP refers to the Index of Industrial Production. CPI refers to the Consumer Price Index measure of inflation.

TABLE A.2

TOP TARGET FACTORS DURING GLOBAL FINANCIAL CRISIS PERIOD (2007–09)

Date	Regime	Target factor	Path factor	Discussion
Mar. 30, 2007	Reddy	−1.586	0.974	Repo rate was increased.
Nov. 3, 2008	Subbarao	−1.344	0.754	Repo rate was lowered.
Jul. 31, 2007	Reddy	1.274	0.008	Repo rate was left unchanged.
Oct. 24, 2008	Subbarao	1.106	0.041	Repo rate was left unchanged.

TABLE A.3

RESPONSE OF ASSET PRICES TO ALTERNATE MONETARY SHOCKS

	5y-yield		10y-yield		Nifty		INR/USD	
T-bill target factor	0.22**	0.22***	0.14**	0.14***	−1.07	−1.07	−0.25**	−0.25*
	[2.14]	[4.21]	[2.01]	[4.01]	[−0.77]	[−1.15]	[−2.03]	[−1.66]
T-bill path factor		0.17***		0.15***		−2.02***		0.13
		[6.78]		[6.28]		[−2.76]		[1.17]
Constant	0.00	0.00	0.01	0.01*	−0.29	−0.29	−0.04	−0.04
	[0.27]	[0.34]	[1.35]	[1.65]	[−1.15]	[−1.20]	[−0.90]	[−0.91]
Obs.	114	114	114	114	114	114	110	110
R^2	0.19	0.49	0.09	0.38	0.01	0.09	0.01	0.02

NOTE: The table shows RBI announcement day regressions of bond yields (5- and 10-year), Nifty 50 return, and INR\USD exchange rate on target and path factors constructed from 3- and 1-year T-bill rates. For each asset price, the first column shows a regression with just a constant and the target factor. The second column adds the path factor. The sample has 114 observations (110 for the exchange rate) from September 2003 to December 2020. t-Statistics based on White heteroskedasticity-robust standard errors are reported in parentheses, $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

TABLE A.4

RESPONSE OF 10-YEAR GOVERNMENT BOND YIELD TO MONETARY SHOCKS

	Reddy		Subbarao		Rajan		MPC	
Target factor	0.06	0.06***	0.04	0.04	−0.01	−0.01	0.72***	0.72***
	[1.37]	[2.67]	[0.71]	[1.48]	[−0.02]	[−0.04]	[5.67]	[4.72]
Path factor		0.19***		0.17***		0.92***		0.32
		[9.20]		[9.74]		[3.88]		[1.35]
Constant	0.03	0.03***	0.01	0.01	0.01	0.01	0.00	0.00
	[1.59]	[2.67]	[0.63]	[1.09]	[0.36]	[0.58]	[−0.29]	[−0.30]
Obs.	25	25	41	41	22	22	27	27
R^2	0.05	0.67	0.02	0.67	0.00	0.62	0.50	0.55

NOTE: The table shows RBI announcement day regressions of 10-year government bond yield on target and path factors, broken down by RBI governor regimes. The first column shows a regression with just a constant and the target factor. The second column adds the path factor. "MPC" represents the period from September 2016 to December 2020 covering the governorships of Urjit Patel and Shaktikanta Das. *t*-Statistics based on White heteroskedasticity-robust standard errors are reported in parentheses, $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

TABLE A.5

RESPONSE OF NIFTY STOCK INDEX TO MONETARY SHOCKS

	Reddy		Subbarao		Rajan		MPC	
Target factor	−1.20	−1.20	−6.82***	−6.82***	−0.84	−0.84	−1.46	−1.46
	[−1.10]	[−0.91]	[−4.20]	[−4.10]	[−0.21]	[−0.33]	[−0.51]	[−0.50]
Path factor		−4.70***		0.42		−10.75***		−1.12
		[−5.06]		[0.57]		[−3.30]		[−0.46]
Constant	−0.42	−0.42	−0.42	−0.42	−0.39	−0.39	0.09	0.09
	[−0.64]	[−0.84]	[−1.22]	[−1.23]	[−0.92]	[−1.07]	[0.25]	[0.25]
Obs.	25	25	41	41	22	22	27	27
R^2	0.03	0.43	0.51	0.51	0.00	0.26	0.01	0.01

NOTE: The table shows RBI announcement day regressions of Nifty stock returns on target and path factors, broken down by RBI governor regimes. The first column shows a regression with just a constant and the target factor. The second column adds the path factor. "MPC" represents the period from September 2016 to December 2020 covering the governorships of Urjit Patel and Shaktikanta Das. *t*-Statistics based on White heteroskedasticity-robust standard errors are reported in parentheses, $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

TABLE A.6

RESPONSE OF INR\USD EXCHANGE RATE TO MONETARY SHOCKS

	Reddy		Subbarao		Rajan		MPC	
Target factor	0.07	0.08	0.81**	0.81**	−1.36	−1.36	−1.26***	−1.26**
	[0.49]	[0.49]	[2.63]	[2.64]	[−1.50]	[−1.55]	[−3.30]	[−2.62]
Path factor		0.03		−0.01		0.40		0.68
		[0.22]		[−0.03]		[0.58]		[0.58]
Constant	−0.03	−0.03	−0.04	−0.04	0.02	0.02	−0.10	−0.10
	[−0.60]	[−0.61]	[−0.45]	[−0.45]	[0.21]	[0.22]	[−1.54]	[−1.56]
Obs.	23	23	40	40	21	21	27	27
R^2	0.02	0.02	0.14	0.14	0.13	0.14	0.13	0.15

NOTE: The table shows the regression of INR\USD exchange rate on target and path factors, broken down by RBI governor regimes. The first column shows a regression with just a constant and the target factor. The second column adds the path factor. "MPC" represents the period from September 2016 to December 2020 covering the governorships of Urjit Patel and Shaktikanta Das. *t*-Statistics based on White heteroskedasticity-robust standard errors are reported in parentheses, $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

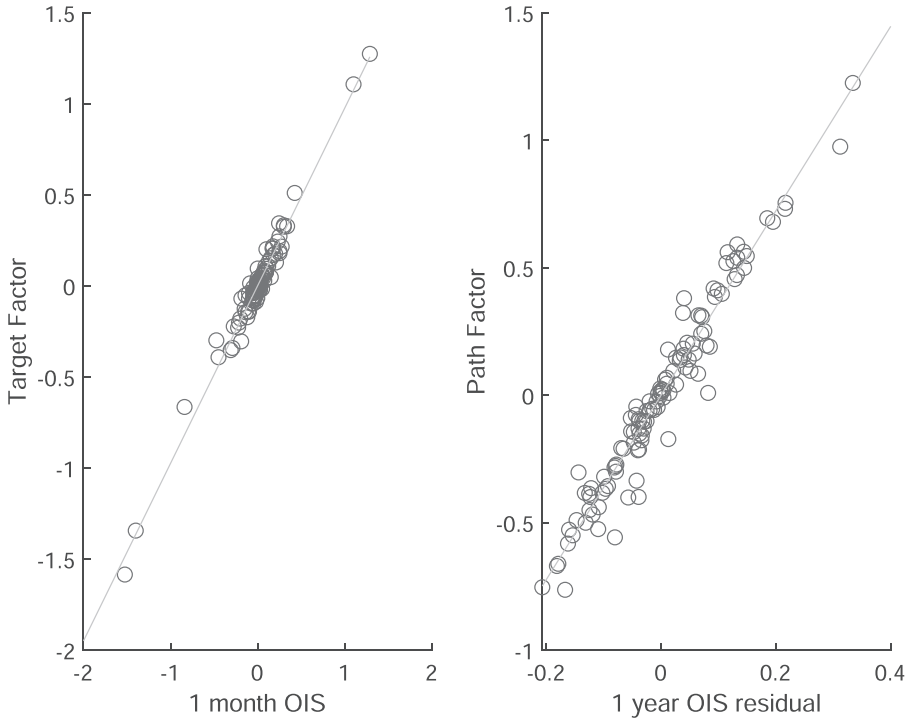

Fig A.1. Scatter Plot of Target and Path Factors with OIS Rates.

NOTES: The left panel shows the scatter plot of target factor versus 1-month OIS rate changes on RBI announcement days. The right panel shows the scatter of path factor versus residual from regressing 1-year OIS rate on 1-month OIS rate on RBI announcement days. The sample is from September 2003 to December 2020.

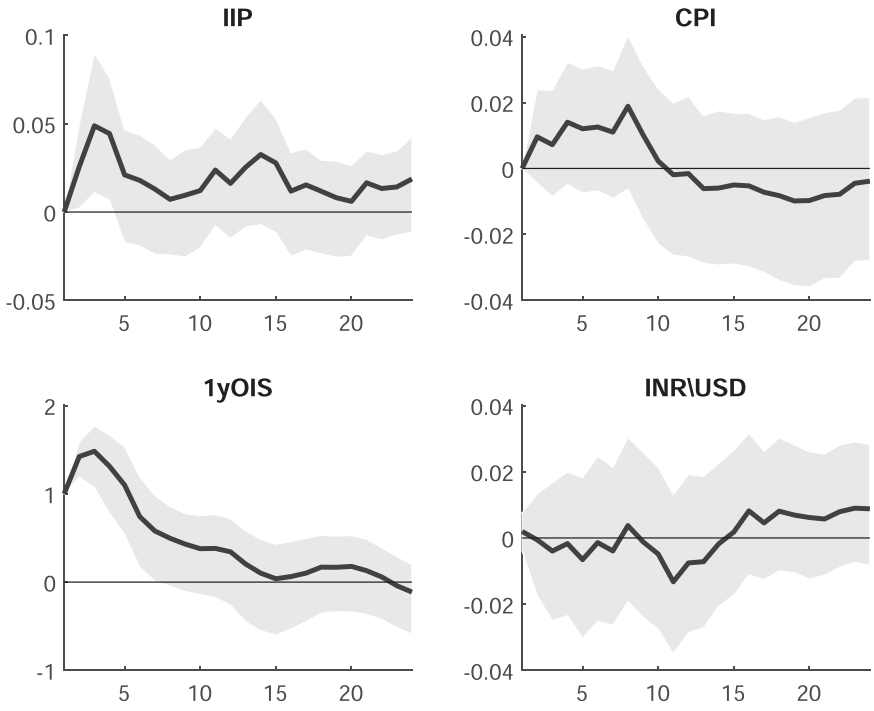

Fig A.2. Impulse Response to a Monetary Policy Shock: Cholesky Identification.

NOTES: Impulse responses to a 100-basis-point shock to the 1-year OIS rate identified using Choleksy (recursive) ordering. The sample runs from September 2003 to December 2020. The shaded gray areas represent bootstrapped 90% confidence intervals.

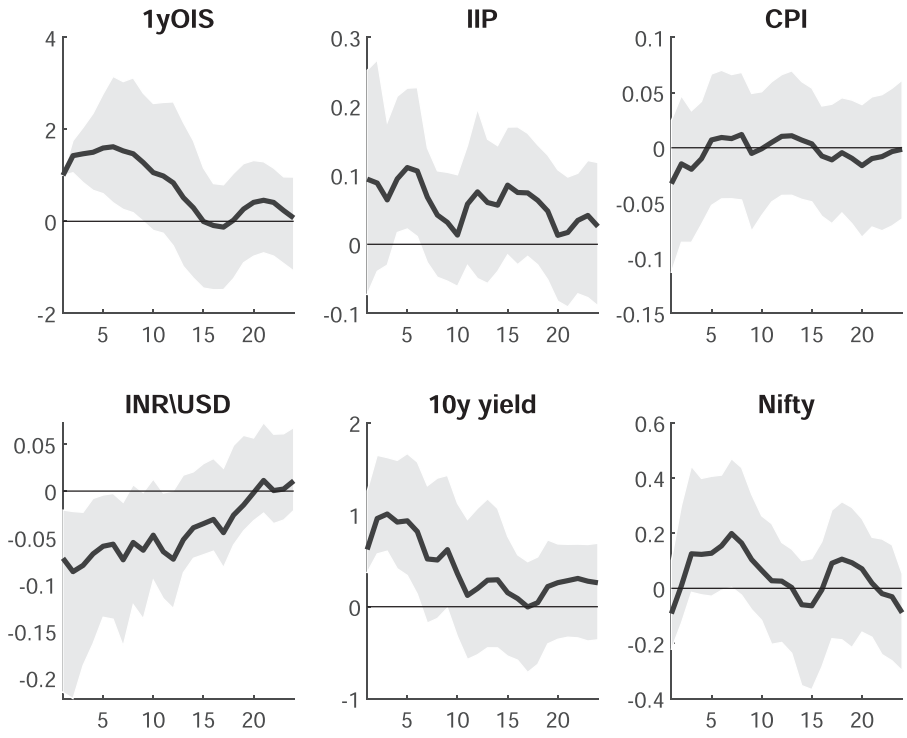

Fig A.3. Impulse Response to a Monetary Policy Shock.

NOTES: Impulse responses to a 100-basis-point shock to the 1-year OIS rate identified using the external instruments/proxyVAR methodology, with the path factor used as the instrument. The sample runs from September 2003 to December 2020. The shaded gray areas represent bootstrapped 90% confidence intervals.

APPENDIX B: TARGET AND PATH FACTOR CONSTRUCTION

The idea in Gürkaynak, Sack, and Swanson (2005) is to transform these two factors such that they have a meaningful economic interpretation. The first one is intended to reflect surprise changes in the short rate (1m OIS (Overnight Index Swap) in our case) called the target factor. The second one and other as changes in medium- to longer-term rates that are orthogonal to changes in the goal is to construct two new factors Z_1 and Z_2 from the first two principal components F_1 and F_2 by finding an orthogonal matrix U

$$[Z_1\ Z_2] = [F_1\ F_2]U. \tag{B.1}$$

U matrix has four unique elements and requires four restrictions for identification

$$U = \begin{pmatrix} \alpha_1 & \beta_1 \\ \alpha_2 & \beta_2 \end{pmatrix}.$$

The first two come from a simple normalization that imposes the columns of U to have unit length, that is, $\alpha_1^2 + \alpha_2^2 = 1$ and $\beta_1^2 + \beta_2^2 = 1$. Next, we maintain the orthogonality of the two factors $E(Z_1 Z_2) = 0$, which gives $\alpha_1\beta_1 + \alpha_2\beta_2 = 0$. Finally, we impose the condition required for identification of the path factor, that is, the second factor Z_2 is not related to the 1-month OIS rate change. This condition is given by $\gamma_2\alpha_1 - \gamma_1\alpha_2 = 0$. To see this last condition, let γ_1 and γ_2 be the factor loadings on F_1 and F_2 for change in current month's futures contract (given by X(1))

$$X(1) = \gamma_1 F_1 + \gamma_2 F_2. \tag{B.2}$$

From equation (B.1), we can write

$$F_1 = \frac{1}{\alpha_1\beta_2 - \alpha_2\beta_1}[\beta_2 Z_1 - \alpha_2 Z_2],$$

$$F_2 = \frac{1}{\alpha_1\beta_2 - \alpha_2\beta_1}[-\beta_1 Z_1 + \alpha_1 Z_2].$$

Now plug these into equation (B.2) and impose the condition that the loading of Z_2 on $X(1)$ is zero to get the restriction $\gamma_2\alpha_1 - \gamma_1\alpha_2 = 0$.

LITERATURE CITED

Acharya, Viral. (2020) "Fiscal Dominance: A Theory of Everything in India." *Indian Public Policy Review*, 1, 1–15.

Aleem, Abdul. (2010) "Transmission Mechanism of Monetary Policy in India." *Journal of Asian Economics*, 21, 186–97.

Altavilla, Carlo, Luca Brugnolini, Refet S. Gürkaynak, Roberto Motto, and Giuseppe Ragusa. (2019) "Measuring Euro Area Monetary Policy." *Journal of Monetary Economics*, 108, 162–79.

Bernanke, Ben S., and Kenneth N. Kuttner. (2005) "What Explains the Stock Market's Reaction to Federal Reserve Policy?" *Journal of Finance*, 60, 1221–57.

Campbell, Jeffrey R., Charles L. Evans, Jonas D.M. Fisher, and Alejandro Justiniano. (2012) "Macroeconomic Effects of Federal Reserve Forward Guidance." *Brookings Papers on Economic Activity*, 1–80.

Das, Satadru, Jay Surti, and Shekhar Tomar. (2020) "Does Inflation Targeting Help Information Transmission?" Technical report, Available at SSRN.

Das, Sonali. (2015) "Monetary Policy in India: Transmission to Bank Interest Rates." IMF Working Papers 2015/129, International Monetary Fund.

Dua, Pami. (2020) "Monetary Policy Framework in India." *Indian Economic Review*, 55, 117–54.

Gertler, Mark, and Peter Karadi. (2015) "Monetary Policy Surprises, Credit Costs, and Economic Activity." *American Economic Journal: Macroeconomics*, 7, 44–76.

Ghosh, Saurabh, Abhinav Narayanan, and Pranav Garg. (2021) "Monetary Policy Transmission in India: New Evidence from Firm-Bank Matched Data." RBI Working Paper Series.

Gupta, Abhijit Sen, and Rajeswari Sengupta. (2016) "Is India Ready for Inflation Targeting?" *Global Economy Journal*, 16, 479–509.

Gürkaynak, Refet S., Brian Sack, and Eric T. Swanson. (2005) "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements." *International Journal of Central Banking*, 1, 55–93.

Jarociński, Marek, and Peter Karadi. (2020) "Deconstructing Monetary Policy Surprises—The Role of Information Shocks." *American Economic Journal: Macroeconomics*, 12, 1–43.

Kamber, G., and M. S. Mohanty. (2018) "Do Interest Rates Play a Major Role in Monetary Policy Transmission in China?" BIS Working Papers No. 714, Bank for International Settlements.

Khundrakpam, Jeevan K., and Rajiv Jain. (2012) "Monetary Policy Transmission in India: A Peep Inside the Black Box." RBI Working Paper 12, Reserve Bank of India.

Kuttner, Kenneth N. (2001) "Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market." *Journal of Monetary Economics*, 47, 523–44.

Lakdawala, Aeimit. (2019) "Decomposing the Effects of Monetary Policy Using an External Instruments SVAR." *Journal of Applied Econometrics*, 34, 934–50.

Lakdawala, Aeimit. (2021) "The Growing Impact of US Monetary Policy on Emerging Financial Markets: Evidence from India." *Journal of International Money and Finance*, 119, 102478.

Lakdawala, Aeimit, and Matthew Schaffer. (2019) "Federal Reserve Private Information and the Stock Market." *Journal of Banking & Finance*, 106, 34–49.

Lakdawala, Aeimit, and Sanjay Singh. (2019) "The Effect of Foreign Shocks on the Indian Economy." *India Policy Forum*, 16, 1–54.

Lloyd, Simon P.. (2021) "Overnight Indexed Swap-Implied Interest Rate Expectations." *Finance Research Letters*, 38, 101430.

Mathur, Aakriti, and Rajeswari Sengupta. (2019) "Analysing Monetary Policy Statements of the Reserve Bank of India." IHEID Working Papers 08-2019, Economics Section, The Graduate Institute of International Studies.

Mertens, Karel, and Morten O. Ravn. (2013) "The Dynamic Effects of Personal and Corporate Income Tax Changes in the United States." *American Economic Review*, 103, 1212–47.

Mishra, P., P. Montiel, and R. Sengupta. (2016) "Monetary Transmission in Developing Countries: Evidence from India." In C. Ghate, K. Kletzer, (eds) *Monetary Policy in India*. New Delhi: Springer. https://doi.org/10.1007/978-81-322-2840-0_3

Mohanty, Deepak. (2012) "Evidence of Interest Rate Channel of Monetary Policy Transmission in India." RBI Working Paper 6, Reserve Bank of India.

Montiel, Peter J., Prachi Mishra, and Rajeswari Sengupta. (2016) "Monetary Transmission in Developing Countries: Evidence from India." IMF Working Papers 2016/167, International Monetary Fund.

Nakamura, Emi, and Jón Steinsson. (2018) "High Frequency Identification of Monetary Non-Neutrality." *Quarterly Journal of Economics*, 133, 1283–330.

Paramanik, Rajendra Narayan, and Bandi Kamaiah. (2014) "A Structural Vector Autoregression Model for Monetary Policy Analysis in India." *Margin: The Journal of Applied Economic Research*, 8, 401–29.

Patnaik, Ila, and Rajeswari Sengupta. (2021) "Analysing India's Exchange Rate Regime." *India Policy Forum*, 18, 53–85.

Rituraj, and Arun Vishnu Kumar. (2021) "Assessing the Markets' Expectations of Monetary Policy in India from Overnight Indexed Swap Rates." *RBI Bulletin*, Reserve Bank of India.

Sahoo, Satyananda, and Indranil Bhattacharyya. (2012) "Yield Curve Dynamics of the Indian G-Sec Market: A Macro-Finance Approach." *Indian Economic Review*, 47, 157–82.

Sensarma, Rudra, and Indranil Bhattacharyya. (2016) "Measuring Monetary Policy and Its Impact on the Bond Market of an Emerging Economy." *Macroeconomics and Finance in Emerging Market Economies*, 9, 109–30.

Stock, James H., and Mark Watson. (2002) "Disentangling the Channels of the 2007-09 Recession." *Brookings Papers on Economic Activity: Spring 2012*, 81.

Swanson, Eric T. (2021) "Measuring the Effects of Federal Reserve Forward Guidance and Asset Purchases on Financial Markets." *Journal of Monetary Economics*, 118, 32–53.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table OA.1: OIS rate summary statistics by governor regime

Table OA.2: Number of expansionary and contractionary changes in OIS rates and factors

Table OA.3: Regression of OIS rates on target and path factors

Table OA.4: Response of asset prices to monetary shocks: Excluding global financial crisis

Table OA.5: Response of asset prices to monetary shocks: 2 day changes

Table OA.6: Response of asset prices to monetary shock (1st principal component)

Table OA.7: Response of asset prices to monetary shocks: Asymmetric effects

Table OA.8: First stage effects of high-frequency shocks on VAR residuals