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VALIDITY OF EXPECTATION HYPOTHESIS: INFORMATION CONTENT OF TERM STRUCTURE

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ABSTRACT

This study tests the validity of the Expectations Hypothesis (EH) in an emerging market context and the utility of the information content of the term structure to predict the interest rate changes. This study extends the model used by Bulkley *et al.* (2011) to test the Expectation Hypothesis with a feature to allow for an unobservable Markov regime switching. The results reveals that the long and short term rates were found co-integrated before the onset of 2008 Global Financial Crisis, whereas, after the crisis, these were only partially co-integrated. These results marginally support the validity of expectation hypothesis in the Indian market. Further, it was found that the yield spread and the forward spot spread contained useful information to predict the interest rate changes. The results of the study provide valuable insights to the policy makers for efficient monetary policy management.

Contribution/ Originality: This study uses new estimation methodology to test the Expectation Hypothesis with a feature to allow for an unobservable Markov regime switching. This is one of the very few studies that test the validity of the Expectation Hypothesis in the context of the emerging Indian bond market.

1. INTRODUCTION

The finance literature widely deliberates about the validity of Expectations Hypothesis (EH) and information content of the term structure of interest rates. However empirical evidence still remains inconclusive. While most of empirical studies in US have rejected the EH, many European studies have reported its validity (Bekaert and Hodrick, 2001; Clarida *et al.*, 2006; Guidolin and Thornton, 2008; Musti and D'Ecclesia, 2008; Beechey *et al.*, 2009; Finlay and Jones, 2011; Zhu, 2011).

According to the EH, the long term interest rate represents the weighted average of the current and expected future short term rates over the holding period, plus a time invariant term premium. The two main reasons for the rejection of EH reported in the literature are the 'overreaction' hypothesis and the 'variable risk premium' hypothesis. The overreaction hypothesis states that long term rates overreact to changes in the short term rates

(Kugler, 1996). As per the variable risk premium hypothesis, the long term rates not only contain information about future short term rates, but also include the time varying risk premium (Mankiw and Miron, 1986). According to Hardouvelis (1994) the time varying risk premium hypothesis is the reason behind the rejection of EH with respect to G7 countries, while the overreaction hypothesis is the reason for the rejection of EH in the US market.

The theory of expectation hypothesis (EH) is based on the concept of the efficient market hypothesis and explains the relationship between interest rates of various maturities. If EH holds valid, forward rates reflect an unbiased forecast of the future short term interest rates. It helps to predict the direction of the changes in the future interest rates (Fama and Bliss, 1987) and also provides effective Monetary policy transmission (Beyaert and Pérez-Castejón, 2009) which is vital of emerging markets.

The Indian economy has evolved as an emerging market in the world and its average growth rate has been above 7% in the last decade. This rapid growth, together with the financial market liberalization, attracted foreign investors and the market received large investment inflows. However, there is only scant literature and the efficacy of the Indian bond markets is still largely unknown to both domestic and foreign investors, which was the motivation for this research.

The study investigates the validity of EH in the emerging market environment and the findings provide insights to the policy makers and the market participants about the efficiency of the Indian bond markets. The purpose of this study was to:

- Test the validity of the expectation hypothesis (EH) in the Indian bond markets.
- Examine the information content of the current interest rates to estimate interest rate changes.
- Further, investigate the impact of the global financial crisis on this relationship.

The results reveals that the long and short term rates were found co-integrated before the onset of 2008 Global Financial Crisis, whereas, after the crisis, these were only partially co-integrated. These results marginally support the validity of expectation hypothesis in the Indian market. Further, it was found that the yield spread and the forward spot spread contained useful information to foresee the interest rate changes.

This study extends the model used by Bulkley *et al.* (2011) to test the Expectation Hypothesis with a feature to allow for an unobservable Markov regime switching. This is one of the very few studies that test the validity of the Expectation Hypothesis in the context of the Indian bond market. The results of the study provide valuable insights to the policy makers for efficient monetary policy management.

The paper is organized as follows: Section 2 describes the data used; Section 3 contains the methodology, Section 4 includes the empirical results; and Section 5 provides the conclusions.

2. DATA

The study has used the zero coupon yield rates of various maturities of government securities. The National Stock Exchange (NSE) in India estimates the zero coupon yield rates for various maturities using the Nelson and Siegel (1987) model. The estimated zero coupon yield rates for each trading day are archived and made available in the Wholesale Debt Market (WDM) database.

Monthly zero coupon yield rates from January 2003 to December 2013 have been used in the present study. The zero coupon yield rates of 0.5, 1, 3, 5, 6, 7 and 10 years are used for analysis. Table 1 presents the descriptive statistics of the zero-coupon yield rates of various maturities. The volatility in the yields of short term maturities was observed to be higher than that of the long term maturities.

Figure 1 shows that in 2003, the 1 year bond was trading at yield rate of 3%, while the 10 year bond was trading at around 6%. Both the rates shifted upwards in 2008 at the onset of the global financial crisis - the 1 year yield rate shifted to 6% and the 10 year rate shifted to around 8%. Subsequently in 2008-09, RBI slashed the benchmark repo rate by about 400 basis points to bring market stability. The repo rate was reduced from 9% to 4.75% and the reverse repo rate was reduced from 6% to 3.25%.

3. METHODOLOGY

3.1. Tests for Long-Run Relationship: Co-Integration

The long-run relationship between yield rates of different maturities was investigated using the co-integration tests. The Engle Granger Co-integration test (Engle and Granger, 1987) was used when the both the variables were not stationary at level but were at first difference. The Autoregressive Distributed Lag (ARDL) approach was followed when one of the variables was stationary at level and other was stationary at the first difference (Pesaran and Pesaran, 1997).The co-integration among different maturity yield rates is a necessary condition but not the sufficient condition to validate the expectation hypothesis. Hence, in order to test the necessary conditions for validating EH, this research study utilized a regression model proposed by Bulkley *et al.* (2011)

3.2. Tests for Expectation Hypothesis

In this research study, the information content of term structure and validity of EH were tested using the models proposed by Bulkley *et al.* (2011).

$$y_{t+m}^{(n-m)} - y_t^{(n)} = \alpha_h + \beta_h \frac{m}{n-m}\left(y_t^{(n)} - y_t^{(m)}\right) - u_{h,t+m}; \qquad (1)$$

Where, $y_t^{(n)}$ represents the yield rate on long term bond (say n= 3 year),

$y_t^{(m)}$ represents the yield rate on short term bond (say m =1 year),

$y_{t+m}^{(n-m)}$ represents the yield rate on n term bond after m years (say 3 year bond rate after 1 year),

$y_{t+m}^{(n-m)} - y_t^{(n)}$ represents the change in the yield rate on long term bond (n) over the m period

For example, $y_{t+1}^{(3-1)} - y_t^{(3)}$ represents the change in the yield rate on 3-year bond over the 1 year.

α_h is the time invariant risk premium term and $u_{h,t+m}$ is error term

$y_t^{(n)} - y_t^{(m)}$ represents the current yield spread measured as the difference in the yield rate of n and m term bonds

(spread = 3 year yield rate – 1 year yield rate)

$\beta_h \frac{m}{n-m}$ represents the slope coefficient of yield spread

For EH to hold, the coefficient β_h should be equal to unity i.e. $\beta_h = 1$ (Bulkley *et al.*, 2011). For the pure expectation hypothesis to hold valid, in addition to the above condition, the risk premium term should be zero i.e. $\alpha_h = 0$.

Similarly, according to EH, if the forward rates represent the unbiased future short term rates, then β_f should be equal to unity i.e. $\beta_f = 1.$

$$y_{t+k}^{(m)} - y_t^{(m)} = \alpha_f + \beta_f\left(f_k^{(m)} - y_t^{(m)}\right) - u_{f,t+n-m}; \quad (2)$$

Where $f_k^{(m)}$ represents the *m*-period forward rate, *k* period from now

For example, $(f_{12}^{(6)})$ represents the 6 month forward rate, 12 months from now

$y_{t+k}^{(m)}$ represents yield rate of *m* period bond after *k* period

$y_{t+k}^{(m)} - y_t^{(m)}$ represents the change in the yield rate of m- period bond over k periods

$f_k^{(m)} - y_t^{(m)}$ represents the forward-spot spread

α_f is time invariant risk premium and $u_{f,t+k}$ is error term

In the above estimations (Eqn. 1 & 2), if $\beta_h \neq 1$ and $\beta_f \neq 1$, but greater than 0, then this implies that even though EH doesn't hold valid, still the yield spread and forward-spot spread observed at time *t* have some information to forecast the changes in future interest rates.

3.3. Tests for Impact of the Global Financial Crisis: Markov Regime Switching Approach

The study extended the approach used by Bulkley *et al.* (2011) with a feature to allow for the unobservable Markov switching regime, to test the expectation hypothesis of term structure. Equations (1) and (2) can be written in the Markov switching regression form as:

$$y_{t+m}^{(n-m)} - y_t^{(n)} = \alpha_{h,s_t} + \beta_{h,s_t}\frac{m}{n-m}\left(y_t^{(n)} - y_t^{(m)}\right) - \varepsilon_{h,t+m,s_t}; \quad (3)$$

With $\varepsilon_{h,t+m,s_t} \sim N(0,\sigma_{s_t}^2)$ and state variable s_t = 1, 2

$$y_{t+k}^{(m)} - y_t^{(m)} = \alpha_{f,s_t} + \beta_{f,s_t}\left(f_k^{(m)} - y_t^{(m)}\right) - \varepsilon_{f,t+k,s_t}; \quad (4)$$

With $\varepsilon_{f,t+k,s_t} \sim N(0,\sigma_{f,s_t}^2)$ and state variable s_t = 1, 2.

4. EMPIRICAL RESULT

4.1. Relationship between Long and Short Term Interest Rates

The co-integration between long and short term interest rates, primarily establishes the long run equilibrium across maturity spectrum. As the model requires the time series data to be stationary. The presence of unit root was examined using the Augmented Dickey Fuller (ADF) test and Philips Perron (PP) unit root test.

Table 2 presents the results of the ADF and PP tests for bond yields of different maturities at level. The bond yields with maturities of 0.5, 1, 5 and 10 years were found non-stationary at level. Hence, unit root was tested for data at the first difference and results are shown in Table 3. At the first difference, the bond yields of all maturities were found stationary. Thus, 0.5, 1, 5 and 10 year years bond yields were integrated of order 1, *I(1)*, whereas 3 and 7 year yields were found stationary at level.

Since, the 3 year and 7 year yields were not satisfying the conditions of the Engle Granger co-integration test, the Autoregressive Distributed Lag (ARDL) approach was applied to test the co-integration for the data combination with *I(0)* and *I(1)* data series (Pesaran and Pesaran, 1997).

The co-integration test was conducted initially for the full sample period from January 2003 to December 2013, and the residuals were tested using Engle Granger's ADF test. Table 4 presents ADF t statistic along with ARDL F statistic. The critical values of the Engle Granger's ADF test developed by MacKinnon (1991) and the critical value of the ARDL's Bound test developed by Pesaran and Pesaran (1997) were used for reporting the statistical significance level.

The zero coupon yield rates of various maturities were found co-integrated for 7 out of the 11 different combinations that were tested. The results indicate the evidence of long term relationship between short term and long term yield rates.

Further, to explore the impact of the 2008 global financial crisis on the interest rate movements, the time series data of zero coupon yield rates was divided into two sub-samples based on the break-point obtained through the Zivot-Andrews test (Zivot and Andrews, 2002). The period from January 2003 to October 2008 is considered as the pre-crisis period and November 2008 to December 2013 as the crisis affected period. The structural break is also visible in Figure I, which reveals a sharp fall in the yield rates across maturities during the last quarter of 2008.

In the pre-crisis period, the yield rates of all maturities were found stationary at first difference and hence, the Engle Granger (EG) co-integration test was used. In the crisis affected period, the ARDL approach was applied for the data which were found stationary at different order. The results for pre-crisis period presented in Table 5 show strong evidence of co-integration among the interest rates. The results also indicate that the short and long term yield rates had long-run equilibrium, thus supporting the validity of EH before the onset of the global financial crisis.

The results for the crisis affected period, reported in Table 6, show only partial evidence of co-integration. The different levels of integration infer that the normal long run equilibrium, generally found, did not hold valid during the economic cycles. During this period, the stock markets went through a roller coaster ride, and offered either low or negative returns. The crisis also induced a reversal of capital flows, which further affected the stock markets. Investors in the market turned to risk free government securities for investments. The additional demand resulted in an increase in prices and fall in the yield rate of government securities.

All these events exacerbated the domestic liquidity conditions. The Reserve Bank of India intervened through open market operations to ease the liquidity pressure in the market. The central bank slashed the bench mark repo rate to boost the demand for borrowing and investment in the economy. At the same time, to fund the fiscal stimulus announcements, the Central Government carried forward a large market borrowing program. These events led to the decoupling of short and long term interest rates. Thus, the long run equilibrium observed in the pre-crisis period was not found to be significant during the crisis affected period.

4.2. Information Content of Yield Spread, Forward-Spot Spread and Validity of EH

Though co-integration establishes a long run equilibrium relationship across the maturity spectrum, it is a preliminary test and is not sufficient for validating the EH. Hence, in order to check the necessary conditions for validation of EH, this study utilized the model proposed by Bulkley *et al.* (2011) as given in Eqns. (1) and (2)

Expectation Hypothesis was tested from the relationship between the yield spread and the change in the yield of long term bond over a period of time. Table 7 reports the OLS regression results, where the dependent variable represents the change in yield on long term bonds and the explanatory variable represents the yield spread as in Equation (1).The regression equation was estimated by the Ordinary Least Square (OLS) method for the long maturity periods of n = 3, 4, 5, 6 and 7 years and short term maturity of m=1 year. The estimated β_h coefficients were significant for four out of five different maturities (m = 4, 5, 6 and 7 year).

The β_h coefficients of the estimated regression equation were positive, which means that the long term rates moved in the direction of the short term rates as implied by the expectations hypothesis. However, β_h coefficients were significantly greater than unity. These results are contradictory to the observations made for US markets (Campbell and Shiller, 1991; Bulkley *et al.*, 2011). The estimated slope coefficients were found negative and significantly lower than unity for US bond yields.

The exact form of EH proposes that β_h =1. This study examined if the estimated coefficients were equal to 1, through the statistical significance of computed t statistics (Wooldridge, 2008). The t statistics was computed by taking the difference between estimated beta coefficients and a hypothesized beta value of one, and then dividing the same by the standard error [(*Estimated* β_h-1)/ *Standard Error*)]. Table 7 clearly shows that t was not found to be statistically significant for 4 out of the 6 maturity pairs tested, accepting the null hypothesis that β_h =1. The results indicate the partial validity of EH in India. However, the R-square value was smaller, indicating that merely the information content of the yield spread is not enough to forecast the movement of long term rates. Engsted (1996) explained that low R-square values are due to the fact that most of the variation in interest rate changes cannot be predicted only by the yield spread.

Further, risk premium α_h which is expected to be zero as per EH, was found to be very small and close to zero in all the cases. The results show the linkages between changes in short and long term rates and lend marginal support for EH.

Table 8 reports the regression results where the dependent variable represented the changes in short term yield rate and the explanatory variable represented the forward-spot spread as in Eqn. (2). The short term represented 3, 6 and 12 month yield rates. The β_f coefficients of the regression were positive and were significant at 1% level for four out of the five forward rates considered. The β_f coefficients, though considerably more than zero, were not closer to unity. The results of the forward yield spread regression on Indian bond yield data were consistent with the results reported by Musti and D'Ecclesia (2008) on Italian yields and Bulkley *et al.* (2011) on U.S bond yield rates. The results infer that the forwards rates have some information to predict the future short-term interest rate changes. Estimated β_f coefficients had value typically lower than 1, whereas the exact form of the expectations hypothesis requires that β_f =1. Even though the exact form of EH was not valid, the statistical significance of the positive beta coefficients indicate that forward-spot spread observed at time t still has useful information to forecast the changes in future spot rates.

4.3. Impact of the Global Financial Crisis on Interest Rate Movements

Business cycles and the consequent changes in monetary policy influence the interest rate movements and cause them to behave differently in different time periods (Ang and Bekaert, 2002). During financial crises, the market uncertainty causes structural breaks and shifts in the regime. These shifts violate the assumption of the linearity in the model estimation. In order to account for the non-linearity, the Markov switching model is used to test EH (Hamilton, 1988; Engsted and Nyholm, 2000; Beyaert and Pérez-Castejón, 2009). The main benefit of the

Markov switching is its flexibility to model regime shifts in the time series data. The model allows all the parameters to be conditional upon on the state s_t . The Markov chain also has finite number of states defined by the transition probability matrix (Hamilton, 1988; Krolzig, 2000).

4.4. Global Financial Crisis and the Presence of Two States across the Term Structure

The sample period spans across 10 years, from Jan 2003 to Dec 2013. This sample period encompassed both the growth phase as well as the market fall resulting from the crisis in the global financial markets. 2003-2007 was a bullish phase for Indian financial markets, whereas 2008-13 was a crisis affected bearish period. In order to understand the crisis effect across the tem structure, a univariate Markov regime switching model was employed to analyze the data distribution properties and characteristics of yield rates across various terms.

Generally, the returns would be positive and the volatility would be lower for a rising bull phase of a market. Negative returns and higher volatility characterize a falling market and a bearish phase. Table 9 presents the mean and variance for two regimes across maturity spectrum. The mean (μ_1, μ_2) and variance terms reported in the Table broadly confirm that state 1 represents the bullish phase with positive returns and state 2 represents the bearish phase with negative returns. Similarly, the volatility of state 1 was generally found lower as compared to that of state 2.

In order to understand the impact of the global financial crisis, Eqns. (3) and (4) were estimated to test the information content and EH using the Markov regime switching approach. The Markov regime regression was estimated for the pair of long term maturity taking n = (3, 4, 5, 6, 7 and 10 years) and taking short term m = (1 year) respectively. The results are reported in Table 10. In state 1, the β_h coefficients of the regression were positive and significant at 1% level for only three out of the six tested maturity pairs. Also, in state 2, for 4 out of 6 maturities pairs, β_h was positive and significant at 1% level. In state 2, most of the estimated β_h coefficients were positive and the values were above unity. In high-volatile regimes, changes in the long term yields follow the changes in the yield spread as implied by the EH. However, in low-volatile regimes, the direction of change in long term yield has a negative coefficient for half of the tested cases. The result indicates that on the whole, the yield rates marginally followed the EH across both the regimes.

Table 11 contains the results of the Markov regime switching regression, in which the dependent variable represents the change in short term yield rate and the explanatory variable represents the forward-spot spread as in Eqn. (4). Here, the regression was estimated for m= (3, 6, 12 months) and k= (3, 6, 12, 24 months). In state 1, the coefficient β_f was positive and significant in all cases except for one pair, while in state 2, the coefficient β_f was significant only in two cases.

Though, coefficient β_f had statistical significance, their values typically were much lower than the unity as perceived by EH. Despite lower coefficients in state 1, the forward-spot spread still contained useful information to estimate the direction of future interest rate movement as implied by EH, which was consistent with the results of Table 3. In state 2, only two long term rate combinations had shown statistically significant dependence upon on the forward-spot spread.

During both the regimes, the coefficients β_f were positive, leading to the inference that the interest rate changes follow the forward rates. However, the impact of forward rates on the movement of interest rates was still lower than the expected movement implied by EH.

5. SUMMARY

This chapter examined the validity of the Expectations Hypothesis (EH). The study investigated the information content of the term structure and it's utility to predict expected changes in the interest rates. The impact of the yield spread and the forward-spot spread upon the changes in the future yield rates was estimated.

Finally, the Markov Regime switch approach was used to examine the changes that occur due to a financial crisis and the consequent monetary policy changes.

The results reveal that the long and short term rates were co-integrated for the period before the 2008 global financial crisis, whereas after the financial crisis, they were only partially co-integrated. Empirical evidence revealed that the yield spread contained useful information to foresee the changes in the future rates. However, as the coefficient values were different from unity, the results were insufficient to confirm the validity of EH in the Indian market. The forward rates also indicated and helped in predicting the short term interest rate changes, but the extent of impact was not as much as required by the EH. The overall inference is that the information reflected in the yield spread and the forward-spot spread did help to predict the interest rate changes in India.

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Table-1. .Summary Statistics of Zero-coupon Bond Yields for Different Maturities in India

Period	Mean	Std Dev.	Minimum	Maximum
3-Month	0.062	0.016	0.030	0.094
6-Month	0.063	0.016	0.033	0.091
1-Year	0.064	0.014	0.037	0.094
2-Year	0.064	0.014	0.039	0.089
3-Year	0.064	0.011	0.038	0.089
4-Year	0.065	0.012	0.033	0.090
5-Year	0.068	0.012	0.037	0.090
6-Year	0.069	0.010	0.040	0.087
7-Year	0.071	0.011	0.043	0.093
8-Year	0.072	0.009	0.046	0.095
9-Year	0.073	0.010	0.047	0.093
10-Year	0.075	0.010	0.049	0.092

Notes: The Table reports the summary statistics of the monthly average zero-coupon yields during the sample period from January 2003-December 2013.

Table-2. Augmented Dickey Fuller (ADF) and Philips Perron (PP) Unit Root Test for Zero-coupon Yields at Level

	Augmented Dickey Fuller Test			Philips Perron Test		
	without Intercept and Trend	with Intercept	with Intercept and Trend	without Intercept and Trend	with Intercept	with Intercept and Trend
6-Month	-0.206	-1.729	-3.595**	-0.605	-3.081**	-4.423***
1-Year	0.33	-0.791	-1.361	-0.519	-1.224	-2.151
3-Year	-2.261**	-3.593***	-4.328***	-2.752***	-3.545***	-4.227***
5-Year	-2.413***	-0.642	-2.281	-3.966***	-2.199	-4.105***
7-Year	-1.952**	-3.731***	-4.709***	-2.042**	-3.717***	-4.724***
10-Year	-0.541	-1.816	-3.449**	-1.271	-2.614*	-4.159***

Notes: *and**denote the statistical significance at 5% and 1% respectively. The critical values of the ADF and PP tests were developed by MacKinnon (1996). Sample period: January 2003-December2013

Table-3. Augmented Dickey Fuller (ADF) Unit Root Test for Zero Coupon Yields at First Difference

	Augmented Dickey Fuller		
	without Intercept and Trend	with Intercept	with Intercept and Trend
6-Month	-3.926***	-3.888***	-3.849**
1- Year	-15.176***	-15.171***	-15.153***
3-Year	-20.254***	-20.781***	-20.733***
5-Year	-16.447***	-7.124***	-7.153***
7-Year	-18.644***	-18.663***	-18.548***
10-Year	-5.082**	-5.062***	-5.067***

Notes: *, ** and *** denote the statistical significance at 10%, 5% and 1% level respectively. The critical values of the ADF and PP tests were developed by MacKinnon (1996).Sample period: January 2003-December2013

Table-4. Engle Granger (EG) and Autoregressive Distributed Lag (ARDL) Co-integration tests (Full sample period: January 2003-December2013)

Dependent Variable	Independent Variable	Engle Granger's ADF Test Error Term t statistic	Autoregressive Distributed Lag (ARDL) Cointegration Test (F-statistic)
3-Year	6-Month	-3.066**	-
5-Year	6-Month	-	4.438
7-Year	6-Month	-	6.666*
10-Year	6-Month	-3.133**	-
3-Year	12-Month	-	4.245
5-Year	12-Month	-1.631	-
7-Year	12-Month	-	4.689
10-Year	12-Month	-2.834*	-
7-Year	3-Year	-	9.241**
10-Year	3-Year	-	7.069*
10-Year	5-Year	-5.192***	-

Notes: This Table reports the results of the co-integration tests for long term rates and short term rates. *, ** and *** denote the statistical significance at 10%, 5% and 1% level respectively. The critical values of the Engle Granger's ADF test were developed by MacKinnon (1991) while the critical value of the ARDL's Bound test was developed by Pesaran and Pesaran (1997).

Table-5. Engle Granger Co-integration Test for the Pre-crisis Period (Sample period: January 2003-October 2008)

Dependent Variable	Independent Variable	Engle Granger's ADF Test Error Term t statistic
3-Year	6-Month	-3.053**
5-Year	6-Month	-0.981
7-Year	6-Month	-3.446**
10-Year	6-Month	-3.273**
3-Year	12-Month	-3.267**
5-Year	12-Month	-2.849*
7-Year	12-Month	-3.739***
10-Year	12-Month	-3.841***
7-Year	3-Year	-2.772*
10-Year	3-Year	-3.803***
10-Year	5-Year	-3.704***

Notes: The Table reports the results of the co-integration tests for long term rates and short term rates. *, ** and *** denote the statistical significance at 10%, 5% and 1% level respectively. The critical values of the Engle Granger's ADF test were developed by MacKinnon (1991). Sample period: January2003-October2008.

Table-6. EG and ARDL Co-integration Tests for the Crisis Affected Period (Sample period: November 2008-December2013)

Dependent Variable	Independent Variable	Engle Granger's ADF Test Error Term *t* statistic	Autoregressive Distributed Lag (ARDL) Cointegration Test (F-statistic)
3-Year	6-Month	-	5.927
5-Year	6-Month	-	1.600
7-Year	6-Month	-	14.233***
10-Year	6-Month	-3.479**	-
3-Year	12-Month	-	1.721
5-Year	12-Month	-	4.383
7-Year	12-Month	-	12.402***
10-Year	12-Month	-3.677***	-
7-Year	3-Year	-	8.345**
10-Year	3-Year	-3.346**	-
10-Year	5-Year	-	14.233***

Notes: The Table reports the results of the co-integration tests for long term rates and short term rates.*, ** and *** denote the statistical significance at 10%, 5% and 1% level respectively. The critical values of the Engle Granger's ADF test were developed by MacKinnon (1991) whereas the critical value of the ARDL's Bound test were developed by Pesaran and Pesaran (1997). Sample period: November2008-December2013

Table-7. Regression Estimates for Testing EH Using the Yield Spread

Dependent Variable	α_h	β_h	R-squared	F-statistic	*t* statistics given H_o: β_h=1
$y_{t+1}^{(3-1)} - y_t^{(3)}$	-0.004***	0.519	0.024	1.974	1.303
	(0.001)	(0.369)			
$y_{t+1}^{(4-1)} - y_t^{(4)}$	-5.25E-05	2.832***	0.293	49.013***	4.534***
	(0.000)	(0.040)			
$y_{t+1}^{(5-1)} - y_t^{(5)}$	0.007***	1.610***	0.18	14.290***	1.435
	(0.001)	(0.242)			
$y_{t+1}^{(6-1)} - y_t^{(1)}$	0.001	1.717***	0.289	48.186***	2.902***
	(0.001)	(0.247)			
$y_{t+1}^{(7-1)} - y_t^{(7)}$	0.001	1.189**	0.058	4.868**	0.350
	(0.001)	(0.353)			
$y_{t+1}^{(10-1)} - y_t^{(10)}$	-0.002	2.954**	0.046	3.989**	1.321
	(0.002)	(1.479)			

Notes: This Table reports the OLS regression results where the dependent variable represents the change in yield on long term bond over m period and independent variable represents yield spread as in Eqn. (1). The regression was estimated for different pairs of long and short term maturities, taking long term (n) = (3, 4, 5, 6 and 7year) and short term (m) = (1 year). The standard errors are reported in parentheses.*,** and *** denote the statistical significance at the 10%, 5% and 1% level respectively. α_h stands for time invariant risk premium and β_h represents yield spread. For EH to be accepted, β_h should be unity i.e. β_h=1 and for pure expectation hypothesis to be accepted, β_h=1 and α_h=0. Sample period: January2003-December2013.The *t* statistic was calculated to test if the computed beta coefficients are equal to 1. The statistic was computed from [(*Estimated* β_h-1)/ *Standard Error*)] and reported in the last column of the Table. (Sample period: January 2003-December2013).

Table-8. Testing EH Using Future Changes in Short Term Yield Rates and Forward-spot Spread

Dependent Variable	α_f	β_f	R-squared	F-statistic
$y_3^{(3)} - y^{(3)}$	0.001*	0.478***	0.121	17.485***
	(0.001)	(0.114)		
$y_6^{(6)} - y^{(6)}$	0.001	0.514***	0.081	10.738***
	(0.001)	(0.157)		
$y_{12}^{(6)} - y^{(6)}$	0.010***	0.028	0.004	0.282
	(0.003)	(0.053)		
$y_{12}^{(12)} - y^{(12)}$	0.002	0.195***	0.085	7.018***
	(0.003)	(0.074)		
$y_{24}^{(12)} - y^{(12)}$	-□.0□3	0.787***	0.393	33.681***
	(0.003)	(0.135)		

Notes: This Table reports the OLS regression results where the dependent variable represents the future changes in short term yield rate and independent variable represents forward-spot spread as in Eqn. (2). The regression was estimated for m = (3, 6, 12 months) and k = (3, 6, 12, 24 months). The standard errors are reported in parentheses.*,** and *** denote the statistical significance at the 10%, 5% and 1% level respectively. α_f stands for time invariant risk premium and β_f represents yield spread. For expectation hypothesis to be accepted, β_f should be unity i.e. β_f=1 and for pure expectation hypothesis to be accepted, β_f=1 and α_f=0. Sample period: January2003-December2013.

Table-9. Estimates of the Univariate Markov Regime Switching Model of the Zero Coupon Yields Rates

Term	State 1		State 2		Transition Probability		Duration	
	μ_1	Variance	μ_2	Variance	p_{11}	p_{22}	D_1	D_2
0.5 year	0.062***	2.68E-04***	-0.022***	4.18E-04***	1	0	4.5E+15	1
	(0.000)		(0.000)					
1 year	0.063***	2.06E-04***	-0.096***	5.00E-05***	1	0.06	6.43E+14	1.07
	(0.000)		(0.000)					
2 year	0.053***	2.52E-04***	-0.103***	7.90E-05***	1	0.07	1.8E+15	1.08
	(0.000)		(0.000)					
3 year	0.060***	1.72E-04***	-0.154***	6.60E-04***	1	0.03	9.01E+14	1.03
	(0.000)		(0.000)					
4 year	0.0643***	1.35E-04***	-0.103***	8.70E-05***	1	0	5.3E+14	1
	(0.000)		(0.000)					
5 year	0.0735***	2.70E-05***	0.0555***	6.70E-05***	0.99	0.96	82.03	22.5
	(0.000)		(0.001)					
6 year	0.0674***	9.40E-05***	-0.0565***	2.05E-04***	1	0.22	9.01E+15	1.28

	(0.000)		(0.000)					
7 year	0.0745***	2.30E-05***	0.0588***	4.90E-05***	0.99	0.96	82.98	22.89
	(0.000)		(0.001)					
8 year	0.0704	8.50E-05***	-0.1604	8.49E-04***	1	0.22	Inf	1.29
	(0.000)		(0.000)					
9 year	0.0782***	1.70E-05***	0.0621***	5.70E-05***	0.95	0.94	19.68	16.72
	(0.000)		(0.001)					
10 year	0.0741***	9.93E-04***	-0.1608	3.95E-04***	1	0	4.5E+15	1
	(0.000)		(0.000)					

Notes: The Univariate Markov regime switching model was estimated for the zero-coupon yields rates during the sample period from January 2003-December2013. The standard errors are reported in parentheses.*, ** and *** denote the statistical significance at the 10%, 5% and 1% levels respectively. Both the mean (μ) and the variance are functions of the state s_t. Sample period: January 2003-December 2013.

Table-10. Markov Regime Switching Regression Estimates for Testing the Impact of the Yield Spread

Dependent Variable	state1			state2			Transition Probability		Duration	
	α_h	β_h	Variance	α_h	β_h	Variance	p_{11}	p_{22}	D_1	D_2
$y_{t+1}^{(3-1)} - y_t^{(3)}$	-0.018***	-0.817**	8.10E-05***	0.007**	0.705	1.49E-04***	0.93	0.80	14.87	5.13
	(0.001)	(0.321)		(0.003)	(0.503)					
$y_{t+1}^{(4-1)} - y_t^{(4)}$	-0.006***	2.832***	1.55E-04***	-0.032***	3.250***	5.65E-04***	1.00	□.00	Inf time	1.00
	(0.000)	(0.000)		(0.000)	(0.000)					
$y_{t+1}^{(5-1)} - y_t^{(5)}$	-0.008***	-1.650***	4.50E-05***	0.004**	1.703***	4.80E-05***	0.96	0.85	24.34	6.73
	(0.001)	(0.345)		(0.002)	(0.480)					
$y_{t+1}^{(6-1)} - y_t^{(6)}$	0.003***	2.730***	9.90E-05***	-0.004**	-0.485**	2.40E-05***	0.94	0.92	17.63	12.93
	(0.001)	(0.302)		(0.001)	(0.246)					
$y_{t+1}^{(7-1)} - y_t^{(7)}$	0.004***	2.561***	6.00E-06***	0.001**	0.631***	1.20E-05***	0.92	0.97	13.18	33.78
	(0.000)	(0.165)		(0.000)	(0.152)					
$y_{t+1}^{(10-1)} - y_t^{(10)}$	.003***	-8.653***	4.40E-05***	.001	3.769***	3.20E-05***	0.94	0.92	17.88	11.91
	(0.000)	(0.176)		(0.001)	(0.745)					

Notes: This Table reports the Markov switching regression results where the dependent variable represents the change in yield on long term zero-coupon bond over m period and the independent variable represents the yield spread as in Eqn. (3). The regression was estimated for different pairs of long and short term maturity taking long term (n) = (3, 4, 5, 6 and 7 years) and short term (m) = (1 year). The standard errors are reported in parentheses.*,** and *** denote the statistical significance at the 10%, 5% and 1% level respectively. α_h stands for time invariant risk premium and β_h represents yield spread. For EH to be accepted, β_h should be unity i.e. β_h=1 and for the pure EH to be accepted, β_h=1 and α_h=0. Sample period: January2003-December2013

Table-11. Markov Regime Switching Regression Estimates for Testing Forward-spot Spread

Dependent Variable	State 1			State 2			Transition Probability		Duration	
	α_f	β_f	Variance	α_f	β_f	Variance	p_{11}	p_{22}	D_1	D_2
$y_3^{(3)} - y^{(3)}$	0.001**	0.479***	1.40E-05***	0.001	0.2059	2.31E-04***	0.93	0.82	14.29	5.51
	(0.001)	(0.080)	(0.000)	(0.002)	(0.201)	(0.000)				
$y_6^{(6)} - y^{(6)}$	0.002***	0.548***	2.10E-05***	-0.004	0.404	4.09E-04***	0.94	0.86	15.89	6.98
	(0.001)	(0.044)	(0.000)	(0.003)	(0.323)	(0.000)				
$y_{12}^{(6)} - y^{(6)}$	0.021***	0.033	1.70E-04***	-0.023***	0.019	1.18E-04**	0.99	0.99	71.33	15.06
	(0.002)	(0.039)	(0.000)	(0.004)	(0.059)	(0.000)				
$y_{12}^{(12)} - y^{(12)}$	0.014***	0.065**	2.50E-05***	-0.004	0.362***	5.49E-04***	0.95	0.97	20.26	29.15
	(0.001)	(0.032)	(0.000)	(0.004)	(0.118)	(0.000)				
$y_{24}^{(12)} - y^{(12)}$	0.005**	0.525***	5.20E-05***	-0.021***	0.756***	6.10E-05***	0.97	0.92	31.98	12.46
	(0.002)	(0.069)	(0.000)	(0.002)	(0.161)	(0.000)				

Notes: This Table reports the Markov switching regression results where the dependent variable represents the future changes in short term yield rate and the independent variable represents forward-spot spread as in Eqn. (4). The regression was estimated for m= (3, 6, 12 months) and k= (3, 6, 12, 24 months). The standard errors are reported in parentheses.*, ** and *** denote the statistical significance at the 10%, 5% and 1% level respectively. α_f stands for time invariant risk premium and β_f represents yield spread. For expectation hypothesis to be accepted, β_f should be unity i.e. β_f =1 and for pure expectation hypothesis to be accepted, β_f=1 and α_f =0. Sample period: January2003-December2013.

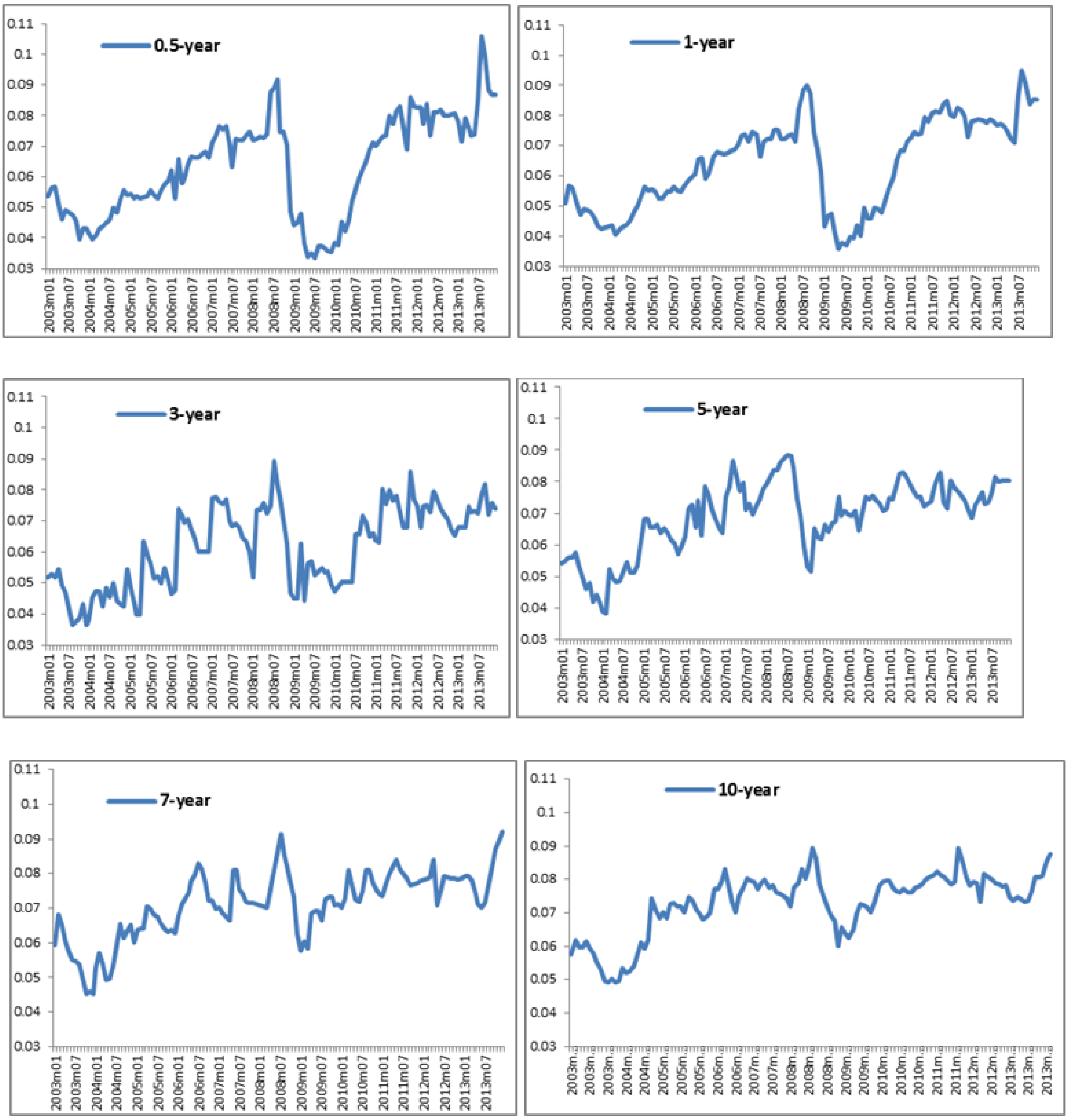

Figure-1. Time varying movements in the zero-coupon yields of various maturities during January 2003-December2013.

Notes: X axis represents the time line and Y axis represents the yield rate.