The Term Structure of Interest Rates in India

Rajnish Mehra and Arunima Sinha

1 Introduction

The financial sector plays a crucial dual role in any economy. It enables households to smooth consumption over their life cycle by insuring against idiosyncratic income shocks and channels savings to productive investments. Consequently, its role in economic development has received considerable attention in the literature on emerging markets. The consensus is that an efficient and transparent financial sector is a crucial concomitant of sustained economic growth.[1]

We thank Ravi Bansal, John Donaldson, an anonymous referee and the editors for their insightful comments and Neeru Mehra for editorial assistance. The usual caveat applies.

[1]While there is a considerable literature documenting the correlation between economic growth and financial development, Rajan and Zingales (1998) provide convincing evidence on causality.

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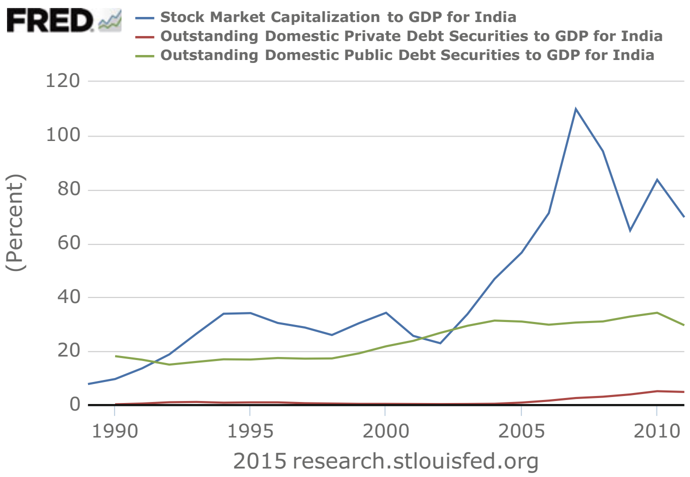

Fig. 1 Evolution of the financial sector in India: 1990–2011

The growth and development of the financial sector in India has been uneven. Indian equity markets have a long and colorful history.[2] They grew exponentially following economic reforms precipitated by the balance of payments crisis in 1991, and the Bombay Stock Exchange (BSE) is currently a "top ten" exchange in terms of market capitalization. Indian equity markets have also been the subject of considerable academic research: almost every study conducted on a major stock exchange has been replicated using Indian data sets.

In marked contrast, debt markets in India have languished. Prior to 1991 the corporate bond market was virtually nonexistent. The government debt market was illiquid, as a large part of the outstanding debt was held as mandated reserves by the banking sector. Consequently, there has been little academic work using Indian debt market data sets.

Figures 1 and 2 show the post-1990 evolution of these markets both in India and the US.

This chapter focuses on Indian debt markets for both government and corporate debt and, in particular, on the term structure of interest rates of government securities. We investigate whether the yield curve can be rationalized based on the 'expectations hypothesis'. To the best of our knowledge, the expectations hypothesis has not been tested in the Indian context. We also explore the information content in the term structure and its implications for monetary policy.

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[2]Indian equity markets had their inception in the early 1830s. The first organized exchange—the Native Share and Stock Brokers' Association (the forerunner of the Bombay Stock Exchange) was established in 1887 making it the oldest in Asia. The market experienced its first crash in 1865. The run up in stock prices prior to the crash was a consequence of the increased demand for Indian cotton precipitated by the disruption of cotton supplies due to the American Civil War.

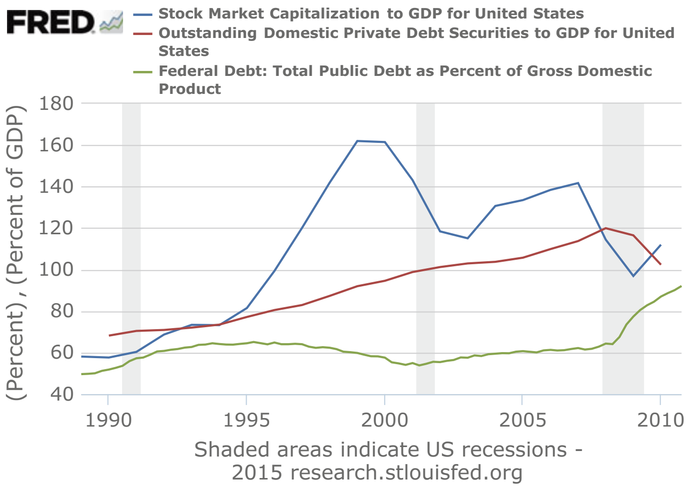

Fig. 2 Evolution of the financial sector in the US: 1990–2011

The chapter consists of six sections. Section 2 documents the evolution of Indian debt markets. Section 3 presents an overview of the literature on the term structure. In Sect. 4, we report and interpret results on tests of the expectations hypothesis and in Sect. 5 we discuss some possible reasons for our findings. Section 6 concludes the paper.

2 The Evolution of Debt Markets in India

The history of public debt in India dates back to the East India Company. After its inception in 1935, the Reserve Bank of India (RBI) was instrumental in managing public debt, issuing debt as needed to finance both fiscal deficits and infrastructure projects. By and large, Sovereign (GoI) debt was held by banks and life insurance companies to maturity and until 1990, there was essentially no secondary market where it was traded.

Corporate investment was almost exclusively financed by equity issues, private placement of bonds or by bank loans, a trend that continues to date.

2.1 The Government Securities Market

Until 1990, the Government securities (G-Secs) market in India was notably underdeveloped due to a variety of factors, including high statutory liquidity ratios (SLRs) governing commercial banks, and administered interest rates. Starting in 1992, a series of reforms were undertaken by the Reserve Bank of India (RBI) and the government to develop and deepen the market: the setting up of a system of Primary Dealers, a Treasury auction system, the introduction of 91-day Treasury

Table 1 Statistics for Government of India securities

Year	Total internal marketable debt	Gross Fiscal Deficit (GFD)	GFD financed through market borrowings
1990–91	26.27	7.61	17.92
1995–96	25.09	4.91	56.43
1999–00	35.30	5.17	59.28
2004–05	39.35	3.87	40.49
2009–10	36.07	6.46	94.23
2012–13	36.92	4.84	103.52

Figures in columns 2, 3, and 4 are expressed as percentages of GDP at market prices

Table 2 Ownership patterns of Government of India securities

Year	Commercial Banks	Insurance Companies	Foreign Institutional Investors Investors	Reserve Bank of India
2007	41.57	26.19	0.18	6.51
2008	42.51	24.78	0.52	4.78
2009	38.85	23.2	0.24	9.71
2010	38.03	22.16	0.59	11.76
2011	38.42	22.22	0.97	12.84
2012	36.28	21.08	0.88	14.41
2013	34.5	18.56	1.61	16.99

Figures in the columns are a fraction of the total

bills and zero-coupon bonds, the introduction of repos in G-Secs and other OTC instruments like Interest Rate Swaps. The Government Securities Act of 2006 modernized the legal infrastructure for this market. For a comprehensive summary of the reforms undertaken, the reader is referred to Annex 1 of Mohan and Ray (2009). Table 1 presents some statistics documenting the evolution of the market.

The outstanding stock of internal government debt as a percentage of GDP increased from 26.3 % to almost 37 % between 1990 and 2013. The percentage of Gross Fiscal Deficit financed by market borrowings increased from 18 % to over 90 % over the same period. As summarized in Table 2, the ownership pattern of these securities has also substantially changed. The fraction of Government of India securities owned by commercial banks and insurance companies declined from 67.7 to 53 %, while the holdings of the RBI rose from less than 7–17 %.

Another notable development is the declining role of the RBI in the primary G-Secs market, with the percentage of gross market auctions with devolvement on the RBI declining to almost zero by 2006–2007, compared to more than 13 % in 1996–1997.

Two other notable trends are (i) the progressive lengthening of the maturity of outstanding debt, with average maturity increasing from 5.7 years in 1995–1996 to 13.8 in 2005–2006 and (ii) a deepening of the secondary market for securities, as evidenced by a 50 % increase in the share of repos in the market transactions of G-Secs.

Table 3 Government and Corporate Bonds as a percentage of GDP, March 2013

Debt as a % of GDP	Government	Corporate	Total
China	33.1	13.0	46.2
Hong Kong	37.8	31.4	69.2
Indonesia	11.4	2.3	13.7
Korea	48.7	77.5	126.2
Malaysia	62.4	43.1	105.5
Philippines	32.2	4.9	37.1
Singapore	53.1	37.0	90.1
Thailand	58.6	15.9	74.4
Vietnam	19.8	0.7	20.5
India	49.1	5.4	54.5

From: R. Gandhi BIS 2015

2.2 *The Corporate Bond Market*

Post the 1990 reformative overhaul, the Government securities market has expanded to an extent that its size is on par with trends in other emerging economies (Table 3). The corporate debt market, however, is an outlier, languishing in the bottom third of its cohort.

This anomalous development has been extensively commented upon[3] and has been the subject of two "high powered" government commissions.[4] We do not revisit their conclusions or review the discussion on the reasons postulated for the under development of the corporate debt market. Suffice to say, they are largely regulatory and include the following:

a. Onerous and time-consuming disclosure regulations relative to those required for private placement.
b. "Prudent Investment" regulations that bias institutions towards holding G-Secs and AAA corporates.
c. Outdated bankruptcy laws and ineffective judicial enforcement.

As result of a heightened awareness that a well-functioning corporate bond market is a concomitant for continued capital formation and effective corporate control, and the implementation of policy initiatives to this end, the past decade has seen an uptick in this market (Fig. 3).

[3]See Wells and Schou-Zibell (2008), Mohan and Ray (2009) for an excellent overview.

[4]The Patil Committee report (2005) and the Rajan Committee report (2008).

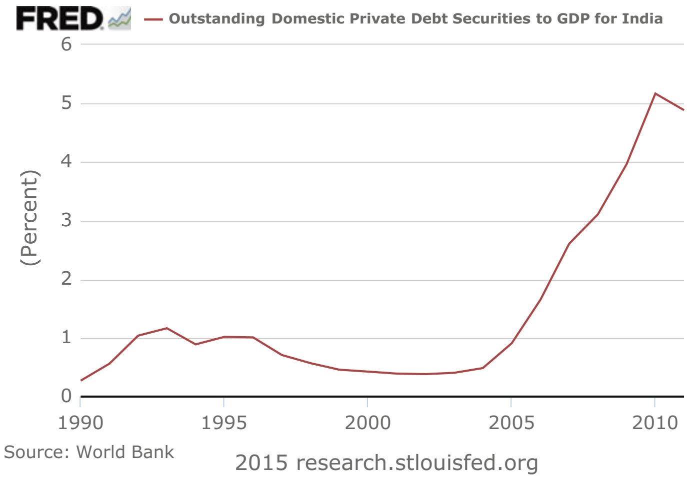

Fig. 3 The corporate debt market in India: 1990–2011

3 The Term Structure of Interest Rates

A major research initiative in finance focuses on the determinants of the cross-sectional and time series properties of asset returns.

An asset-pricing model is characterised by an operator that maps the sequence of future random payoffs of an asset to a scalar, the current price of the asset.[5] If the law of one price[6] holds in a securities market where trading occurs at discrete points in time, this operator $\Psi(.)$ can be represented as[7]

$$P_t = \Psi(\{y_{s+t}\}_{s=1}^{\infty}) = E\left[\sum_{s=1}^{\infty} m_{s+t,t} y_s | \Phi_t\right] \quad (1)$$

where P_t is the price at time t of an asset with stochastic payoffs $\{y_{s+t}\}_{s=1}^{\infty}$, $\{m_{s+t,t}\}_{s=1}^{\infty}$ a stochastic process,[8] Φ_t is the information available to households who trade assets at time t and E is the expectations operator defined over random variables that are measurable with respect to the sigma algebra generated by Φ_t. If

[5]Both the payoffs and the price are denominated in the numeraire consumption good.

[6]Assets that have identical payoffs have identical prices.

[7]See Ross (1976), Harrison and Kreps (1979), Hansen and Richards (1987) for the technical restrictions on the payoff process for Eq. (1) to hold.

[8]$m_{s+t,t} = \prod_{k=0}^{s-t-1} m_{t+k+1,t+k}$, where $m_{t+k+1,t+k}$ is a random variable such that $P_{t+k} = E[m_{t+k+1,t+k}\, y_{t+k+1} | \Phi_{t+k}]$.

the asset payoffs end T periods from now, we define the random variables $\{y_{s+t}\}_{s=T+1}^{\infty}$ to be zero. If the securities market is arbitrage-free,[9] then the process $\{m_{s+t,t}\}_{s=1}^{\infty}$ has strictly positive support (with probability one) and is unique if the market is complete.[10]

No arbitrage is a necessary condition for the existence of security market equilibrium in an economy where all agents have access to the same information set. If, however, there is an agent in the economy with preferences that can be represented by a *strictly increasing*, continuous utility function defined over security payoffs, then the no arbitrage condition is both necessary and sufficient for the existence of a security market equilibrium[11] (Dybvig and Ross 2008). In an economy characterized by such an agent and no arbitrage, *all* equilibrium asset-pricing models are simply versions of Eq. (1) for different stochastic processes $\{m_{s+t,t}\}_{s=1}^{\infty}$, often referred to as stochastic discount factors or pricing kernels.

An important subclass of asset-pricing models focuses on the pricing of default free zero-coupon bonds of varying maturities at a point in time. Since these bonds make only one deterministic payoff they are easy to price, as Eq. (1) simplifies to

$$P_{s,t} = \Psi(\{1_{s+t}\}) = E[m_{s+t,t}|\Phi_t] \tag{2}$$

where $P_{s,t}$ is the price of an s-period bond at time t. This bond has a unit payoff, 1_{s+t} at time $s + t$. Security prices in this setting are simply the expected value of the stochastic discount factors. For a one-period bond, maturing at time $t + 1$

$$P_{1,t} = E\,[m_{t+1,t}|\Phi_t]$$

$$P_{s,t} = E\,[m_{t+1,t}P_{s-1,t+1}|\Phi_t] \tag{3}$$

Hence, if the process on $m_{t+1,t}$ is known, in principle a bond of any maturity can be priced by chaining together the period discount factors (see footnote 8).

We next define some terms to be used later in this section and the following sections.[12]

The yield to maturity $Y_{s,t}$ of an s-period bond is defined by

$$P_{s,t} = (1 + Y_{s,t})^{-s} \tag{4}$$

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[9]A securities market is arbitrage-free if no security is a "free lottery" and any portfolio of securities with a zero payoff has zero price.

[10]If markets are incomplete, there will, in general, be multiple processes $\{m_{s+t,t}\}_{s=1}^{\infty}$ such that (1) holds. Not all of them need have a strictly positive support.

[11]Households maximize utility given their endowments and security prices and supply equals demand at these security prices.

[12]Our definitions below draw on Campbell et al. (1997).

In the bond pricing literature it is common to use continuously compounded yields ($y_{s,t}$)

$$y_{s,t} = \ln(1 + Y_{s,t})$$

Hence,

$$y_{s,t} = -s^{-1} p_{s,t} \tag{5}$$

where $p_{s,t} = \ln P_{s,t}$. Henceforth, we will use lower case letters to denote log-transformed variables.

The (log) *yield spread* $\delta_{s,t}$ is the difference in yield between an s-period bond and a one-period bond.

$$\delta_{s,t} = y_{s,t} - y_{1,t} \tag{6}$$

The (log) *holding period return*, $h_{s,t+1}$, at time t, on an s-period bond is the return on holding the bond from time t till $t + 1$. It is a random variable at time t.

$$h_{s,t+1} = p_{s-1,t+1} - p_{s,t} \tag{7}$$

or using (5)

$$h_{s,t+1} = s y_{s,t} - (s-1) y_{s-1,t+1} \tag{8}$$

The (log) *s-period ahead forward rate* at time t is the rate on an investment in a one-period bond from time $s + t$ to $s + t + 1$ that is implicit in current bond prices. This future rate can be guaranteed at time t.

$$f_{s,t} = p_{s,t} - p_{s+1,t} \tag{9}$$

The *term structure of interest rates* at a point in time t refers to the (log) yields to maturity $y_{s,t}$ for a set of default-free zero-coupon bonds. *The yield curve* is a plot of these yields versus the time to maturity s. A time series plot of the yields on government bonds of different maturities for India and the US is shown in Figs. 4 and 5. Figures 6 and 7 plot the term structure on February 29, 2012 and June 1, 2015 for the two countries.

The discussion so far has focused on a real economy, with payoffs and prices denominated in the numeraire consumption good and "real" returns. In contrast, much of the term structure literature deals with the nominal term structure of interest rates, primarily because government bonds in most countries have nominal payoffs.[13] One approach to pricing nominal bonds is to deflate nominal prices by the price index and then use Eq. (3).

[13]In the US, Treasury Inflation Protected Securities (TIPS) debuted in 1997 and research on the real term structure is still in its infancy. See Pflueger and Viceira (2013). India briefly issued inflation indexed bonds in 1997 and again starting in 2013.

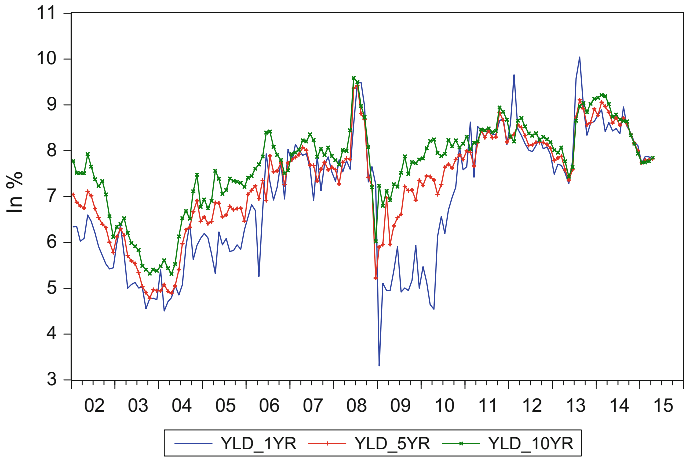

Fig. 4 Zero-coupon yields from January 2002 to April 2015 for India using the Nelson-Siegel methodology (detailed in Sect. 4)

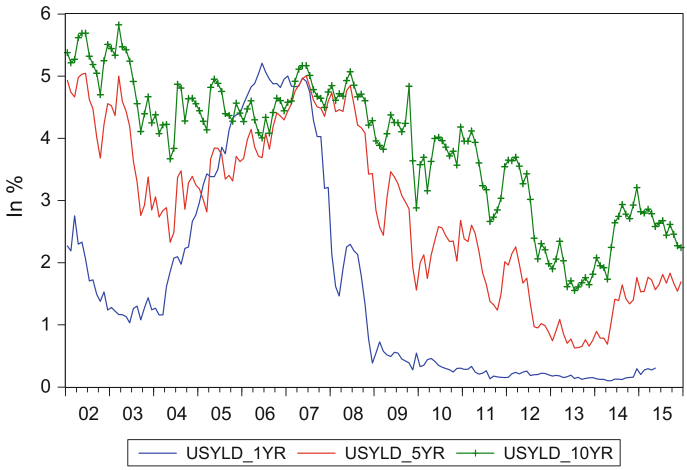

Fig. 5 Zero-coupon yields from January 2002 to April 2015 for USA using the Nelson-Siegel methodology

If I_t is the price index and P_t^n the nominal price of the bond at time t, we can rewrite (3) as

$$P^n_{s,t}/I_t = E\left[m_{t+1,t}P^n_{s-1,t+1}/I_{t+1}|\Phi_t\right]$$

$$\text{or} \quad P^n_{s,t} = E[m_{t+1,t}P^n_{s-1,t+1}/\Pi_{t+1}|\Phi_t] \qquad (10)$$

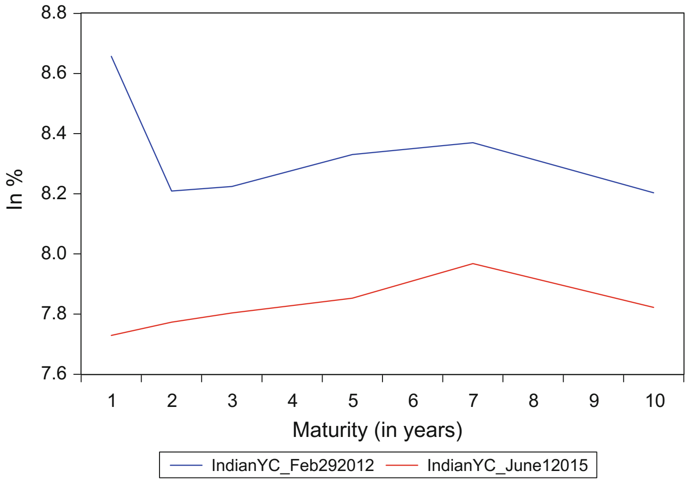

Fig. 6 Term structure for India on February 29, 2012 and June 1, 2015

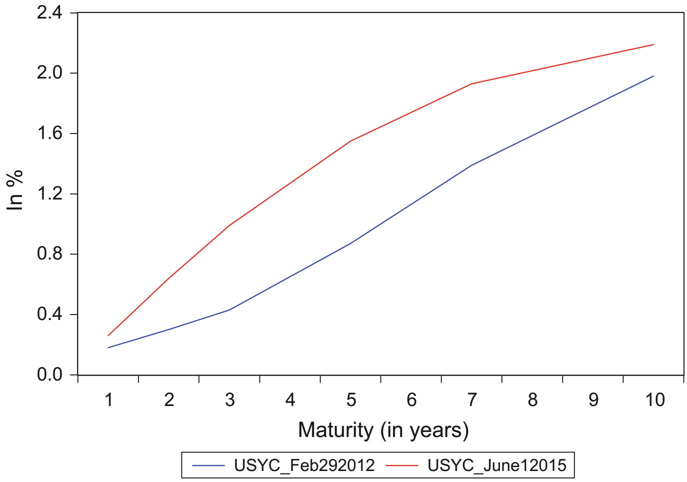

Fig. 7 Term structure for the US on February 29, 2012 and June 1, 2015

$$\text{or} \quad P^n_{s,t} = E\,[m^*_{t+1,t} P^n_{s-1,t+1} | \Phi_t] \tag{11}$$

where $\Pi_{t+1} = I_{t+1}/I_t$ is the gross inflation rate between time t and $t + 1$ and $m^*_{t+1,t}$ is the *nominal stochastic discount factor*.

The various term structure models in the literature are different specifications of the process on $m_{t+1,t}$ and Π_t or the process $m^*_{t+1,t}$ may be modeled directly.[14] The process may be chosen in an ad hoc manner so as to match the empirically observed yield curve[15] or it may be endogenously determined in an equilibrium model. In consumption-based asset-pricing models, $m_{s+1,t}$ is usually expressed as a function of the marginal rate of substitution of consumption between time s and t of the agents who trade securities. For example, Donaldson et al. (1992) and Backus et al. (1989) model $m_{s+t,t}$ as $\beta^s u'(c_{s+t})/u'(c_t)$. Here c_t is the aggregate per capita consumption at time t, $u'(c_t)$ is the marginal utility of consumption at time t and β is the rate of time preference. In the case of constant relative risk aversion (CRRA) preferences this specializes to $\beta^s(c_{s+t}/c_t)^{-\alpha}$, where α is the coefficient of relative risk aversion and simultaneously, the reciprocal of the elasticity of intertemporal substitution.

What is the information content in the yield curve? Do current short-term rates predict future short-term rates? If the current yield spread is high does it imply that future long rates will increase? That is, is there a mapping from short-term rates to long-term rates? Is this relationship stable over time? If it is stable, what fraction of the change in long rates will be a change in "real rates" as opposed to a compensation for changes in the price level? These questions are not of mere academic interest; they are of first-order importance for policymakers. Monetary policy acts on the short end of the yield curve, but it is the *real* long-term rate that is relevant for the investment decisions of firms that translate into economic growth. A stable mapping from short-term to *real* long-term rates is necessary if monetary policy is to be an effective tool for influencing real output. In fact, much of the debate on the effectiveness of monetary policy can be recast in terms of the stability of this mapping.

We plan to examine some of these questions through the lens of the *expectations hypothesis*. There are a number of versions of the expectations hypothesis, some of them mutually inconsistent (Cox et al. 1981). However, the difference in their implications is not *quantitatively*[16] significant. In this study, we use the version used by Campbell and Shiller (1991), as we use their methodology. Their interpretation emphasizes that the expected holding period returns on zero-coupon bonds of different maturities differ, at most, by a constant. This constant may depend on the time to maturity but it is *time invariant*. Equivalently, the hypothesis implies that the expected excess holding period returns of long bonds over short bonds—*the term premium*—is a constant. Any model where the product of the stochastic discount factor and bond price, $m^*_{t+1,t}P^n_{s-1,t+1}$ in Eq. 11 is log normally

[14]This is what is commonly done in practice.

[15]Backus et al. (1998) provide an excellent introduction to this literature.

[16]If bond returns are log normally distributed, it can be shown that the maximum "error" introduced by using one version instead of the other is bounded by $2 \times (2^{-1}\sigma^2)$; since the standard deviation σ of bond returns is typically a few percentage points, the quantitative effect is small. Technically, the error arises due to Jensen's inequality ($E\ \ln(x) \neq \ln\ E(x)$ and $E(1/x) \neq 1/E(x)$).

distributed implies a constant term premium and is consistent with the expectations hypothesis as we have defined it. This condition is satisfied by numerous term structure models, including Vasicek (1977).

Using the notation developed earlier, this implies[17]

$$E(h_{s,t+1} - h_{1,t+1}) = E(h_{s,t+1}) - y_{1,t} = \theta_s \tag{12}$$

or equivalently, using (8)

$$E(sy_{s,t} - (s-1)y_{s-1,t+1}) - y_{1,t} = \theta_s$$

which can be rewritten as

$$E(y_{s-1,t+1}) - y_{s,t} = \theta_s/(s-1) + (y_{s,t} - y_{1,t})/(s-1) \tag{13}$$

where θ_s is a time invariant constant.

An implication of the expectations hypothesis that follows from (13) is that if the current yield spread $\delta_{s,t}$ is high, the future long yield is expected to be higher than the current long bond yield. Intuitively, if the s-period bond has a higher yield than the one-period bond, the expected yield on the s-period bond should rise over the next period to induce a capital loss if the expected holding period returns are to be the same for the s-period and one-period bonds.

Another implication of the expectations hypothesis is that the long rate is an average of expected future returns per period over the life of the bond. Using (5) and (7) we see that

$$y_{s,t} = \frac{1}{s}\sum_{i=0}^{s-1} h_{s-i,t+1+i}$$

This has implications for the relative volatility of short and long rates: long-term bonds should be less volatile than short-term bonds.

In the next section, we explore the implications of the expectations hypothesis using data sets on Indian government securities.

4 Tests of the Expectations Hypothesis

In order to examine the nominal yield curve, we need the zero-coupon yield curve of government securities. Although most traded government bonds, especially those with long maturities are not pure discount bonds, they can be used to construct the

[17]Campbell et al. (1997) introduce yet another variation on the expectations hypothesis, the "pure expectations hypothesis." This is simply Eq. (12) with $\theta_s = 0$. We do not use this interpretation here.

zero-coupon yield curve. A widely used technique to do this is based on the Nelson-Siegel-Svensson methodology, detailed below.

The yield on a s-period zero-coupon bond $y_{s,t}$ is approximated as

$$y_{s,t} = \beta_0 + \beta_1 \frac{1 - \exp\left(\frac{-s}{\tau_1}\right)}{\frac{s}{\tau_1}} + \beta_2 \left[\frac{1 - \exp\left(\frac{-s}{\tau_1}\right)}{\frac{s}{\tau_1}} - \exp\left(\frac{-s}{\tau_1}\right)\right] + \beta_3 \left[\frac{1 - \exp\left(\frac{-s}{\tau_2}\right)}{\frac{s}{\tau_2}} - \exp\left(\frac{-s}{\tau_2}\right)\right] \tag{14}$$

where β_0 approximates the level of the yield curve, β_1 approximates its slope, β_2 the curvature, and β_3 the convexity of the curve. The convexity captures the hump in the yield curve at longer maturities (20 years or more). The specification in (14) is the Svensson (1994) extension[18] of the Nelson-Siegel (1987) formulation, which is a special case of (14) with $\beta_3 = 0$.

This technique of constructing nominal and real yield curves has been extensively used. Gürkaynak et al. (2007), for example, construct the zero-coupon nominal (and real) yield curve for the United States using this methodology.[19] The parameters β_0, β_1, β_2, β_3, τ_1, and τ_2 are estimated using maximum likelihood by minimizing the sum of squared deviations between actual Treasury security prices and predicted prices.[20] Other techniques for fitting the zero-coupon curve include McCulloch (1990), using cubic splines and the Fama and Bliss (1987) forward rate curve.[21]

The National Stock Exchange (NSE) uses the Nelson-Siegel (1987) methodology to estimate the zero-coupon yield curve for Indian government securities[22] using data on secondary market trades for government securities reported on the Wholesale Debt Market. This market constitutes approximately 70 % of the secondary market volume in the traded GoI securities. The methodology used is detailed in Darbha et al. (2000). A notable feature of the NSE methodology is that it uses prices for each individual trade, for each bond traded on a specific date, in contrast to the practice of using volume-weighted prices in deeper and more liquid markets.

In this study, we use the NSE data on the zero-coupon yields. Figure 4 shows a time series plot of this data for the period January 2005–April 2015. For purposes of comparison, the zero-coupon yields for the US over the same time period are shown in Fig. 5.

[18]This extension makes the fitted yield curve more flexible.

[19]The estimates for this nominal curve are updated daily, and are available from January 1972 on the Federal Reserve Board website.

[20]The prices are weighted by the inverse of the duration of the securities. Underlying Treasury security prices in the Gürkaynak, Sack, and Wright estimation are obtained from CRSP (for prices from 1961–1987), and from the Federal Reserve Bank of New York after 1987.

[21]For an application of this methodology to other countries see, for example, Jondeau and Ricart (1999).

[22]The yield curve is updated daily.

For the Indian case, nominal yields across the maturity structure move in tandem for most of the sample period, except between 2008 and 2010: even though the 1-year yield had fallen to approximately 5 % on average, 5- and 10-year yields remained significantly higher. It is interesting to note that a similar (albeit, opposite) discrepancy between the short- and long-term yields was observed in the United States in 2004: as 1-year yields rose, longer term yields remained flat and briefly declined. A similar disconnect between short and long rates was observed in the Indian data in 2011 and 2013.

A major difference between the US and Indian yields emerged in the aftermath of the financial crisis and the subsequent "Quantitative Easing" in the US. While US. long-term yields declined, Indian long yields have remained steady (and risen), except for the period between mid 2011–2013. Finally, compared to the near zero yields seen in the US, the short-term rates in India have been relatively high.

4.1 Tests of the Expectations Hypothesis

There is a large extant literature on testing the expectations hypothesis. A popular approach is to test if the condition in Eq. (13) holds using the regression methodology in Campbell and Shiller (1991). The difference between the ($s - 1$)-period yield expected next period, and the current s-period yield $y_{s,t}$ is regressed on the spread between the s and one-period yields:[23]

$$y_{s-1,t+1} - y_{s,t} = \alpha_s + \gamma_s \left(\frac{y_{s,t} - y_{1,t}}{s-1} \right) + \varepsilon_t. \tag{15}$$

The expectations hypothesis implies that the slope coefficient γ_s in the Campbell-Shiller regression[24] (15) should not be statistically different from one.[25]

While the Campbell-Shiller regression tests movements in long-term yields relative to the yield spread over short horizons, another strand of the literature tests long-term movements in short yields as predicted by the yield spread. Fama and Bliss (1987) construct a forward rate spread and test if this spread can predict the future spot rate. The authors find that the forecasting power of the term structure improves as the time horizon increases. In this chapter, we restrict our attention to the original Campbell and Shiller (1991) formulation.

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[23]Campbell and Shiller (1991) refer to the spread between the current s- and one-period yields as the "perfect foresight" spread.

[24]One of the concerns with the Campbell-Shiller regression is that the long yield $y_{s,t}$ appears on both sides of the regression. Thus, the negative sign may be a result of measurement error. To deal with this, Campbell and Shiller (1991) test the robustness of their results using instrument variables for the long yields.

[25]In addition, under the pure expectations hypothesis the intercept term should be zero.

Table 4 Campbell-Shiller slope coefficients for US nominal yields (γ^C are the slope coefficients of Eq. (15) reported by Campbell (1991) using estimated US monthly coupon yields for 1952–1987 from McCulloch (1990). γ^{DS} are the slope coefficients of Eq. (15) reported by Dai and Singleton (2002) using the Fama and Bliss (1987) dataset. The regressions are constructed using the 1-month yield as the one-period yield)

Coeffs	3 mo	1 yr	2 yrs	3 yrs	4 yrs	5 yrs	7 yrs	10 yrs
γ^C	−0.17	−1.38	−1.81	−2.23	−2.66	−3.09	na	−5.02
	(0.36)	(0.68)	(1.15)	(1.44)	(1.63)	(1.74)		(2.31)
γ^{DS}	−0.42	−1.42	−1.70	−1.19	−2.14	−2.43	−3.09	−4.17
	(0.48)	(0.82)	(1.12)	(1.29)	(1.41)	(1.51)	(1.70)	(1.98)

Numbers in parentheses are the corresponding standard errors

4.2 Campbell-Shiller Regression for US Data

The main finding for the US data sets is that the Campbell-Shiller slope coefficient is smaller than one, and becomes negative at longer maturities. This implies that when the yield spread in the regression in (15) is high, the yield on the long-term bond falls over the life of the short-term bond, instead of rising, as predicted by the hypothesis. The robustness of these findings on the slope coefficient, across sample periods, and combinations of yield maturities has been interpreted as a rejection of the expectations hypothesis in the data. Table 4 presents a summary of the results from two prominent analyses.

4.3 Campbell-Shiller Regression Using Indian Data Sets

> "Does the slope of the term structure-the yield spread between longer term and shorter-term interest rates-predict future changes in interest rates? And if so, is the predictive power of the yield spread in accordance with the expectations theory of the term structure? These questions are important, both for forecasting interest rates and for interpreting shifts in the yield curve."
>
> Campbell and Shiller (1991)

Given the central role of the expectations hypothesis in the term structure literature, we analyze this construct for the Indian case. To the best of our knowledge, the expectations hypothesis has not been tested in the Indian context.

We look at four specific time periods: January 2002–December 2007, January 2006–June 2009, and July 2009–April 2015 in addition to a complete data set from January 2002 to April 2015. The first sample data subset is the period marking the beginning of the worldwide financial crisis; the second period corresponds to a period of financial turmoil in the United States and the third period to the aftermath of the crisis. In our regressions, we use the 1-month Treasury bill rate as a proxy for the short rate.

Table 5 Campbell-Shiller coefficients for India nominal yields (The regression in (15) is constructed using the 1-month yield as the one-period yield) 2002:1–2015:4

	Yield maturity							
Coeffs	3 mo	1 yr	2 yrs	3 yrs	4 yrs	5 yrs	7 yrs	10 yrs
α	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.01
	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)
γ	4.00*	1.01	−0.32	−1.28*	−2.11*	−2.69*	−3.15*	−2.84*
	(0.97)	(1.41)	(1.51)	(1.40)	(1.35)	(1.22)	(1.90)	(2.50)

Numbers in parentheses are the corresponding HAC Newey-West standard errors. The asterisks denote coefficients statistically different from 1

Table 6 Campbell-Shiller coefficients for India nominal yields 2002:1–2007:12

	Yield maturity							
Coeffs	3 mo	1 yr	2 yrs	3 yrs	4 yrs	5 yrs	7 yrs	10 yrs
α	0.06	0.01	0.00	0.02	0.03	0.04	0.05	0.04
	(0.06)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)
γ	7.73*	2.77	−1.60	−4.74*	−6.69*	−7.68*	−8.02*	−7.32*
	(2.79)	(2.19)	(0.08)	(1.49)	(1.62)	(1.50)	(2.51)	(4.40)

Numbers in parentheses are the corresponding HAC Newey-West standard errors. The asterisks denote coefficients statistically different from 1

The slope coefficients of the Campbell-Shiller regression for the Indian nominal yield curve are reported in Tables 5, 6, 7 and 8.

Another implication of the expectations hypothesis is that when the yield spread is positive, short yields tend to rise to equate returns over the life of the long bond. To test this, we use the following regression, discussed in Campbell (1995):

$$\frac{\sum_{i=1}^{s-1} y_{1,t+i}}{s-1} - y_{1,t} = \alpha_s + \gamma_s \left(\frac{s-1}{s}\right)(y_{s,t} - y_{1,t}) + \varepsilon_t \tag{16}$$

Table 7 Campbell-Shiller coefficients for India nominal yields 2006:1–2009:6

	Yield maturity							
Coeffs	3 mo	1 yr	2 yrs	3 yrs	4 yrs	5 yrs	7 yrs	10 yrs
α	0.18	0.05	−0.01	−0.03	−0.02	−0.01	0.00	0.01
	(0.09)	(0.06)	(0.07)	(0.09)	(0.09)	(0.09)	(0.10)	(0.07)
γ	7.33*	4.74*	2.02	−1.15	−3.97*	−5.93*	−7.18*	−5.28
	(2.24)	(1.56)	(2.65)	(3.33)	(3.02)	(2.79)	(2.54)	(4.83)

Numbers in parentheses are the corresponding HAC Newey-West standard errors. The asterisks denote coefficients statistically different from 1

Table 8 Campbell-Shiller coefficients for India nominal yields 2009:7–2015:4

	Yield maturity							
Coeffs	3 mo	1 yr	2 yrs	3 yrs	4 yrs	5 yrs	7 yrs	10 yrs
α	0.03	0.04	0.04	0.03	0.02	0.01	0.01	0.00
	(0.06)	(0.04)	(0.04)	(0.03)	(0.03)	(0.02)	(0.02)	(0.03)
γ	2.32*	−1.19*	−1.70*	−1.25*	−0.91*	−0.73*	−0.63	−0.50
	(0.45)	(0.86)	(1.25)	(0.94)	(0.80)	(2.79)	(2.54)	(2.22)

Numbers in parentheses are the corresponding HAC Newey-West standard errors. The asterisks denote coefficients statistically different from 1

Table 9 Additional test of the expectations hypothesis for 2002:1–2015:4

	Yield maturity							
Coeffs	3 mo	1 yr	2 yrs	3 yrs	4 yrs	5 yrs	7 yrs	10 yrs
α	0.04	0.08	0.11	0.08	0.11	0.09	0.09	1.42
	(0.06)	(0.14)	(0.18)	(0.20)	(0.21)	(0.22)	(0.16)	(0.31)
γ	4.77*	1.33*	1.25*	1.20*	1.13*	1.08	0.95	−0.01*
	(0.86)	(0.15)	(0.09)	(0.08)	(0.08)	(0.08)	(0.08)	(0.30)

Numbers in parentheses are the corresponding HAC Newey-West standard errors. The asterisks denote coefficients statistically different from 1

This equation tests the relation between long-run changes in the short-term interest rate and the yield spread for the 2002–2015 period. As before, if the expectations hypothesis holds, the slope coefficient should not be statistically different from one. The results are presented in Table 9; we find that for yield maturities up to 4 years, slope coefficients are statistically larger than one. We interpret this to imply that the yield spread has significant predictive power for long-run changes in the short rates only up to the 4-year maturity. Campbell (1995) finds that in the US, the yield spread has predictive power for both the short and long end of the maturity structure, but not at the medium term. However, as in the US data, the results in Table 9 appear to contradict those of Table 5. Campbell (1995) suggests that this may not be the case. In accordance with his analysis, the size of the slope coefficients at the 5- and 7-year maturities in Table 9 suggests that Indian investors are better informed about future movements in short-term interest rates at medium-term horizons, rather than at the shorter end of the maturity structure.

Here the regression is tested on the full sample set. For shorter subsamples, the computation of long-run changes in the short rate leads to a large reduction in the length of the time series.

We also compute the term structure of variances for the Indian nominal yield curve, (shown in Table 10) and contrast these to the US data in Table 11.

Table 10 Variances across the term structure for India

	3 mo	1 yr	2 yrs	3 yrs	4 yrs	5 yrs	7 yrs	10 yrs
2002:1:2015:4	2.59	1.99	1.61	1.39	1.26	1.16	1.02	0.86
2002:1:2007:12	1.37	1.05	0.92	0.88	0.86	0.85	0.84	0.82
2006:1:2009:6	1.95	1.51	1.20	0.97	0.81	0.68	0.53	0.43
2009:7:2015:4	2.73	1.63	0.93	0.59	0.41	0.32	0.24	0.20

Table 11 Variances across the term structure for US data

	1 yr	2 yrs	3 yrs	4 yrs	5 yrs	7 yrs	10 yrs
1972:1:2015:5	12.49	11.90	11.20	10.52	9.90	8.88	7.84
1984:1:2007:12	5.24	5.20	5.07	4.92	4.78	4.50	4.15
2006:1:2009:6	3.17	2.58	2.01	1.52	1.13	0.62	0.29
2009:7:2015:4	0.01	0.05	0.13	0.23	0.31	0.45	0.55

4.4 Results

For the period 2002–2015 and the subperiods of interest our results provide strong support for the predictability of nominal yields and for the predictability of their difference in Indian bond data. As Table 5 (which spans the entire sample period) documents, the estimated slope coefficients γ are significantly different from zero for all bonds with duration 3 or more years, a pattern broadly repeated in Tables 6, 7 and 8. However, these coefficients are also significantly different from 1, which implies a rejection of the null hypothesis that the expectations hypothesis holds.

Our results for the entire sample period (Table 5) are surprisingly similar to those for the US documented in Table 4. As the yield to maturity rises, patterns seen in the Campbell-Shiller coefficients for US data are replicated: the slope coefficients are smaller than 1, and negative. This implies that as the short yields rise, the expected long yields fall, instead of rising as predicted. The subsample analyses are also informative: other than at the very short end of the term structure,[26] the slope coefficients for Indian data are quantitatively similar to those of the US Notably, in the second and third subsamples, the deviations from the expectations hypothesis at the long end of the yield curve are almost double the coefficients observed for the US and, in the most recent sample, the size of the slope coefficients are significantly smaller.

A naïve strategy of buying high yielding long-term bonds would have paid off handsomely over the past 15 years, contrary to the predictions of the expectations hypothesis. The negative slope coefficients (notably large in Tables 6 and 7) imply that in addition to high yields, investors in these bonds would have realized a

[26]For bonds with duration less than 2 years, in many instances we cannot reject the expectations hypothesis. This is in contrast to the observations in the US.

substantial capital gain. However, investors holding high yielding bonds with maturity less than 1-year would have realized capital losses.

Our results on the term structure of variances for the Indian nominal yield curve are consistent with the implications of the expectations hypothesis: the variance of the yields on longer duration bonds is smaller than the variance of bonds with a shorter duration. Over most time periods the variance of the 10-year yield is less than half of the variance of the 1-year yield.

Our observations are in contrast to those in the US. As Table 11 shows, in the most recent period, the long end of the curve is more volatile than the short end. During the Great Moderation period (1984–2007), the variance of the 10-year yield is approximately 80 % of the 1-year yield implying that long bonds were excessively volatile. This "volatility puzzle" is not observed in the Indian data.

5 Rationalizing the Rejections of the Expectations Hypothesis

The consistent rejections of the expectations hypothesis and the implied predictable variation in excess returns for long bonds[27] has been a "puzzle" as it suggests a trading strategy[28] with higher expected returns than implied by the constant term premium model. A number of explanations have been offered for this "predictability" in bond returns. These explanations can be broadly classified into three categories:

a. Failure to account for a time-varying risk premium
b. Bounded rationality and policy credibility of the central bank
c. The small sample properties of the test itself.

In the following discussion, we analyze these explanations in some detail.

Time-Varying Risk Premium: There is a strand of literature that argues that the "term premium" regression in (15) is time varying and the failure to account for this leads to a bias in the slope coefficient. A number of models that allow for a time-varying term premium can rationalize the deviation of the slope coefficients from one as a "risk premium."

Wachter (2006) introduces external habits in a consumption-based asset pricing model with a short interest rate that varies with surplus consumption. This endowment economy is successful in generating the negative Campbell-Shiller coefficients as a risk premium that is positive and varies in a countercyclical manner. Bansal and Shaliastovich (2012) show that the predictability in bond

[27]As evidenced by the slope coefficients of the Campbell-Shiller regression being different from 1.

[28]As noted by Campbell (1995), going long in bond holdings during periods in which the yield curve is steep, and shorting in periods of a flat yield curve is an investment strategy that has, historically, produced higher than average returns.

returns can arise due to a time-varying risk premia that increases with uncertainty about expected inflation and falls with uncertainty about expected growth.

While the literature has focused primarily on using the covariation or risk premia term to explain predictability in expected excess returns, there is increasing evidence to suggest that subjective expectations, which are different from those implied by the true probability distribution of the underlying process of returns, may be important.

Bounded Rationality and Credibility of Central Bank Policy: This explanation proposes that investors in financial market have irrational expectations. The regression in (15) is a joint test of the expectations hypothesis and the belief that investors have rational expectations. If the latter is not true, the regression error will no longer be orthogonal to the regressor and the slope coefficient will be biased. Kozicki and Tinsley (2001) and Fuhrer (1996) use shifts in agents' expectations about monetary policy to explain the rejection of the hypothesis in US data. In the first paper, the authors link changes in long-run forecasts of short yields to shifts in perceptions about the inflation target. Adaptive learning is used to model agents' behavior as they update their estimates of the long-run inflation target. These shifting endpoints in the short rates are incorporated into the determination of longer yields, and the expectations hypothesis is no longer rejected. Fuhrer (1996) models the short rate as being determined by the Federal Reserve, in response to output gap and inflation. He finds that the changes in the Federal Reserve's inflation target and response coefficients (to output gap and inflation) lead to variations in the long nominal rates of the magnitude that are observed in the data.[29] He concludes that if shifts in the expectation formation process of future short rates is accounted for, the hypothesis fares well relative to the data.

A rich literature has attempted to explain the findings on the Campbell-Shiller coefficients by allowing for a time-varying term premia and subjective expectations. It is also useful to interpret the negative bias with respect to 1 as the under-reaction of expected future yields of maturity $(s - 1)$ to changes in the current short yield. In Froot's (1989) analysis, the test of the expectations hypothesis in (15) is decomposed into two slope coefficients, one corresponding to the error in expectations and the other a term premium. The first is found to be negative, that is, a portion of the deviation of γ from one can be attributed to errors in expectations. It is also found that at longer maturities, the slope coefficient corresponding to the term premium becomes quantitatively less important.

Mankiw and Summers (1984) also reject the hypothesis that expected future yields are excessively sensitive to changes in the contemporaneous short yield, along with the expectations hypothesis. They test if myopic expectations can justify the rejections of the expectations hypothesis, but the latter is rejected as well—that is, financial markets are "hyperopic," giving lesser weight to contemporaneous fundamentals than to future fundamentals.[30]

[29]The long rates are derived using the expectations hypothesis.

[30]The authors use the term premia to explain the rejections of the expectations hypothesis.

Piazzesi et al. (2015), Sinha (2016) highlight the importance of subjective expectations. In the first paper, using survey data for professional forecasters in the US, the authors show that prior to 1980, when the level of yields was rising and the yield spread was small, survey forecasters predicted lower long yields than those that would be predicted by a statistical model. Since the forecasters update their information about high long yields slowly, they predict lower excess returns than were observed in the data. Thus, when the yield spread was low, and yield levels were high, survey forecasters predicted that long rates would fall, as seen in the empirical data. In Sinha (2016), the fact that optimizing agents misperceive the current increase in the short yield (due to a monetary policy shock) as an increase in yields for decisions they face over the infinite horizon results in a fall in the actual expected future yields. Therefore, in an endowment economy framework, the fact that the adaptive learners update their beliefs about yield processes slowly leads them to predict different paths of yields than under the true model. Nimark (2012) uses a model of trading to show that when traders have differential information, the non-nested information sets imply that individual traders can systematically exploit excess returns. They are able to take advantage of the forecasting errors of other traders in the model, even when no trader is better informed than the other. In Nimark's analysis, traders are rational, and the dispersion in their expectations about bond returns are caused by observing different signals. Under perfect information, the expectations hypothesis holds. However, when information sets are non-nested, and long bonds are traded frequently (and not necessarily held to maturity), the hypothesis no longer holds and excess returns are predictable.

Kozicki and Tinsley (2005) explore bounded rationality of agents and relate it to the credibility of monetary policy. Long-term yields have long horizon inflation expectations built into them. When the gap between long horizon inflation expectations and current inflation is large, the difference between long and short rates will also be large (this is the spread that appears in equation (15)). This may also be interpreted as low perceived credibility of policy. As policy credibility rises, long rates will fall. Thus, a large spread (reflecting low policy credibility) will precede falling long rates, as credibility improves.

Properties of the Campbell–Shiller Test: Finally, the expectations hypothesis may be rejected in the data because of the poor properties of the test itself, for finite sample data. This may be due to high persistence in variables or learning. Bekaert and Hodrick (2001) consider the Expectations Hypothesis in a vector autoregressive (VAR) framework. The VAR is estimated subject to the constraints of the expectations hypothesis, and the authors use this system to generate data and investigate the small sample properties of a variety of tests, such as the Wald test. They find that the rejections of the hypothesis may be explained, in part, by the poor properties of the Wald test in finite samples.

The rejections of the expectations hypothesis in the Indian context may arise due to a combination of the diverse factors detailed above. Additional research is required to disentangle and decompose the concomitants of predictability in expected returns.

6 Information in the Term Structure, Policy Implications and Concluding Comments

The joint term structures of real[31] and nominal interest rates encode critical information about risk free discount factors and expectations of future inflation. Both are crucial inputs for financing and investment decisions. Discount factors are a benchmark for the pricing of financial assets in the economy and for determining the cost of capital for capital budgeting, while expectations about future inflation impact the formulation and implementation of monetary policy.

Policymakers use the nominal term structure to infer expectations of inflation and real interest rates. As Haubrich et al. (2012) note, "Inflation expectations can gauge the credibility of a government's fiscal and monetary policies, whereas real rates measure the economic cost of financing investments and the tightness of monetary policy."

Changes in the level of nominal yields can be attributed to changes in the real interest rate, expected inflation or the inflation risk premium. Furthermore, the term structure of nominal expected returns can be decomposed into the real interest rate, the premium for holding a real long-term bond (the excess returns of holding nominal long-term bonds over real bonds), expected inflation and the inflation risk premium. An empirical identification of these different components, and their response to different inflation regimes, has been a rapidly expanding area of research for developed economies. Bansal and Shaliastovich (2012) use survey data on GDP growth and inflation for the US between 1969–2010 to identify the link between nominal bond premia and volatilities in expected growth and expected inflation. Uncertainty in real growth and inflation are found to have significant predictive power for excess bond returns. The authors also find that the nominal term premia decreases when real uncertainty declines, and increases with rising inflation uncertainty. Similar results are obtained for U.K. data. Ang et al. (2008) use a model with regime switches, inflation and time-varying prices of risk to identify whether changes in the nominal yields can be attributed to real interest rates, expected inflation or inflation risk premia. The authors document a negative correlation between the real short rate and expected as well as unexpected inflation.

Identifying the effects of expected inflation and inflation surprises on the real interest rates for the Indian case has been relatively unexplored so far. There is evidence to suggest, however, that there may be different inflation regimes in the Indian data. Hutchison et al. (2013) use a regime-switching model to investigate the monetary policy rule in the Indian context. The authors find that the Reserve Bank of India did not adopt inflation targeting; empirical estimates suggest that the RBI switched between two regimes, which are distinguished by their relative emphasis on output and price stability. This suggests that investigating the link between

[31]In the Indian context, however, the real term structure of interest rates is not available as inflation indexed bonds have only been recently introduced. Hence expectations about future inflation cannot be inferred from the term structure.

Table 12 Response of Zero-coupon yields to changes in the RBI policy repo rate

1-year	5-years	10-years
2002:1–2015:4		
0.86*	0.56*	0.32*
(0.37)	(0.20)	(0.16)
2002:1–2007:12		
0.29	0.35*	0.27*
(0.27)	(0.13)	(0.13)
2006:1–2009:7		
1.55*	0.84*	0.43
(0.34)	(0.32)	(0.30)
2009:7–2015:4		
−0.20	0.21	0.21*
(0.35)	(0.13)	(0.10)

Note This table reports the slope coefficients (β) from the regression in Eq. (17). The numbers in brackets are the heteroscedasticity adjusted standard errors. The starred coefficients are statistically different from zero

varying inflation volatility, nominal excess returns, and the real interest rate is an important avenue for future research in the Indian context, which we intend to explore in subsequent work.

While monetary policy clearly affects the short end of the yield curve it is the *real* long-term rate that is relevant for the investment decisions of firms that translate into economic growth. Much of the debate about the effectiveness of monetary policy can be recast in terms of the mapping from short-term to *real* long-term rates. There is, however, considerable disagreement in the literature about the effectiveness of monetary policy in affecting real economic activity.

Starting in May 2011 the RBI has used the repo rate as an instrument to implement monetary policy.[32] Lacking data on the real term structure, we explore whether nominal long-term zero-coupon yields at different maturities respond to changes in this policy rate. We consider the following regression:

$$\Delta y_{s,t} = \alpha + \beta(\Delta \text{repo}_t) + \varepsilon_t \tag{17}$$

Table 12 presents the response of the 1-, 5- and 10-year yields to the change in the repo rate.[33]

[32]Source: RBI's Handbook of Statistics on the Indian Economy.

[33]Since we are using monthly data, there are several qualifications to our exercise. As noted by Gürkaynak et al. (2005), this regression may be subject to the simultaneous equation or omitted variables bias. For example, the change in the RBI's policy rate may be a response of the rate to the change in asset prices that took place in the previous month. That is, the change in the policy rate is not a surprise. Analysis of the change in daily yields in response to surprise changes in the repo rate is a promising topic for future research.

While there is clear evidence of predictability in the data, we find that the mapping from short-term to *nominal* long-term rates over the period 2002–15 is not stable.[34] Our results imply that implementing monetary policy in India would prove to be a challenging exercise.

Appendix

Data Sources

Statistic	Source
Total Internal Marketable Debt	Outstanding central government debt from: Handbook of Statistics on Central Government Debt
Gross Fiscal Deficit and its Financing	Handbook of Statistics on the Indian Economy, 2013–14 (Table 105). RBI publication
GDP at Market Prices	Handbook of Statistics on the Indian Economy, various editions. RBI publication
Ownership patterns of GoI Securities	Handbook of Statistics on Central Government Debt

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[34]It is possible that the mapping from *real* short-term to *real* long-term rates is stable but the risk premium for inflation is time varying.

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