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Testing the Expectations Hypothesis and Explaining the Determinants of Term Premia: Evidence from the Indian Money Market

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Testing the Expectations Hypothesis and Explaining the Determinants of Term Premia: Evidence from the Indian Money Market

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The pure expectations hypothesis states that the current yields on bonds with different maturities reflect investor expectations of future interest rates. Analyzing the short-term inter-bank rates in a Vector Error Correction framework (VECM), the study could reject pure as well as the general expectations theory in case of the 1 month and 3 month rates but not in case of 14 day rates. The term premia is found to be time-varying. The study attempts to quantify and decompose the term premia, inherent in the money market rates. The study uses the market spreads derived from Swap market (OIS), T-Bills and CD markets to understand the level of decomposition of the term premia. A latent factor model was used to break down the risk premia and decompose the same into credit and liquidity risk factors by using information from related money market instruments.

JEL Classification: C5, E43, E44, G12, G21

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1. INTRODUCTION

Money markets are a good source of funding for large institutions and are also used by central banks around the world to support systemic liquidity through infusion or absorption using policy rates. The Indian money market has a natural anchor of support and resistance levels of interest rate as market participants like Banks and Primary Dealers can access the central bank's Liquidity Adjustment Facility (LAF) window[1] by borrowing and lending around policy rates.

In the money markets, borrowing and lending can be either uncollateralized or collateralized with acceptable securities such as treasury bills, dated government securities, state development loans and corporate papers. Prior to 2005, the uncollateralised money market in India consisted of bank as well as non-bank participants. With the implementation of the recommendation of the Internal Working Group of *Reserve Bank of India (1997)* and the report by *Narasimham Committee (1998)*, various reforms were initiated in a phased manner from 2001 through 2005 to restrict the access to the uncollateralized market among Banks and Primary Dealers. In order to enable the exit of non-bank participants from the uncollateralised money market segment in a calibrated manner and to create avenues for them to deploy their excess funds, new money market instrument like Collateralized Borrowing and Lending Obligation (CBLO) were introduced[2]. These restrictions helped in reducing the high dependence on the uncollateralized market and participants majorly moved to collateralized market. Currently, the daily average value of trading in the uncollateralized money market segment stands at around Rs.18,903 crores in comparison to Rs.48,320 crores in case of the market repo and Rs.1,31,654 crores in case of TREP (*Panel A of Table 1*). Nonetheless, the importance of the uncollateralised money market cannot be undermined, since the weighted average call money market rate is considered to be the operating target rate of monetary policy in India and is the primary rate through which the transmission of monetary policy rate action takes place.

The uncollateralized short term market is further divided into three categories - Call market for borrowing/lending of funds on an overnight basis; Notice market for transactions from 2 to 14 days and the Term market in which transactions take place for a tenor between 15 and 365 days. India has a well-functioning money market but overnight market plays the dominant role, with over 95% of the daily average traded value being dealt in the overnight segments (*Panel B of Table 1*). The daily average traded value in the notice/term segment is very low.

Other money market instruments such as Certificate of Deposits (introduced in June 1989) and Commercial Papers (introduced in January 1990) are also traded in the Indian money markets, to aid market participants to meet their short term funding requirements. While certificate of deposits are essentially tradable short-term time deposits issued by banks and all-India financial institutions to meet their funding needs, commercial papers are issued by corporates with better

[1] Central Bank Repo window to infuse and absorb systemic liquidity through Banks and Primary Dealers.

[2] *CBLO was converted into Triparty Repo (TREP) on 05th November 2018.*

Table 1: Market-Wise Breakup of Daily Average Money Market Values (Rs. Cr.)

Market Type	Panel A: Segment-Wise Breakup Based on Market Type						Panel B: Tenor-Wise Break-up									
	Segment	**2015**	**2016**	**2017**	**2018**	**2019**	**Sub-Segment**	**Jan-2019**	**Feb-2019**	**Mar-2019**	**Apr-2019**	**May-2019**	**Jun-2019**	**Jul-2019**	**Aug-2019**	**Sep-2019**
Collateralized	TREP	77349	83378	114274	129523	131654	**O/N**	139327	160409	141794	132294	134763	148419	137182	149176	150194
							Notice/Term	972	1317	4676	904	1341	3149	1520	1632	2539
	Market Repo	34705	46225	52475	56997	48320	**O/N**	44549	55281	46834	43291	53261	62166	54328	52922	53738
							Notice/Term	1269	805	1535	3778	2021	2019	834	1405	765
Uncollateralized	Call/ Notice/ Term	14116	17438	14826	18004	18903	**Call**	20324	24267	25157	25510	20471	19971	14345	17641	18349
							Notice/Term	286	380	268	497	376	566	440	363	444
							15D	69	86	64	135	135	221	193	110	174
							30M	2	9	0	39	1	3	1	0	0
							91M	12	0	3	11	9	4	0	19	2
Allied Money Market Instruments	CD	5440	4791	3173	4448	4854	**All Tenors**	3946	4472	10606	6717	5429	8998	1892	3310	4073
							14D	*614*	*743*	*1814*	*532*	*1385*	*969*	*996*	*865*	*339*
							1M	*225*	*728*	*728*	*1000*	*1017*	*594*	*459*	*128*	*30*
							3M	*777*	*845*	*3042*	*1213*	*577*	*238*	*173*	*518*	*722*
	T-bills	3551	3988	4720	3554	4483	**All Tenors**	3438	4740	4230	4101	4001	5336	5376	7443	6102
							14D	*475*	*492*	*1039*	*145*	*269*	*305*	*553*	*1615*	*766*
							1M	*740*	*2066*	*350*	*175*	*331*	*637*	*532*	*963*	*1174*
							3M	*805*	*733*	*554*	*2008*	*1414*	*1361*	*1605*	*1873*	*1517*
	OIS	9778	7879	10720	22969	19637	**All Tenors**	25471	32582	23540	23930	20756	18570	14025	18494	19068
							1M	*466*	*5078*	*2592*	*83*	*1120*	*1955*	*955*	*1025*	*1159*
							3M	*2255*	*928*	*3242*	*2563*	*4652*	*2303*	*1002*	*1735*	*1495*
RBI LAF	Repo	80875	85239	16210	93572	73558	**O/N**	6002	13922	6039	12303	7890	7302	5725	4393	4758
							Term	110945	108627	124965	116083	62930	38273	31141	26428	38280
							14D	*71822*	*64383*	*67510*	*44568*	*51183*	*38273*	*31141*	*24070*	*26630*
							28D	*0*	*0*	*18751*	*6250*	*0*	*0*	*0*	*0*	*0*
	Reverse Repo	24826	58459	277745	77614	113570	**O/N**	53500	40916	71518	55948	33416	73656	108985	154126	155710
							Term	31395	16875	6085	4621	1270	20671	58409	15706	38
							14D	*143645*	*128766*	*135020*	*89136*	*102366*	*76545*	*62523*	*48140*	*53260*
							28D	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

Notes:
1.RBI LAF represents the daily average outstanding values
2. TREP was launched on 05th November 2018, prior to which the daily average value of CBLO is presented.
3. A break-up of key traded tenors upto 3 months are provided.

rating and high new worth, mainly during periods of tight liquidity conditions (*Reserve Bank of India (2007))*. However, these markets are quite illiquid beyond 3 months.

As per the international standards, the market should derive its Benchmarks from the trades executed by the market participants or if the executed trades are not representative, then Benchmarks may be derived through polling mechanism. Given the reasonable trading in the overnight market, India derives its MIBOR[3] using the Call money transactions executed in the market. The uncollateralised term rates like 14 days, 1 month and 3 months are derived through polling mechanism as liquidity in these markets are very low.

Theoretically, the long term rates have certain economic relationship with the short term rates. A trader has a choice to borrow for 14 days at one go or borrow at the overnight rate and sequentially rollover his position each day for next 13 days. The future 13 days rates are uncertain and not known, but an analysis to predict the possible movement of future overnight interest rates on the basis of the expectation theory is essential. The expectation theory relies on the proposition that the long-term rate is determined purely by current and future expected short-term rates.

Given the prevailing market microstructure, this paper addresses the following questions: Does the expectations theory of interest rate hold in the Indian money markets? If not, would it be possible to arbitrage the disparity between the interest rates in the term and the overnight segments? Are market participants earning a riskless profit from such arbitrage strategies? If not is there a term premia being factored in the quoted term rates? Can this term premia be quantified and decomposed into interpretable risk factors based on information from existing instruments traded in the interbank money markets?

The paper is organized as follows- *Section 2* surveys the empirical literature in the international context. *Section 3* outlines the data used in the study. *Section 4* lays downs the framework to test for the expectation theory under a no-arbitrage condition and identifies the methodology for testing the same in the Indian uncollateralised money markets. *Section 5* emphasizes on the theoretical design of the term premia. *Section 6* gives the empirical analysis and findings. A check of the robustness of the findings is laid down in *Section 7*. The conclusion is provided in *Section 8.*

2. LITERATURE REVIEW

2.1. Review of literature on Expectations Hypothesis:

The expectations theory is amongst the basic building blocks that attempts to explain interest rate term structure. An extensive analysis of its validity over the last few decades has often indicated

[3] Mumbai Interbank Outright Rate (MIBOR) is derived from inter-bank Call market deals executed between 9.00AM and 10.00AM on NDS-Call electronic platform owned by the Reserve Bank of India (RBI). MIBOR is widely used for OTC derivatives contracts.

that the theory has found support for only the short end of the curve. A review of the arguments and evidence for and against this theory was laid down in *Browne and Manasse (1989)*. The study noted that the yields taken from the shorter end of the maturity spectrum (spreads in between three months to two years) were more reliable indicators of the markets' expectation, in comparison to the use of spreads between very long rates (the spreads between rates of 10-Year bonds and 3-month treasury-bills).

Surveying literature on interest rate expectations and the slope of the money market yield curve, *Cook and Hahn (1990)* noted that the yield curve from three to twelve months has had negligible power to forecast interest rates three and six months in the future. They further noted that the variation in the term premium at the three and six month horizons had been substantial relative to the variation in the expected change in rates.

Using a standard regression as well as an error correction framework, the finding of *Jondeau and Ricart (1999)* cite the existence of a country puzzle, suggesting that the expectations hypothesis was rejected in case of interest rates in countries like the United States and Germany but not in case of the French and UK interest rates.

Analyzing the period from 1996 to 2003 by using an OLS regression framework, *Grahame Johnson (2003)*, found that the expectations hypothesis appeared to provide a reasonably accurate representation of the mechanics of the short end of the Canadian yield curve following the introduction fixed announcement dates by Bank of Canada. Empirically testing data on zero-coupon U.S. Treasury bond yields with maturities of 1 month to 10-years over the sample period 1970 through 2003, *Guidolin and Thornton (2008)* provide evidence suggesting that the failure of the expectations hypotheses is likely a consequence of market participants' inability to predict the short-term rate.

Carpenter and Demiralp (2011) examined the expectations hypothesis by using the 90 days U.S. Treasury bill rate and the overnight federal funds rate. The hypothesis was tested by comparing the 90 days T-bill rate with the average realized federal funds rate over the next 90 days. As an alternative methodology, the expectations hypothesis was tested by using the expected federal funds rate derived from federal funds futures contracts as well as the OIS swap trades. The authors found that using measures of the expected federal funds rate instead of the realized federal funds rate yielded results that tend to support the expectations hypothesis.

Tronzano (2018) explored the validity of the expectations hypothesis in term structure Korean markets using a vector error correction framework and found one common stochastic trend between short term and long term interest rates. The study observed a significant liquidity premia and a causal relationship from long to short term interest rates.

2.2. Review of literature on Decomposition of Term Premia:

In the international context, empirical literature has often referred to the LIBOR-OIS spread to gauge the term premia in the interbank money markets. *Sengupta and Tam (2008)* highlight the usefulness of LIBOR-OIS spread as a barometer of distress in money markets. The authors noted that the LIBOR-OIS spread has been the summary indicator showing the illiquidity waves that severely impaired money markets in 2007 and 2008.

In their study, *Michaud and Upper (2008)* highlight that the expectations hypothesis of interest rates, need not hold perfectly due to the presence of counterparty credit risk, liquidity factors or a term premium related to the uncertainty about the future path of short-term interest rates. The authors provide empirical evidence on the role of credit and liquidity factors on the increase the term premia, as represented by the LIBOR-OIS spread, in the interbank market during the financial turmoil in 2008. Using a regression framework to model the term premia, the authors used the CDS spreads as a measure of credit risk, liquidity in the overnight market as a proxy for liquidity in term deposits and treated funding liquidity of the borrowing bank as the residual of the model. Using an event analysis, the authors concluded that the evidence of a rise in the term premia was mainly on account of the liquidity rather than credit factors.

On similar lines, studies such as *Taylor and Williams (2009), Gefang, Koop and Potter (2010), Chung and Lo (2010), Filipovic and Trolle (2011) and King and Lewis (2015)* analyze the LIBOR-OIS spread as a measure of term premia and decompose the same to capture a credit and a liquidity risk component. In all cases, the credit risk is proxied using the CDS spreads.

McAndrews, Sarkar and Wang (2017) empirically evaluated the efficacy of the term auction facility (TAF) in reducing the risk in the interbank market, which was measured by the LIBOR-OIS spread. The authors noted that regressions using the daily change in the LIBOR-OIS spread (instead of the level of spreads) were robust to the type of the TAF effect and the stationarity problem of the LIBOR-OIS spread. The authors modelled the changes in LIBOR-OIS spread as a function of the changes in the CDS spread and the changes in the TAF effect. The CDS spread, which was considered as a measure of credit risk premia, was estimated as the average CDS spreads of banks in the LIBOR panel and was found to be statistically significant predictor. Additionally, changes in the term premia, changes in interest rate volatility and the quarter end effects were introduced in the model as control variables. Among these, the changes in the term premia and in volatility were found to be statistically significant predictors.

Estimating a no-arbitrage model of the term structure of money market spreads during the recent financial crisis, *Smith (2012)* identified that much of the sharp movements in spreads were attributed to observable interest rate, credit and liquidity factors. The study partitioned the linear representation of spreads into two distinct components: one related to time-varying expectations of spreads, and the second to time-variation in risk premia.

Looking at the spike in the LIBOR-OIS spread during the first quarter of 2018, *Gladchun (2018)* decomposed the LIBOR-OIS spread into three technical factors- the spread of the T-Bill rate over the OIS rate, the spread of the CP rate over the T-Bill rate and the spread of LIBOR over CP rate. The author noted that the widening of the LIBOR-OIS spread was on account of a supply and demand imbalance and not on account of deterioration in the health of the financial system. This imbalance was trigged by a surge in demand for US dollars by money markets, on account of an increase in T-Bill supply and CP issuances, amid a reduction in the supply of funds due to US dollar repatriation.

In the context of the Indian money markets, empirical literature on quantifying and decomposing the inherent term premia is quite sparse. Absence of a CDS market in India has resulted in the unavailability of a quantifiable measure of credit risk - an indicator often used in the literature. In this paper, the authors seek to arrive at a method to the decomposed term premia by using the information from related money market instruments in the term segment.

3. DATA

The paper considered the benchmark interest rates provided by FBIL[4] to test for the pure expectations theory under a no-arbitrage condition. The FBIL Term Rates (14 days, 1 month and 3 months) are used as reference rates for the uncollateralised term segment. These rates are currently polled between 11:00 AM to 11:15 AM from 12 banks using electronic polling mechanism. The FBIL MIBOR rate (henceforth O/N Rate) is used as the representative rate for the overnight call money market segment. To test the pure expectation theory, the returns from investing at the Term Rate should ideally be equal to the returns from investing at the O/N rate compounded for the same period as that of the term rate, using the money market convention to account for holidays. A series of the compounded O/N Rate (henceforth Compounded O/N Rate), was thus constructed for this purpose. The Compounded O/N Rate was estimated on an ex-ante and ex-post basis. A daily data sample from September 2015 to May 2019 was considered for the purpose of the study.

The descriptive statistics of the rates in level and first difference are highlighted in *Table 2*. A preliminary analysis of the data suggests that the Term Rates on an average are higher than the Compounded O/N Rate for all the tenors considered indicating a premia paid for certainty of funding vis-à-vis an open position to cover on daily basis in future exposing oneself to rollover risk. The distribution of daily changes in rates indicates excess kurtosis with negative skewness.

The Pearson's correlation (ρ) at level indicates that the correlation between the Term Rates and Compounded O/N Rates (on an Ex-Post basis) ranged between 0.71 and 0.89. The numbers indicate statistical significance at 1%. The correlation between the changes in the rates, although statistically significant, drops to a range of 0.48 to 0.64. These figures were largely consistent with the results obtained from computing the compounded O/N Rate on an ex-ante basis as well. However, since the sampling distribution of the term and compounded O/N rate is skewed, the Fisher's z transformation was estimated to support the Pearson's correlation statistic (as the later measures merely the linear association between the two variables). The Fisher's z transformation

[4] Financial Benchmarks India Pvt. Ltd – the company which has been set up for disseminating financial benchmarks in India.

Table 2: Descriptive Statistics of the Term Rate versus the Compounded O/N Rate						
Ex Ante - Level (in %)*						
	Term Rate 14D	*Compounded O/N Rate 14D*	*Term 1M*	*Compounded O/N Rate 1M*	*Term 3M*	*Compounded O/N Rate 3M*
Mean	6.6536	6.3717	6.7848	6.3810	7.0438	6.4144
Median	6.6300	6.2670	6.8300	6.2756	7.1300	6.3080
Mode	6.1900	6.0064	6.4600	6.0143	6.5600	6.2979
Stdev.	0.3538	0.3193	0.3927	0.3202	0.4928	0.3237
Kurtosis	-0.1936	-0.0138	0.2306	-0.0129	-0.8099	-0.0109
Skewness	0.4569	0.7828	0.5099	0.7830	0.1404	0.7839
Min	6.1400	5.9062	6.2100	5.9148	6.2700	5.9426
Max	8.1000	7.3897	8.1700	7.4017	8.3400	7.4468
Count	883	883	883	883	883	883
Ex Ante – First Difference (in Bps)*						
Mean	-0.1020	-0.1455	-0.1009	-0.1460	-0.0760	-0.1475
Median	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mode	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Stdev.	6.0530	6.5473	5.0185	6.5709	4.1850	6.6402
Kurtosis	120.5970	15.5476	145.9715	15.4987	154.7404	15.5389
Skewness	-8.2656	-0.2552	-8.8634	-0.2587	-9.3518	-0.2560
Min	-94.0000	-56.1418	-90.0000	-56.3168	-79.0000	-56.9134
Max	27.0000	54.1873	27.0000	54.2257	12.0000	54.9230
Count	882	882	882	882	882	882
Ex Post - Level (in %)						
	Term Rate 14D	*Compounded O/N Rate 14D*	*Term 1M*	*Compounded O/N Rate 1M*	*Term 3M*	*Compounded O/N Rate 3M*
Mean	6.6575	6.3931	6.7879	6.3970	7.0460	6.4067
Median	6.6300	6.2900	6.8300	6.3000	7.1300	6.3100
Mode	6.1900	6.0100	6.4600	6.0200	6.5600	6.2900
Stdev.	0.3599	0.3424	0.3960	0.3149	0.4940	0.2967
Kurtosis	0.0395	0.8343	0.2465	-0.1940	-0.8119	-0.0853
Skewness	0.5295	0.9976	0.5271	0.6816	0.1417	0.6807
Min	6.1400	5.9200	6.2100	5.9000	6.2700	5.7800
Max	8.1000	7.7800	8.1700	7.3800	8.3400	7.1500
Count	887	887	887	887	887	887
Ex Post - First Difference (in Bps)						
	d_Term 14D	*d_Compounded O/N Rate 14D*	*d_Term 1M*	*d_Compounded O/N Rate 1M*	*d_Term 3M*	*d_Compounded O/N Rate 3M*
Mean	-0.1016	-0.1377	-0.1005	-0.1230	-0.0756	-0.1343
Median	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mode	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Stdev.	7.6833	7.7589	5.8750	3.8382	4.9424	1.4066
Kurtosis	144.6732	199.1395	121.0055	189.0907	102.2903	127.8640
Skewness	-9.3095	-4.9970	-8.1463	-2.5930	-7.3790	-0.6321
Min	-126.0000	-145.0000	-91.0000	-68.0000	-67.0000	-21.0000
Max	45.0000	107.0000	32.0000	59.0000	32.0000	21.0000
Count	886	886	886	886	886	886

*compounded rates (ex-ante basis) as on last business day of March were significantly higher than the rest of the sample period and hence were eliminated from the sample.

helps convert the skewed distribution of the correlation (ρ) into a distribution that is approximately normal[5]. After correcting for non-normality in the sampling distribution, the Fisher transformed correlation estimate was also found to be statistically different from 0 at a 1% level of significance (*Table 3*).

Table 3: Pearson Correlation Statistics (Fisher's z Transformation) for Null of $\rho = 0$					
Variable	**With Variable**	**Pearson's Correlation**	**Fisher's z**	**95% Confidence Limits**	
At Level					
Compounded 14D	Term 14D	0.8976*	1.4599*	0.884	0.9097
Compounded 1M	Term 1M	0.8706*	1.3356*	0.8537	0.8857
Compounded 3M	Term 3M	0.7112*	0.8896*	0.677	0.7423
At First Difference					
d_Compounded 14D	d_Term 14D	0.6493*	0.774*	0.6095	0.6858
d_Compounded 1M	d_Term 1M	0.6086*	0.7068*	0.5654	0.6485
d_Compounded 3M	d_Term 3M	0.4803*	0.5234*	0.428	0.5294
Notes: $z = \frac{1}{2}\log\left(\frac{1+\rho}{1-\rho}\right)$. * indicates significance at 1% .					

The term premia is calculated as the difference between the Term Rate and the Compounded Rate on an ex-post basis. To decompose the term premia in the Indian money market, the paper relies on rates of related instruments traded in the interbank markets. These include rates for various tenors derived from OIS, T-bills and CD market. These are transaction based rates[6] released on daily basis by FBIL. Specifically, the spreads of the CD over T-bill Rate (henceforth *CD - TBill Spread*), the T-Bill over OIS Fixed Rate (henceforth TBill - OIS Fx Spread) and the OIS-Fixed Leg Rate over the OIS Floating Leg Rate[7] (henceforth OISFx - OISFL Spread) are used to decompose the term premia for the purpose of the study. It is pertinent to note that in case of an OIS contract, the OIS Floating Leg Rate (OISFL) is computed by compounding the realized O/N MIBOR for the given term of the contract.

The tenor-wise descriptive statistics of the term premia along with each of the sub components are stated in *Table 4* and graphically depicted in *Annexure 1*. The Pearson's Correlation (along with the associated Fisher's z transformation statistics) between the spreads is highlighted in *Table 5*. The T-bill-OIS spread and the CD-TB spread exhibit the highest correlation with the

[5] The z transformation, which is the inverse hyperbolic tangent function of the Pearson's correlation, has a distribution that is approximately normal.
[6] The computation methodologies on the benchmarks published by FBIL are provided on the website https://fbil.org.in/content?p=2103&mq=d. For this study, the 14 days OIS Fixed Rate was extrapolated from the 1 month and 2 month rate. Additionally, the CD rate was modified to include the previous day's rate plus the average spread of the nearby tenors, in case of non-availability of the traded rate for the respective tenor.
[7] The OIS Floating Rate is the same as the Compounded O/N Rate discussed above. OIS trades base MIBOR as the underlying Overnight rate.

Table 4: Descriptive Statistics of Term Premia and sub components in Bps

	Risk Premia 14D	*Risk Premia 1M*	*Risk Premia 3M*	*CD-TB 14D*	*CD-TB 1M*	*CD-TB 3M*	*TB-OIS Fx. 14D*	*TB-OIS Fx. 1M*	*TB-OIS Fx. 3M*	*OIS Fx.-OIS Fl. 14D*	*OIS Fx.-OIS Fl. 1M*	*OIS Fx.-OIS Fl. 3M*
At Level												
Mean	26.4419	39.0936	63.9324	23.3251	30.8201	40.8534	-11.1128	-5.8301	5.5850	2.1838	2.2089	2.8570
Median	25.0000	33.0000	56.0000	13.9400	20.3200	31.3600	-4.0000	-1.0000	6.0000	1.0000	1.0000	1.6500
Mode	25.0000	21.0000	31.0000	16.1100	7.7300	28.3700	-4.0000	0.0000	7.0000	1.0000	0.0000	0.0000
Stdev.	15.9789	19.7108	35.1594	45.4216	35.2519	33.6506	29.6719	20.3973	14.5092	22.2638	14.1278	9.9727
Kurtosis	5.7845	0.3559	-0.9919	61.5716	4.6086	-0.2271	7.8691	5.7787	2.5020	11.0957	15.0379	3.3884
Skewness	-0.6110	0.6551	0.4524	6.1632	1.7872	0.8093	-2.4350	-2.0531	-0.6891	1.0446	2.6447	0.6841
Min	-79.0000	-22.0000	0.0000	-76.9700	-59.1900	-18.3900	-193.0000	-117.0000	-58.0000	-143.6313	-66.3700	-34.0000
Max	101.0000	121.0000	162.0000	623.3600	235.9700	149.5500	49.0000	32.0000	49.0000	113.0000	103.0000	45.0000
Count	887	887	887	887	887	887	887	887	887	887	887	887
At First Difference												
Mean	0.0361	0.0226	0.0587	0.0058	-0.0008	0.0287	0.0169	0.0214	0.0135	-0.0147	-0.0293	-0.0192
Median	0.0000	0.0000	0.0000	0.4100	-0.2350	0.1550	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mode	0.0000	0.0000	0.0000	-1.4800	13.7100	0.5800	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
Stdev.	6.4670	4.6689	4.4416	36.4436	21.9911	14.5849	16.4718	10.4016	4.9388	11.6342	7.9497	3.5622
Kurtosis	98.0407	51.8172	66.2365	50.8670	8.4176	12.9355	24.7472	25.1039	6.5120	81.6035	111.0405	43.6860
Skewness	-5.4071	-3.6619	-4.8400	-2.5316	-0.1158	-0.4307	0.8740	0.7724	-0.0300	0.2033	-3.7622	-2.2926
Min	-106.0000	-59.0000	-56.0000	-418.6700	-134.4400	-137.5100	-117.0000	-86.0000	-27.0000	-149.0000	-131.0000	-45.0000
Max	46.0000	31.0000	32.0000	322.7500	119.6700	81.3800	148.0000	108.0000	24.0000	144.8400	82.0000	26.0000
Count	886	886	886	886	886	886	886	886	886	886	886	886

Table 5: Pearson Correlation Statistics (Fisher's z Transformation) between the Term Premia and Independent Variables for Null of $\rho = 0$

Tenor	Independent Variables	Pearson's Correlation	Fisher's z	95% Confidence Limits	
Ex Post At Level					
14D	CD - TBill Spread	0.2003	0.2031*	0.1362	0.2626
	TBill - OIS Fx. Spread	0.2653	0.2718*	0.2028	0.3253
	OISFx - OISFl Spread	0.1960	0.1985*	0.1317	0.2584
1M	CD - TBill Spread	0.5965	0.6877*	0.5521	0.6371
	TBill - OIS Fx. Spread	-0.0059	-0.0059*	-0.0717	0.06
	OISFx - OISFl Spread	0.2999	0.3094*	0.2386	0.3585
3M	CD - TBill Spread	0.8053	1.1136*	0.7807	0.8272
	TBill - OIS Fx. Spread	0.3953	0.418*	0.338	0.4492
	OISFx - OISFl Spread	0.4092	0.4346*	0.3526	0.4623
Ex Post At First Difference					
14D	Δ (CD - TBill Spread)	0.1451	0.1461*	0.0799	0.2089
	Δ (TBill - OIS Fx. Spread)	0.0984	0.0987*	0.0327	0.1631
	Δ (OISFx - OISFl Spread)	0.1945	0.1971*	0.1302	0.257
1M	Δ (CD - TBill Spread)	0.0743	0.0745**	0.0084	0.1394
	Δ (TBill - OIS Fx. Spread)	0.1099	0.1104*	0.0443	0.1745
	Δ (OISFx - OISFl Spread)	-0.0158	-0.0158	-0.0816	0.0501
3M	Δ (CD - TBill Spread)	0.1610	0.1624*	0.096	0.2244
	Δ (TBill - OIS Fx. Spread)	0.1335	0.1343*	0.0682	0.1975
	Δ (OISFx - OISFl Spread)	-0.0439	-0.0439	-0.1094	0.0221

Notes: $z = \frac{1}{2}\log\left(\frac{1+\rho}{1-\rho}\right)$. * and ** indicates significance at 1% and 5% respectively.

term premia for the 3 month tenors. The highest correlation numbers for the 3 month spreads could be on account of a higher liquidity and issuance in the 3 month tenor versus the 14 day and 1 month in the OIS, Treasury Bill and CD markets. The Fisher adjusted correlation estimates between the term premia and its sub-components (at level and first difference) were also found to be statistically different from 0 at 1% level of significance, with the exception of the changes in the OISFx - OISFL Spread.

4. EXPECTATION THEORY UNDER THE NO-ARBITRAGE CONDITION

In order to test the expectation theory in the Indian money market under the assumption of a no-arbitrage condition, term rate for a given time *t* are compared with the Compounded O/N Rate for the same time period (*t*). There are two versions of the expectations hypothesis. The first version, viz. **the pure expectation hypothesis,** posits that long term interest rates are purely a function of investor expectations of future short term interest rate, with the absence of any term premia associated with longer tenors. In other words, this expectations hypothesis makes an assumption that perfect substitution is possible among the various maturities without any arbitrage profit. It suggests that the shape of the yield curve depends on market participants' expectations of possible future interest rates. These expected rates are used to construct a complete yield curve. Returns on a long-term instrument are equal to the geometric mean of the returns on a series of short-term instruments, as given by:

$$(1 + y_{lt})^n = (1 + y_{st})^{m1} \times (1 + y_{st})^{m2} \times \dots \dots \times (1 + y_{st})^{mn}$$

Where, y_{lt}, y_{st}, are the long term and short term interest rates for the period n and m respectively.

The second version, namely the **general expectation hypothesis**, postulates that the long term interest rate is a function of the future short term interest rate expectations plus a term premia, which is expected to be constant over time.

The expectations theory can be analyzed by computing the Compounded O/N Rate on an ex-ante basis as well as ex-post basis. On an **ex-ante basis**, the future short term rates are assumed to remain constant, and as such the long term interest rate will equal the short term rates plus a constant term premia. In other words, the difference, if any, between the returns from investing at the Term Rate and that from investing in the short term interest rate (i.e. Compounded O/N Rate) would be merely a function of a time-invariant term premia.

In our context, on an ex-ante basis, the expectation hypothesis can be represented in Equation (*1*) as:

$$Term\ Rate_t = E\left[[\ \prod_{i=0}^{n} (1 + O/N\ \ Rate_{t+i}) - 1]^{\frac{365}{n}}\ |\ \Omega_t \right] + a_n \qquad ..(1)$$

where, t is the contract initiation date, n is the contract expiry date, Ω_t is the information set at time t and a_n represents the ex-ante term premia at time n. Since, the $O/N\ Rate$ for a time period greater than t is unknown, we assume that the best estimate of the expected O/N Rate would be the same as the current O/N Rate and hence the Compounded O/N Rate is merely a geometric average of the current O/N rate from period t to period n.

On an **ex-post basis** however, the difference between the Term Rate and the realized short term interest rates can be explained by a term premia plus expectation errors (*Browne and Manasse, 1989*). The expectations hypothesis on an ex-post basis can be expressed in Equation (*2*) as:

$$Term\ Rate_t \ = \left[[\ \prod_{i=0}^{n} (1 + O/N\ \ Rate_{t+i}) - 1]^{\frac{365}{n}} \right] + a_n \ ..(2)$$

where, t is the contract initiation date, n is the contract expiry date and a_n represents the realized term premia plus expectation errors. On an ex-post basis, the $O/N\ Rate$ for a time period greater than t is known, hence we can compute Compounded O/N Rate as a geometric average of the realized O/N Rate from time t to $t + n$.

A value of a_n = 0 would imply that the Term Rates are equal to the geometric average of the short term interest rates without the existence of any term premia. Hence at any point in time, a temporary disparity between the two rates could provide for an arbitrage opportunity. To illustrate the possibility of arbitrage, two hypothetical scenarios are considered in *Annexure 2* that calculates an arbitrage profit.

4.1. Test the Pure Expectation Theory

The following statistical techniques were used to test if the term rate and the compounded O/N rate are identical.

Two Sample *t*-test:

A two sample *t*-test is performed under the assumptions that the sample of the Term rate and the Compounded O/N Rate are independent of each other and that each rate follows a standard normal distribution. The procedure for the two sample *t*-test, first involves testing for the equality of the variances of the two rates. The test for the equality of means is then carried out after adjusting the test statistic based upon the outcome of an equal or unequal variance between the two rates. The two sample *t*-test, assumes a null hypothesis of equality of the means of the Term rate and the Compounded O/N Rate. The derivation of the two sample t-test is provided in *Annexure 3.1*.

An insignificant t-stat would result in a failure to reject the null hypothesis (Pooled or Satterthwaite as the case may be) and would suggest that the means of both rates are equal i.e. the term rate is on an average equal to the compounded O/N rate and thus suggest the lack of any term premium.

Wilcoxon Scores (Rank Sums) Test:

One drawback of the two sample *t*-test is the assumption of normality, which might not always be observed in interest rate time series. To overcome this drawback, the Wilcoxon's scores test was performed, which is a non-parametric test. The test makes the assumption of independence between the two rates but do not require the rates to follow a normal distribution.

Like in the case of the two sample *t* test, the null hypothesis of the Wilcoxon's scores test is that the Term Rates are not significantly different from the Compounded O/N Rate. A failure to reject the null hypotheses (insignificant Z stat) would thus invalidate the existence of any term premia. The derivation of the Wilcoxon Scores test is provided in *Annexure 3.2.*

Ordinary Least-Squares (OLS) Regression Analysis:

The regression specification to model the relationship between the Term rate and the O/N rate can be expressed as follows:

$$Term\ Rate_t = a + \beta * \ O/N\ Rate_t + \varepsilon_t \qquad ...(3)$$

The pure expectations theory can be tested with a null hypothesis of $\alpha = 0$. A rejection of the null hypothesis of the pure expectations theory in Equation *3* would imply that the Term Rate is a function of the overnight rate and would suggest the existence of a constant term premia. Since the general expectations theory allows for a non-zero but time-invariant term premia, one would expect $a > 0$, hence the null hypothesis in such a case would require $\beta = 1$. Rejecting the null hypothesis of the general expectations theory would further suggest that this term premia varies with time. A graphical description of the rationale for the existence of a term premia is illustrated in *Annexure 4*.

Vector Error Correction Model (VECM):

It is imperative to note that the inferences drawn from the OLS specification can be impacted by the presence of unit root in the interest rates and the existence of a cointegrating relationship between them. The presence of unit root in interest rates (at level) would violate the critical assumptions of a constant mean and variance in the time series. To ensure stationarity, interest rates identified as I (1) processes would require differencing. The Phillips Perron unit root test was conducted to detect the presence of unit root in the O/N rate and Term rates at level and first difference.

If the O/N and Term rates are found to contain unit root at level, the spread between the two rates may either be stationary or non-stationary. If the spread is stationary, then one can infer that this pair of interest rates are cointegrated, since a linear combination of these variables is stationary (*Engle and Granger (1987)*). If these rates are unit root processes, and cointegrated, they are stationary in levels in the direction of the cointegrating vector (*Thornton (2004)).* To identify the presence of a cointegrating vector, the Johansen's cointegration rank test was conducted. The test determines the number of linearly independent cointegrating vectors (rank) by carrying out an eigenvalue decomposition.

To address these concerns, the relationship between the Term and O/N rates can be expressed in a VECM form. Specifically, the VECM framework would help in addressing three primary concerns raised in the OLS model for testing the expectations theory. First, the VECM model accounts for the changes in the interest rates at first difference, thereby alleviating concerns of non-stationarity in the series. Second, the model introduces a long term cointegrating vector between the interest rates which explains the correction from a temporary disequilibrium between the rates. Third, this framework, takes into account the nature of persistence in interest rates, by introducing a lead-lag structure in the model[8].

The VECM is expressed in Equation *(4.1)* and *(4.2)* as:

$$\Delta Term_t = \lambda_T + \sum_{i=1}^{k} \eta_{T,i} \Delta Term_{t-i} + \sum_{i=1}^{k} \theta_{T,i} \Delta O/N_{t-i} + \alpha_{Term} \beta' \binom{Term_{t-1}}{O/N_{t-1}} + \varepsilon_{F,t} \qquad (4.1)$$

$$\Delta O/N_t = \lambda_O + \sum_{i=1}^{k} \eta_{O,i} \Delta O/N_{t-i} + \sum_{i=1}^{k} \theta_{O,i} \Delta Term_{t-i} + \alpha_{O/N} \beta' \binom{Term_{t-1}}{O/N_{t-1}} + \varepsilon_{S,t} \qquad (4.2)$$

In the above equation, $\Delta Term_t$ and $\Delta O/N_t$ stand for the change in the Term and O/N rates respectively. λ_T and ζ_O are the intercept terms. The coefficients $\eta_{T,i}$ and $\eta_{O,i}$ explain the autoregressive nature of the Term Rates and O/N respectively. $\theta_{T,i}$ detects the presence of the dependence of the Term Rates on the lagged O/N Rate (at lag of $t-i$). $\theta_{O,i}$ examines whether the lagged Term Rates impacts the O/N Rate. The optimal lag length of the model can be estimated using the AIC information criteria. $\beta' = (\beta_{Term}, \beta_{O/N})$ wherein coefficient β_{Term} and $\beta_{O/N}$ are the parameters of the common stochastic trend that exists between the Term and O/N Rate.

We normalize β_{Term} by restricting it to 1, such that the long run cointegrating relationship can now be expressed as $Term_{t-1} = \beta_{O/N}\, O/N_{t-1} + \nu$, where $\beta_{O/N}$ and ν are the slope and the error terms of the common stochastic trend. The terms α_{Term} and $\alpha_{O/N}$ are the coefficients that explain the speed of adjustment of the Term and O/N rates to the long run cointegrating levels. The larger the values of α_{Term} and $\alpha_{O/N}$, faster is the adjustment to the common stochastic trend.

The validity of the expectations theory can be examined in the VECM framework using the following tests:

- ***Cointegration and Restriction on Slope Parameters***: A pre-requisite for testing the expectations hypothesis is to determine the presence of a cointegrating vector between the Term and O/N rates. A cointegrating vector would suggest a common permanent or long run

[8] *King and Kurmann (2002)* highlight stylized facts on the behavior of interest rates such as stationarity, cointegration and the persistence in interest rates.

equilibrium relationship between the rates. Further, it is imperative to ascertain if the error correction model contains a deterministic term. In the presence of cointegration, the expectations theory can be tested in the following steps:

- *Step 1:* Estimate an **Unrestricted** VECM with the cointegrating spread between the lagged Term rate and O/N rate (after normalizing the Term Rate) expressed as:

$$\nu_{t-1} = Term_{t-1} - \beta_{O/N}\, O/N_{t-1} \text{ (model without drift)}$$

$$\nu_{t-1} = Term_{t-1} - \beta_{O/N}\, O/N_{t-1} + Drift \text{ (model with drift)}$$

where (1, $-\beta_{O/N})'$ *is the vector of the cointegrating parameters*

The eigenvalue associated with the cointegrating vector with and without a drift term is compared using a chi-square test. An insignificant chi-square statistic would suggest that the models with and without a drift are not significantly different from one another i.e. the drift term is not significantly from 0.

- *Step 2:* Estimate a **Restricted** VECM such that the cointegrating vector is restricted to $(1,-1)'$.[9] In such a case, the speed of adjustment parameter to the long run cointegrating vector of $(1,-1)'$ is re-estimated.
- *Step 3:* Compare the eigenvalue of the Unrestricted VECM with the eigenvalue obtained from the Restricted VECM using a chi-square test. The null hypothesis of the test is expressed as $1 + \beta_{O/N} = 0$. A failure to reject the null hypothesis would imply that the cointegrated vector *(1,* $-\beta_{O/N})'$ is not significantly different from $(1,-1)'$ and that the slope $(\beta_{O/N})$ of the vector explaining the spread between the two rates is equal to 1. In other words, there is a one to one relationship between the Term and O/N rates towards the long run equilibrium trend.

If a cointegrating vector of $(1,-1)'$ is found, it would suggest that the expectations hypothesis holds for the two rates considered. The validity of the version of the expectations hypothesis, either pure or general hypothesis, depends on the presence of a drift term. If such a cointegrating vector was obtained from a model without a drift, it would suggest that a term premia is absent and that the pure version of the expectations hypothesis is valid. If however, such a cointegrating vector was obtained from a model with a drift term, one can confirm that the expectations theory holds but only in the presence of a constant term premia (i.e. the general expectations hypothesis). A failure to obtain a cointegrating vector of $(1,-1)'$ would invalidate both the pure and general form of the expectations hypothesis.

- ***Test of weak Exogeneity and Granger Causality:*** Supporting evidence to test the validity of the expectations hypothesis can be obtained by analyzing the long run and short run parameters of the VECM. One can examine the validity in the long run by examining the

[9] The restriction of (1,-1) in the VECM model is similar to this restriction of imposing β = 1 in the OLS model.

significance of the $\alpha_{O/N}$ parameter. A value of $\alpha_{O/N}$ significantly different from 0 would suggest that the changes in the O/N Rate adjust to make up for the temporary deviations in spread between the Term and O/N rates.

To support this result, a test of weak exogeneity (long run causality) of the O/N Rate can be conducted. The test of weak exogeneity of O/N Rate given the parameters $(\alpha_{Term}, \beta_{O/N})$ determines whether $\alpha_{O/N} = 0$. Weak exogeneity means that $\alpha_{O/N}$ does not react to the disequilibrium created between the two rates. A test of weak exogeneity can be conducted by restricting the $\alpha_{O/N}$ to 0 and re-estimating the VECM under such restriction. A chi-square test, is estimated to compare the eigenvalue of the unrestricted model with that obtained from restricting the $\alpha_{O/N}$ to 0, to test if the O/N Rate is weakly exogenous. A statistically significant chi-square would suggest that the O/N Rate is not the weak exogeneity of the Term Rate (i.e. it is an endogenous variable in the model). An insignificant chi-square statistic would indicate that the O/N Rate can be characterized as a pure random walk independent of the error correction term.

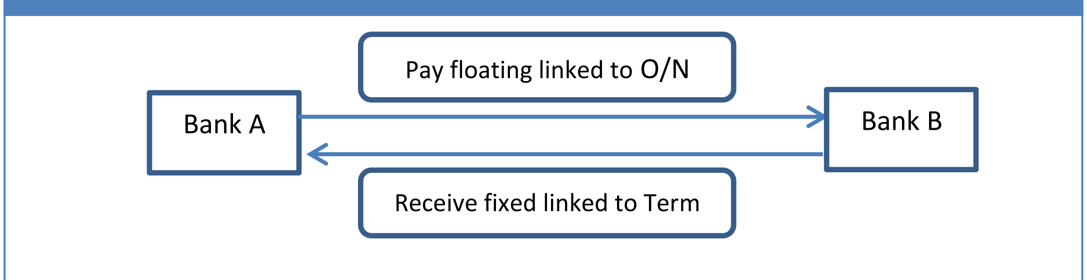
The expectations theory can be tested in the short run by using the Granger Causality Wald test, which is a joint test on the lagged coefficients in each VECM equations, wherein the null hypothesis assumes that the sum of the lagged parameters is equal to 0. The null hypothesis is that the Term Rate (O/N Rate) is influenced only by itself, and not by the lagged returns in the O/N Rate (Term Rate). A rejection of the null hypothesis would suggest that the Term Rate (O/N Rate) is influenced not only by its past returns but also by the past returns in the O/N Rate (Term) market.

5. DECOMPOSITION OF MONEY MARKET TERM PREMIA:

A term premium can be defined as the excess return that an investor would require to commit to holding an investment at the Term Rate instead of a series of shorter-term investments rolled over at the O/N Rate. Empirical literature highlights that the term premia in money markets can be decomposed into key risk factors related to credit and liquidity.

The term premia is modelled here as a payoff of a hypothetical swap contract wherein the fixed leg would be the Term Rate and the floating leg would be linked to the O/N Rate compounded on a daily basis during the term of the contract (*Figure 1*).

Figure 1: Hypothetical swap contract Payoff:



The term premia (payoff of the hypothetical swap) can be further deconstructed into 4 components: the payoff of an OIS swap contract for the same tenor as that of the hypothetical swap contract, a spread of Treasury bill rate over the OIS Fixed rate, a spread of CD rate over Treasury bill rate and the spread of Term Rate over the CD Rate. The individual components and their associated risk factors are depicted in *Figure 2*.

Figure 2: Theoretical Decomposition of Term Premia

Term Premia	Components	Explanation
[Term Rate – Compounded O/N Rate]	[Term Rate – CD Rate] +	• Reflects credit risk in an uncollateralized market
	[CD Rate– T-bill Rate] +	• Reflects credit risk in a collateralized market
	[T-Bill – OIS Fixed Rate] +	• Reflects funding cost • Liquidity risk in a collateralized market
	[OIS Fixed Rate–OIS Floating Rate]	• Reflects the expectation error • marginal funding cost • minimal credit risk

- **Spread of OIS Fixed Rate over OIS Floating Rate:** In an OIS contract, the fixed leg is the determined at contract initiation while the floating leg is anchored to the O/N MIBOR compounded on a daily basis. The payoff structure of an OIS swap would be similar to that of our hypothetical swap contract since the floating leg of both these swaps is linked to the O/N MIBOR. However, the Term Rate would be higher than the OIS Fixed rate as the Term Rate is an inter-bank rate that accounts for a credit risk exposure to an amount equal to the principal borrowed/lent at the beginning plus the interest. The OIS on the other hand does not involve an exchange of principal at the onset of the contract. The only inherent exposure is the net interest obligation from the swap (OIS Fixed Rate – OIS Floating Rate)[10] that is settled at maturity (in case of swaps with a maturity of less than 1 Year). The OIS fixed rate serves as an indicator of market expectations of the O/N MIBOR for the term of the contract. *The difference between the fixed and floating leg of an OIS contract would therefore indicate the error in expectations of market participants, between the fixed rate which is pre-determined at the inception of the contract and the realization of the floating interest rate.*

[10] About 73% of periodic net cash flows settlement of all swap contracts are routed through central counterparties in India and hence risk is marginal for remaining 23%.

- **Spread of T-Bill Rate over OIS Fixed Rate***:* The T-Bill rate is ideally considered as a risk free rate and would be lower than the Term Rate for two reasons: (1) the T-bill rate represents the exposure to the Government while the Term rate is an interbank rate (2) the T-bill rate is an asset buy / sell rate vis-à-vis the MIBOR rate which is an uncollateralized rate. Unlike the OIS rate however, Treasury bills will have *a funding cost / opportunity cost*, which should be reflected in the spread of the T-bill Rate over OIS Fixed Rate. *The spread would not reflect an interbank credit risk but would reflect a liquidity risk in a market given the overall funding cost and liquidity requirements of participants*.
- **Spread of CD Rate over T-bill Rate**: Certificate of Deposits (CDs) are instruments issued by banks and financial institutions and are traded in the institutional markets. T-bills are sovereign instruments and to the extent do not command a credit risk. The spread between the CD rate and corresponding maturity T-Bill rate *represents the credit risk in an institutional market*. It may be noted that in the absence of any CDS market, the spread of the CD rate over the Tbill rate is considered as an available proxy for pricing of credit risk.
- **Spread of Term Rate over CD Rate:** The term rate and the CD rates are interbank rate for instruments. The spread would represent the credit risk in an uncollateralized interbank market.

The spread of the CD rate over the T-bill rate and the spread of the Term rate over CD Rate should ideally reflect credit risk with and without collateral respectively. However, considering the low depth (low trading volumes) in these markets, one cannot rule out the existence of a premia for illiquidity that may be built into these spreads as well.

5.1. Partial Correlation Network Analysis:

As a precursor to decompose term premia, we construct a partial correlation network consisting of the Term Premia (Ex-Post) and its underlying risk factors. A partial correlation network measures the magnitude of a linear relationship between two continuous variables, after controlling for the effect of one or more other continuous variables in the network. The risk factors used in this analysis include:

- The spread of CD rate over the T-bill rate (in bps)
- The spread of T-bill rate over the OIS rate (in bps)
- Spread of OIS Fixed Rate over OIS Floating Rate (in bps)

The partial correlation coefficients are estimated by way of a node-wise regression. To do so, each variable is expressed as a function of the associated variable in the network. For example, partial correlation between the term premia and the *Tbill-OIS* spread can be computed as:

$$Term\ Premia = \beta_{10} + \beta_{11}(CD - TBill) + \beta_{12}\,(Tbill - OISFx) + \beta_{13}\,(OISFx - OISFl) + \varepsilon_1$$

$$CD - TBill = \beta_{20} + \beta_{21}\, Term\ Premia + \beta_{22}\,(Tbill - OISFx) + \beta_{23}\,(OISFx - OISFl) + \varepsilon_2$$

$$PartialCor[(Term\ Premia), (CD - TBill)] = \frac{\beta_{11} SD(\varepsilon_2)}{SD(\varepsilon_1)} = \frac{\beta_{21} SD(\varepsilon_1)}{SD(\varepsilon_2)} \quad \ldots (5)$$

where,

- $PartialCor[Term\ Premia, (CD - TBill)]$ *represents the Partial Correlation between the* $Term\ Premia$ *and* $CD - TBill$ *spread.*
- *SD is the standard Deviation of the errors.*

The estimated partial correlations can be visualized in the form of a weighted network structure (*Epskamp and Fried, 2018*), wherein each node represents the variable in the network and each edge (line connecting two nodes) represents the relationship (partial correlation) between the two connected variables, after controlling for all other variables in the network. The weight of the edges represents the magnitude of partial correlation coefficient[11].

5.2. Money Market Term Premia Decomposition - An OLS Approach:

The study also uses an OLS regression framework to decompose the term premia on the basis of *Figure (2)* into components that would act as a proxy for the liquidity and credit premia. When modelling the term premia using a multivariate time series analysis, one would ideally need to take into account the phenomenon of a spike in the call money rates on the last business day of the financial year[12].

The term premia using an OLS model is expressed as follows:

$$Term\ Premia_t = a + \beta_1 (CD - TBill)_t + \beta_2 (TBill - OISFx)_t + \beta_3 (OISFx - OISFl)_t + \varepsilon_t \quad \ldots (6)$$

$$Term\ Premia_t = a + \beta_1 (CD - TBill)_t + \beta_2 (TBill - OISFx)_t + \beta_3 (OISFx - OISFl)_t + \beta_4 Dummy\ Year\ End + \varepsilon_t \quad \ldots (7)$$

where:

- *TBill-OIS* and *CD-TBill* spreads are expressed in *Section 4*.
- Dummy Year End represents a dummy variable introduced to account for the turn of the year effect. The dummy variable is assigned a value of 1 on each day when the last business day of March is a part of the outstanding term period. An illustration of method in which the dummy has been assigned is provided in Annexure 5.

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[11] In this study, the edges in red indicate negative partial correlations, while edges in green indicate positive partial correlations, with wider and more saturated lines indicating stronger partial correlations.

[12] Yearend turn is an accepted financial market phenomena.

5.3. Money Market Term Premia Decomposition- A Latent Factor Approach:

While the OLS model specified in Equation *(6)* and *(7)* sated above, can be used to estimate term premia for each of the tenors individually i.e. 14 day, 1 month and 3 months, the issue of decomposition of the term premia could also be addressed in the latent factor model framework. An Multiple Partial Least Square (MPLS) regression framework would allow for jointly considering all the tenor-wise information, to identify the common latent factors. This would give us an estimate of the endogenous factors that drive the term premia across the various tenors of the term money market.

Specifically, an MPLS regression, which falls under the category of statistical factor models, is applied to predict a set of response variables by determining latent factors from a series of predictor variables. Each variable in the analysis is standardised[13].

In the MPLS model we define:

- Y_0 as a matrix of three *response* variables *viz.* the Term Premia computed for the 14 days, 1 month and 3 months; and
- X_0 as a matrix of *nine predictor variables viz.* OISFx-OISFl spread (for 14 days, 1 month & 3 month); T-Bill-OISFx spread (for 14 days, 1 month & 3 month) and CD-TB Spread (for 14 days, 1 month & 3 month).

The model entails estimation of the factor score u (which is a linear combination of response variables in Y_0) and t (which is a linear combination of predictor variables in X_0), which can be constructed as:

$$u = Y_0 q \quad \text{and} \quad t = X_0 w$$

where, q is the weight associated with each vector of Y_0 and w are the weight associated with each vector of X_0. A higher weight would indicate a larger contribution of the variable (predictor or response as the case may be) in the construction of their respective factor score. It is pertinent to note that the factor score t is computed in such a manner that it has the maximum covariance with the factor score u. The MPLS model then predicts both X_0 and Y_0 as:

$$\hat{X}_0 = tp'$$

$$\hat{Y}_0 = tc'$$

where, p' and c' are the loadings[14] associated with the factor scores t. The loading would indicate the significance of the factor on the response and predictor variables.

[13] A variable can be standardised by centering and scaling. For instance, vector 'X' is standardised as $\frac{(X_i - \overline{X})}{\sigma_X}$, where x_i is the value of X at time i, $\bar{x}$ is the sample mean of X and σ_X is its sample standard deviation.

[14] Loadings in a PLS model are analogues to the beta coefficients in an OLS model.

A split sample cross validation method was followed to determine the number of factors that explain the variation in the underlying variables (both predictor and response). The choice for the number of extracted factors was decided based on the model with the lowest Root PRESS and the Hotelling's T^2 statistic. [15]

6. FINDING AND EMPIRICAL ANALYSIS:

6.1. Testing the Pure Expectation Theory

Preliminary Analysis using T-test and Wilcoxon scores (Rank Sums) test:

A two sample t-test was estimated to analyze if the mean and variance structure of the Term Rate was significantly different from that of the Compounded O/N Rate. It was found that the variance of 14 day Term Rates was not statistically different from that of the Compounded O/N Rate (as indicated by the Folded F Stat). The Pooled t-stat however indicated that the means of the samples were statistically different from one another. In case of the 1M and 3M tenors, there was a significant difference in the mean and variance structures of both the rates (Term and Compounded O/N). The results are highlighted in *Table 6*. Similar results were obtained upon computing the Compounded O/N Rate on an ex-ante basis as well.

Table 6: Two Sample T-Test Results (Ex-Post Basis)$

Variable	Mean	95% Confidence Interval from the Mean		Std. Dev	95% confidence Interval from Std. Dev		Folded F Stat	t Stat	
								Pooled	Satterthwaite
14 Day									
(a) Compounded O/N Rate	6.3931	6.3705	6.4156	0.3424	0.3271	0.3591	1.1000	-15.8500*	-
(b) Term Rate	6.6575	6.6338	6.6812	0.3599	0.3439	0.3775			
(b)-(a)	0.2644	0.2971	0.2317	0.3512	0.3400	0.3632			
1 Month									
(a) Compounded O/N Rate	6.3970	6.3762	6.4177	0.3149	0.3009	0.3303	1.5800*	-	-23.0100*
(b) Term Rate	6.7879	6.7618	6.8140	0.3960	0.3784	0.4154			
(b)-(a)	0.3909	0.4243	0.3576	0.3578	0.3464	0.3700			
3 Month									
(a) Compounded O/N Rate	6.4067	6.3871	6.4262	0.2967	0.2835	0.3112	2.7700*	-	-33.0400*
(b) Term Rate	7.0460	7.0134	7.0785	0.4940	0.4721	0.5182			
(b)-(a)	0.6393	0.6773	0.6014	0.4075	0.3945	0.4214			

*$Similar inferences were drawn from ex-ante sample as well. *indicates significance at 1%.*

Specifically, the spread of the Term Rates over the Compounded O/N Rate were found to be positive and increased with an increase in tenor. The spread was around 26 bps, 39 bps and 64 bps for the 14 day, 1 month and 3 months respectively, suggesting that market participants might

[15] See Van der Voet, H. (1994) for derivation of the Hotelling's T^2 statistic.

require a higher compensation for uncertainties pertaining to longer tenors. The 95% confidence limits from the mean of the spreads also indicated a persistently positive difference for all the tenors considered.

However, a graphical representation of the distribution of spreads, highlighted in *Annexure 6*, exhibits a deviation from normality, which violates a critical assumption that is required to be maintained for the validity of the two sample t-test results. To overcome the drawback of non-normality, the Wilcoxon scores (Rank Sums) test was estimated. The Z-stat was statistically significant at 1% level which indicates that the null hypothesis was rejected (as indicated in *Table 7* and *Annexure 7*). We therefore conclude that the mean scores of the Term Rates were significantly different from than that of the Compounded O/N Rate. Specifically, the mean score for the Term Rates were higher than that of the Compounded O/N Rate for all the tenors considered, thus providing a preliminary evidence of the existence of a term premia. Further, this difference also tends to increase with maturity.

Table 7: Wilcoxon Scores (Rank Sums)-Ex Post Analysis$

Variable	Mean Score	Sum of Scores	Expected Score Under H0	Std. Dev Under H0	*Z*-Stat
14 Days					
Term Rate	1,070.78	949,786.00	787,212.50	10,786.81	15.0715 *
Compounded O/N Rate	704.22	624,639.00			
1 Month					
Term Rate	1,128.50	1,000,981.00	787,212.50	10,786.73	19.8177 *
Compounded O/N Rate	646.50	573,444.00			
3 Months					
Term Rate	1,210.78	1,073,965.00	787,212.50	10,786.42	26.5845 *
Compounded O/N Rate	564.22	500,460.00			
$ Similar results were recorded on an ex-ante basis as well. *,** and *** indicate significance at 1%, 5% and 10% respectively.					

Testing Expectations Hypothesis using OLS and VEC model:

To test the expectations theory in the uncollateralised money market, the OLS regression models specified in *Equations (3)* were estimated for the full period and two equally sub-sample periods. The results indicate that the O/N Rate was a statistically significantly predictor to the applicable Term Rates. For the full period the β values of 0.98, 0.99 and 0.97 were reported for the respective tenors of 14 days, 1 month and 3 months. Further, the α parameter of 0.40, 0.45 and 0.85 were recorded in case of the 14 days, 1 month and 3 months. An F-test revealed that the α parameter was found to be significantly different from 0 while the β parameter was not significantly different from 1. However the α and β parameters showed a wide variation in the sub-sample periods, with many cases of a negative term premia being reported. The inconsistent results might suggest the instability of a simple OLS model for testing expectations hypothesis (*Table 8*).

Table 8: OLS Regression Results For Testing Pure Expectation Theory							
Dependent Variable	Independent Variable	Estimate	HAC Standard Error	*t* -Stat	Total R-Square	*F*-Stat for Null Hypothesis:	
						$\alpha = 0$	$\beta = 1$
Full Period							
14D Term Rate	Intercept	0.3979	0.0977	4.0700*	0.8248	16.5900*	1.2200
	O/N Rate	0.9829	0.0155	63.3400*			
1M Term Rate	Intercept	0.4543	0.1392	3.2600*	0.7059	10.6500*	0.0600
	O/N Rate	0.9947	0.0221	45.0900*			
3M Term Rate	Intercept	0.8571	0.1951	4.3900*	0.4728	19.3000*	0.7300
	O/N Rate	0.9739	0.0306	31.8500*			
Period 1							
14D Term Rate	Intercept	0.0051	0.1459	0.0300	0.8822	0.0000	2.1500
	O/N Rate	1.0336	0.0229	45.0900*			
1M Term Rate	Intercept	-0.7685	0.2003	-3.8400*	0.8440	14.7200*	27.7500*
	O/N Rate	1.1671	0.0317	36.7900*			
3M Term Rate	Intercept	-2.1612	0.2510	-8.6100*	0.8206	74.1100*	104.6400*
	O/N Rate	1.4066	0.0397	35.3900*			
Period 2							
14D Term Rate	Intercept	-0.6965	0.1002	-6.9500*	0.8288	48.2900*	114.2100*
	O/N Rate	1.1708	0.0160	73.2700*			
1M Term Rate	Intercept	-0.5725	0.1301	-4.4000*	0.7183	19.3500*	76.1200*
	O/N Rate	1.1784	0.0204	57.6300*			
3M Term Rate	Intercept	-0.4931	0.1954	-2.5200**	0.5732	6.3700**	56.6800*
	O/N Rate	1.2277	0.0302	40.6000*			
Notes: *,** and *** indicate significance at 1%, 5% and 10% respectively.							

Further, since the inferences drawn from the OLS specification might be impacted by the presence of unit root in the O/N Rate and Term Rates, a Phillips Perron test was estimated. It was found that the O/N and Term Rates were non-stationary at level but stationary after first differencing *(Table 9).*

Additionally, to determine if a linear combination of the O/N rate with each of the term rates are stationary, the Johansen's cointegration test was conducted (*Table 10*). When estimating the model with and without a drift term, null hypothesis of a rank=0 was rejected in all cases[16]. This suggests the presence of a linearly independent cointegrating vector which explains the spread between the Term and O/N rates. However, a chi-square statistics, used to compare the eigenvalues of the models with and without a drift, were found to be insignificant for each of these tenors.

[16] A cointegrating vector between the 3 months Term Rate and the O/N rate could be estimated only in case of a model without a drift term.

Table 9: Phillips Perron Unit Root Test for Spreads								
	Level				First Difference			
Type	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**
14 Days								
Zero Mean	-0.2989	0.6149	-0.9387	0.3100	-672.8358	<.0001	-23.7569	<.0001
Single Mean	-15.7175	0.0331	-2.7527	0.0663	-672.5610	0.0018	-23.7588	<.0001
Trend	-18.8043	0.0877	-3.0293	0.1249	-672.5641	0.0008	-23.7452	<.0001
1 Month								
Zero Mean	-0.2860	0.6179	-0.9888	0.2885	-682.4860	<.0001	-22.6153	<.0001
Single Mean	-10.8478	0.1097	-2.2586	0.1857	-682.6284	0.0018	-22.6241	<.0001
Trend	-12.0013	0.3140	-2.3935	0.3826	-682.6309	0.0008	-22.6123	<.0001
3 Months								
Zero Mean	-0.2394	0.6285	-0.9794	0.2925	-763.7830	<.0001	-23.9590	<.0001
Single Mean	-5.8273	0.3612	-1.6543	0.4544	-764.1441	0.0018	-23.9692	<.0001
Trend	-5.8600	0.7552	-1.6614	0.7679	-764.1017	0.0008	-23.9573	<.0001
O/N Rate								
Zero Mean	-0.3185	0.6105	-1.3434	0.1666	-865.5253	<.0001	-34.7932	<.0001
Single Mean	-11.1062	0.1030	-2.4426	0.1305	-863.7395	0.0018	-34.8562	<.0001
Trend	-17.9283	0.1045	-3.0735	0.1135	-863.7491	0.0008	-34.8343	<.0001

We can therefore infer that a drift introduced in the error correction model was not significantly different from 0. Hence, a cointegrating vector without a drift term was introduced in the VECM.

Table 10: Term Rate and O/N Rate Cointegration Rank Test Using Trace						
H0:	**H1:**	**Drift in Model ECM**		**No Drift in Model ECM**		**χ^2- stat**
Rank=r	**Rank>r**	**Eigenvalue**	**Trace**	**Eigenvalue**	**Trace**	
14 Days						
0	**0**	0.0590	65.1230*	0.0590	64.0029*	1.1200
1	**1**	0.0083	7.8516	0.0071	6.7315	
1 Month						
0	**0**	0.0261	31.4656*	0.0260	30.2079*	1.1100
1	**1**	0.0070	6.5676	0.0058	5.4559	
3 Month						
0	**0**	0.0142	16.8038	0.0135	15.5217**	0.5600
1	**1**	0.0035	3.3113	0.0029	2.7555	
Notes: *,** and *** indicate significance at 1%, 5% and 10% respectively.						

The results of the VECM are highlighted in *Table 11*. In case of 14 days tenor, an analysis of the long run parameters of the unrestricted VECM, reveals that the slope of the cointegrating vector was close to 1.0596[17]. Further, the statistically significant speed of adjustment parameters viz.

[17] The cointegrating vector for 14 days can be expressed $Term\ Rate\ _{t-1} - 1.0596\ O/N\ \ Rate_{t-1} = v_t$, with a slope coefficient of 1.0596.

α_{Term} and $\alpha_{\text{O/N}}$ revealed that the 14 days Term Rate as well as the O/N Rate adjust to correct for any temporary disequilibrium created between the rates in the direction of the long run cointegrating vector.

Table 11: VECM Results (Unrestricted and Restricted) and Test of Weak Exogeinity on the Long Run Parameters								
Coefficient	**Unrestricted VECM**		**Restricted VECM**		**Weak Exogeinity of O/N Rate**		**Weak Exogeinity of Term Rate**	
	parameter	***t*-stat**	**parameter**	**χ^2- stat**	**parameter**	**χ^2- stat**	**parameter**	**χ^2- stat**
14 Days								
α_{Term}	-0.0632	-5.2600*	-0.0665	*0.9000*	-0.0796	*9.9300**	0.0000	*24.0700**
$\alpha_{O/N}$	0.0453	3.3600*	0.0412		0.0000		0.0668	
β_{Term}	1.0000	-	1.0000		1.0000		1.0000	
$\beta_{O/N}$	-1.0596	-	-1.0000		-0.9861		-1.2126	
1 Months								
α_{Term}	-0.0084	*-1.3500*	-0.0139	*2.6300****	-0.0220	11.8500*	0.0000	*1.4300*
$\alpha_{O/N}$	0.0345	*3.9100**	0.0294		0.0000		0.0371	
β_{Term}	1.0000	-	1.0000		1.0000		1.0000	
$\beta_{O/N}$	-1.2538	-	-1.0000		-0.9005		-1.3565	
3 Months								
α_{Term}	0.0020	*0.8100*	-0.0022	*5.1500***	-0.0052	*9.8300**	0.0000	*0.5200*
$\alpha_{O/N}$	0.0143	*3.5500**	0.0136		0.0000		0.0146	
β_{Term}	1.0000	-	1.0000		1.0000		1.0000	
$\beta_{O/N}$	-2.0817	-	-1.0000		-0.4551		-1.8689	

Notes:
1. β_{Term} is normalised to 1.
2. The cointegrating vector for 14 days can be expressed $Term\ Rate\ _{t-1} - 1.0596\ O/N\ \ Rate_{t-1} = v_t$, with a coefficient of 1.0596.
3. Values highlighted in Red indicate a restriction on the coefficient.
4. The Restricted VECM imposes [1,-1] restriction on the slope parameters
5. The Test of weak Exogeinity imposes a restriction of 0.
6. *,** and *** indicate significance at 1%, 5% and 10% respectively.

A chi-square test estimated to compare the eigenvalues of the Unrestricted VECM with that of the Restricted VECM, indicated that the slope parameters of the unrestricted VECM (i.e. of $(1, -1.0596)'$) were not statistically different from $(1, -1)'$. This result of cointegrating vector insignificantly different from $(1, -1)'$ and without a drift term supports the validity of the pure expectations hypothesis. Since the slope for the tenors of 1 month and 3 months are different from one (in this study it was found to be greater than 1), it shows that the term rates are moving by more than the O/N rates on an average. This empirical finding is consistent with the presence of a time varying term premia for these tenors.

A test of weak exogeneity by imposing a zero restriction on the long run parameters of α_{Term} and $\alpha_{\text{O/N}}$ parameters was rejected at 1%, in case of both the Term and O/N Rates. This indicates that both the Term and O/N rates react to adjust for any disequilibrium created between the two rates.

The validity of pure expectations theory in case of the 14 days tenor was re-affirmed by looking at the short run parameters in case of the 14 days period (*Table 12*), which suggest that the lagged changes in the term rate was a significant predictor to the O/N Rate at time t. A bi-directional causality was also found between the 14 days Term rate and the O/N Rate. The granger causality test suggests that the 14 days Term Rate was influenced not only its own lagged values, but also by the lagged O/N Rate and vice-versa.

Table 12: VECM Results (Unrestricted) and Test of Weak Exogeinity on the Short Run Parameters

Panel A: Unrestricted VECM[&]					Panel B: Granger Causality	
Dependent Variable	**Regressor**	**Coefficient**	**Parameter**	**t-stat**	**(χ^2- stat)**	
	14 Days					
$\Delta 14D\ Term\ Rate_t$	$\Delta 14D\ Term\ Rate_{t-1}$	$\eta_{T,i}$	0.2628	7.8700*	$\Delta O/N$ Rate $\rightarrow$ $\Delta 14D\ Term\ Rate$	$\Delta 14D\ Term\ Rate$ $\rightarrow$ $\Delta O/N$ Rate
	$\Delta O/N\ \text{Rate}_{t-1}$	$\theta_{T,i}$	-0.0195	-0.6300		
$\Delta O/N$ Rate	$\Delta 14D\ Term\ Rate_{t-1}$	$\theta_{O,i}$	0.0737	1.9700**	(21.1900)*	(15.5300)*
	$\Delta O/N\ \text{Rate}_{t-1}$	$\eta_{O,i}$	-0.0914	-2.6200*		
	1 Month					
$\Delta 1M\ Term$	$\Delta 1M\ Term\ Rate_{t-1}$	$\eta_{T,i}$	0.3171	9.4900*	$\Delta O/N$ Rate $\rightarrow$ $\Delta 1M\ Term\ Rate$	$\Delta 1M\ Term\ Rate$ $\rightarrow$ $\Delta O/N$ Rate
	$\Delta O/N\ \text{Rate}_{t-1}$	$\theta_{T,i}$	-0.0167	-0.6800		
$\Delta O/N$ Rate	$\Delta 1M\ Term\ Rate_{t-1}$	$\theta_{O,i}$	0.0698	1.4800	(1.0200)	(13.2200)*
	$\Delta O/N\ \text{Rate}_{t-1}$	$\eta_{O,i}$	-0.0915	-2.6200*		
	3 Months					
$\Delta 3M\ Term\ Rate$	$\Delta 3M\ Term\ Rate_{t-1}$	$\eta_{T,i}$	0.2712	8.0500*	$\Delta O/N$ Rate $\rightarrow$ $\Delta 3M\ Term\ Rate$	$\Delta 3M\ Term\ Rate$ $\rightarrow$ $\Delta O/N$ Rate
	$\Delta O/N\ \text{Rate}_{t-1}$	$\theta_{T,i}$	-0.0185	-0.8500		
$\Delta O/N$ Rate	$\Delta 3M\ Term\ Rate_{t-1}$	$\theta_{O,i}$	0.1308	2.4300**	(1.5400)	(11.9800)*
	$\Delta O/N\ \text{Rate}_{t-1}$	$\eta_{O,i}$	-0.1066	-3.0800*		

Notes:
(1) The Test of weak Exogeinity imposes a restriction of 0. (2) *,** and *** indicate significance at 1%, 5% and 10% respectively.

In case of the 1 month and 3 months rates however, the slope of the cointegrating vector was found to be 1.2538 and 2.0817 respectively. The chi-square test after imposing a restriction on these long run parameters to $(1, -1)'$ was rejected at 10% and 5% respectively. This suggests that coefficient of 1.2538 and 2.0817 was significantly different from 1. The results violate the assumption of a one-to-one equilibrium relationship of the 1 month term rates and 3 month term rates with the O/N rate. It also rejects the pure as well as general expectations hypothesis for the two tenors considered. We further failed to reject weak exogeneity of the α_{Term} parameter in the 1 month and 3 months VEC model.

Although it is pertinent to note that the $\alpha_{\text{O/N}}$ rate was statistically significant. This suggests that the O/N rate follows the lead of the Term rate to correct for any long run dis-equilibrium in case of these two tenors. Similar results were obtained in the Granger Causality test for these two tenors considered, wherein it was found that the changes in Term rates granger caused the changes in the O/N Rate but the reverse did not hold.

6.2. Money Market Term Premia Decomposition- Network Analysis

Based on the framework laid down in *Section 5.1*, a partial correlation network then was constructed, to identify the underlying factors that drive the term premia. The graphs highlighting the network topography are specified in *Annexure 8*. Two key inferences can be drawn from the analysis:

- After individually controlling for the effects of each of the remaining regressors, the term premia was positively correlated with the CD-Tbill Spread, the Tbill-OISFx. Spread as well as the OISfx. – OISFl. Spread.
- The magnitude of the edges indicated a stronger positive relationship with the credit risk factor (as measured by the *CD-Tbill Spread*) than the liquidity risk factor (as measured by the *Tbill-OIS spread*) specifically in case of the 3-month tenors.

Based on the inferences from the partial correlation network analysis, the authors decompose the term premia using the OLS and MPLS approach in *Section 6.3* and *6.4* respectively.

6.3. Money Market Term Premia Decomposition- OLS Regression Results

Given that the highest correlation between the spreads was found at the 3 month tenor, the OLS regression model was estimated using the spreads for the maturity of 3 month. The spreads used in the analysis were tested for unit root to avoid spurious regression results. The results of the Phillips Perron unit root test are highlighted in *Table 13*.

Table 13:Phillips Perron Unit Root Test for Spreads

	Level				First Difference			
Type	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**
Term Premia 3M								
Zero Mean	-1.2722	0.4287	-0.6007	0.4570	-893.0953	<.0001	-27.6748	<.0001
Single Mean	-8.2919	0.2025	-1.8757	0.3436	-892.9171	0.0018	-27.6627	<.0001
Trend	-13.3091	0.2499	-2.6140	0.2740	-892.8985	0.0008	-27.6691	<.0001
CD- TBill Spread 3M								
Zero Mean	-17.1090	0.0039	-2.9816	0.0029	-1067.3985	<.0001	-52.3537	<.0001
Single Mean	-64.1189	0.0018	-5.9129	<.0001	-1067.4035	0.0018	-52.3205	<.0001
Trend	-77.7665	0.0008	-6.4913	<.0001	-1067.3351	0.0008	-52.2973	<.0001
TBill OIS Fx. Spread 3M								
Zero Mean	-29.1506	<.0001	-3.9516	<.0001	-1012.1364	<.0001	-41.5248	<.0001
Single Mean	-36.0338	0.0000	-4.3713	0.0004	-1012.1312	0.0018	-41.5003	<.0001
Trend	-36.7658	0.0000	-4.4261	0.0021	-1012.0985	0.0008	-41.4784	<.0001
OIS Fx. – OIS Fl. Spread 3M								
Zero Mean	-48.5557	<.0001	-5.1482	<.0001	-850.6366	<.0001	-32.1715	<.0001
Single Mean	-52.7045	0.0018	-5.3391	<.0001	-850.6448	0.0018	-32.1525	<.0001
Trend	-54.8628	0.0008	-5.4845	<.0001	-850.6304	0.0008	-32.1416	<.0001

The Term Premia was found to be non-stationary at level as we fail to reject the null hypothesis at a 1% level of significance. However, these spreads were found to be stationary after first differencing. Hence, to avoid concerns of non-stationarity, the model was estimated at first difference for the 3 month tenor.

On estimating the regression model (*Table 14.1*), it was found that the changes in the term premia exhibited a positive and statistically significant relationship with the OISFx. –OISFl. Spread, the TBill-OISFx spread as well as the CD-TBill spread. A 100 bps increase in the OISFx – OISFl Spread, TBill-OIS spread and CD-TBill spreads (over the previous day i.e. $t-1$) resulted in an increase in term premia by 32.36 bps, 20.28 bps and 3.08 bps respectively. A period-wise analysis, by splitting the sample into two equal sub-samples, provided consistent results. A 100 bps change in the OISFx-OISFl spread resulted in a change in the term premia in a range of around 26 bps to 40 bps. Likewise, the change in the term premia for a percentage change in the Tbill-OIS Fx Spread ranged between 20 to 28 bps. It was also found that a change in the CD-Tbill spread resulted in an increase in the term premia in the range of 3 to 4 bps.

Table 14.1: Regression Results of Δ Term Premia for 3 Month Tenor^

Variable	Estimate	OLS Estimated		HAC Consistent#		Root MSE	SBC	R^2	DW	ARCH (LM Test)@
		Standard Error	*t* Value	Standard Error	*t* Value					
Model 1-Full Period										
Intercept	0.1725	0.0940	1.8400***	0.0939	1.8400***	2.7843	4312.92	0.1302	1.6614	1: 2.9540
Δ(3M CD-TBill Spread)	0.0308	0.0068	4.5500*	0.0077	4.0000*					5: 7.2746
Δ(3M TBill-OIS Fx Spread)	0.2028	0.0222	9.1400*	0.0396	5.1200*					12: 8.3919
Δ(3M OIS Fx -OIS Fl Spread)	0.3236	0.0336	9.6300*	0.0629	5.1500*					
Model 1- Period 1										
Intercept	0.0792	0.1388	0.5700	0.1385	0.5700	2.9077	2203.29	0.1823	1.7191	1: 0.3506
Δ(3M CD-TBill Spread)	0.0476	0.0128	3.7100*	0.0156	3.0600*					5: 0.1171
Δ(3M TBill-OIS Fx Spread)	0.2762	0.0325	8.5000*	0.0575	4.8000*					12: 0.5810
Δ(3M OIS Fx -OIS Fl Spread)	0.3963	0.0479	8.2700*	0.0886	4.4700*					
Model 1- Period 2										
Intercept	0.2660	0.1253	2.1200**	0.1249	2.1300**	2.6251	2113.51	0.0873	1.5794	1.7595
Δ(3M CD-TBill Spread)	0.0232	0.0077	3.0300*	0.0081	2.8500*					2.3685
Δ(3M TBill-OIS Fx Spread)	0.1301	0.0302	4.3100*	0.0499	2.6100*					4.1785
Δ(3M OIS Fx -OIS Fl Spread)	0.2590	0.0473	5.4800*	0.0695	3.7300*					

Notes:
*,** and *** indicates significance at 1%, 5% and 10% respectively.
heteroscedasticity and autocorrelation consistent covariance matrix estimators
@ ARCH Lagrange Multiplier test was tested at 1, 5 and 12 lags and was found to be statistically insignificant at 1%
^Extreme values reported on the last working day of march and first working day of April were dropped from the sample.

It was also found that the changes in term premia were accentuated during financial year end turns (*Table 14.2)*, as indicated by the Year-End dummy variable. The results indicated that the daily average term premia increases by 0.98% (ranged from around 0.58% to 1.35% during the sub-samples) when the last business day of March was a part of the term contract.

To test the robustness of the model, regression errors were tested for conditional heteroscedasticity. The Lagrange Multiplier (LM) test was run to determine if the variance of the error terms were constant and did not increase with the changes in the independent variables. The Durbin Watson (DW) test was also estimated to identify if the errors of the regression model exhibited autocorrelation. The null hypothesis of DW test is that there is no positive autocorrelation of the errors.

The errors were found to exhibit a significant ARCH effect upto 12 lags. The DW statistics was also significant which suggest the presence of positive serial correlation in the errors. The presence of conditional heteroscedasticity and autocorrelation of the error can likely lead to underestimating the standard errors (and overstating the t stat) and result in incorrectly indicating a statistically significant variable. To avoid this problem, the Whites heteroskedastic and autocorrelation consistent (HAC) standard errors were estimated to validate the results of the model. The HAC t-stat values for the CD-TBill spread, TBill-OISFx spread and the OISFx-OISFl spread were found to statistically significant at 1% respectively.

Table 14.2: Regression Results of Δ Term Premia for 3 Month Tenor using Year End Turn Dummy^

Variable	Estimate	OLS Estimated		HAC Consistent#		Root MSE	SBC	R^2	DW	ARCH (LM Test)@
		Standard Error	*t* Value	Standard Error	*t* Value					
Model 2- Full Period										
Intercept	-0.0967	0.1090	-0.8900	0.1037	-0.9300	2.7512	4297.66	0.1517	1.6934	1: 2.954 5: 7.2746 12: 8.3919
Δ(3M CD-TBill Spread)	0.0297	0.0067	4.4500*	0.0075	3.9800*					
Δ(3M TBill-OIS Fx Spread)	0.2056	0.0219	9.3800*	0.0399	5.1500*					
Δ(3M OIS Fx -OIS Fl Spread)	0.3275	0.0332	9.8600*	0.0615	5.3300*					
Dummy Year End	0.9815	0.2083	4.7100*	0.2255	4.3500*					
Model 2- Period 1										
Intercept	-0.2857	0.1593	-1.7900***	0.1473	-1.9400***	2.84822	2190.22	0.2172	1.7635	1: 0.3354 5: 7.8004 12: 9.6312
Δ(3M CD-TBill Spread)	0.0443	0.0126	3.5100*	0.0150	2.9400*					
Δ(3M TBill-OIS Fx Spread)	0.2774	0.0318	8.7200	0.0576	4.8200*					
Δ(3M OIS Fx -OIS Fl Spread)	0.3913	0.0470	8.3300	0.0847	4.6200*					
Dummy Year End	1.3490	0.3066	4.4000	0.3359	4.0200*					
Model 2- Period 2										
Intercept	0.1056	0.1470	0.7200	0.1376	0.7700	2.61524	2115.29	0.0962	1.5955	1: 1.5798 5: 2.2191 12: 3.7586
Δ(3M CD-TBill Spread)	0.0229	0.0076	3.0000*	0.0080	2.8600*					
Δ(3M TBill-OIS Fx Spread)	0.1325	0.0301	4.4000*	0.0503	2.6300*					
Δ(3M OIS Fx -OIS Fl Spread)	0.2662	0.0472	5.6400*	0.0697	3.8200*					
Dummy Year End	0.5779	0.2795	2.0700**	0.2951	1.9600**					

Notes:
*,** and *** indicates significance at 1%, 5% and 10% respectively.
heteroscedasticity and autocorrelation consistent covariance matrix estimators
@ ARCH Lagrange Multiplier test was tested at 1, 5 and 12 lags and was found to be statistically insignificant at 1%
^Extreme values reported on the last working day of march and first working day of April were dropped from the sample.

6.4. Money Market Term Premia Decomposition- Latent Factor Analysis:

Having established a statistically significant relationship of the Term Premia with the, CD-TBill spread, TBill-OISFx spread and the OISFx-OISFl spread, an MPLS regression model was estimated to determine the latent factors that explain the variation in term premia, The ideal number of factors to be extracted was determined by split-sample cross validation method. The sample was divided into different sub-groups comprising of *n*-observations[18]. The model was fit to each of the groups (training set) except one (test set). The model which was estimated using the training set was then applied to predict the response variables in the test set. A predicted residual sum of squares (PRESS) was computed from the residuals generated from the predicted values of the response variables. This process was followed by sequentially increasing the number of factors to be extracted. The results are highlighted in *Table 15*.

Table 15: Split-sample Validation Results

	60-fold Split-sample Validation			90-fold Split-sample Validation			120-fold Split-sample Validation		
Number of Extracted Factors	**Root Mean PRESS**	T^2	**Prob > T^2**	**Root Mean PRESS**	T^2	**Prob > T^2**	**Root Mean PRESS**	T^2	**Prob > T^2**
0	1.0110	372.8047	<.0001	1.0026	373.0590	<.0001	0.9994	372.6923	<.0001
1	0.7354	102.5736	<.0001	0.7282	103.0630	<.0001	0.7330	102.9289	<.0001
2	0.6753	76.7669	<.0001	0.6701	77.5556	<.0001	0.6746	77.1423	<.0001
3	0.6530	82.3629	<.0001	0.6479	83.4125	<.0001	0.6531	83.1434	<.0001
4	0.6354	31.8175	<.0001	0.6303	31.4599	<.0001	0.6353	31.5258	<.0001
5	0.6153	27.1602	<.0001	0.6112	27.5649	<.0001	0.6156	27.2648	<.0001
6	0.6100	11.1126	0.0080	0.6059	11.3859	0.0040	0.6104	11.3831	0.0110

Identifying the Number of Key Risk Factors:

Based on the Hotelling's T^2 statistic, it would found that the root mean PRESS for a model with four extracted factors was not significantly different from that with five extracted factors. Further, the coefficient of determination (R^2), depicted in *Annexure 9*, indicates that the four factor model explained over 60% of the variation in the response variables. The R^2 of the response model did not significantly improve with the addition of a 5th factor. Hence a four factor model was retained for further analysis. It is pertinent to note that each factor is arrived at by maximizing covariance between the factor scores derived from the response variables and the factor scores derives from the predictor variables.

Percentage of Variation Explained By Individual Risk Factors:

The proportion of variation of each predictor and response variable account for by the individual factors is provided in *Table 16 and Table 17*. The results suggest that the first factor explained around 32% to 60% of the variation in the CD-TBill Spreads. The contribution of the first factor in explaining the variation in the TBill-OIS

Table 16:Percent Variation Accounted For PLS Factors

Number of Extracted Factors	Predictor Model (X_0)		Response Model (Y_0)	
	Current	**Total**	**Current**	**Total**
1	25.87	25.87	47.61	47.61
2	27.29	53.17	8.46	56.07
3	18.35	71.52	3.11	59.18
4	10.11	81.63	2.35	61.53

[18] In a split-sample validation, the different groups are composed of every n^{th} observation beginning with the first value, followed by every n^{th} observation beginning with the second, and so on. The value of *n* was chosen under various scenarios such as 60, 90 and 120 days . The results were consistent in all the scenarios.

Table 17: Percent Variation Accounted for by Partial Least Squares Factors (%)															
	Model Effects										**Dependent Variables**				
Number Of Factors	**CD – TB Spread 14D**	**CD - TB Spread 1M**	**CD - TB Spread 3M**	**TB - OIS Fx Spread 14D**	**TB - OIS Fx Spread 1M**	**TB - OIS Fx Spread 3M**	**OIS Fx. - OIS Fl. Spread 14D**	**OIS Fx. - OIS Fl. Spread 1M**	**OIS Fx. - OIS Fl. Spread 3M**	**Current**	**Total**	**Term Premia 14D**	**Term Premia 1M**	**Term Premia 3M**	**Current**	**Total**
1	**31.19**	**59.77**	**57.75**	9.42	6.22	18.89	9.46	19.99	20.18	25.87	25.87	13.64	**58.31**	**70.86**	47.61	47.61
2	31.62	64.79	58.25	**84.03**	**92.12**	**68.50**	23.59	35.19	20.42	27.29	53.17	**33.60**	61.57	73.03	8.46	56.07
3	35.62	81.07	71.21	87.01	92.20	70.47	**81.99**	**82.07**	**42.03**	18.35	71.52	40.26	61.82	75.47	3.11	59.18
4	80.15	85.27	85.20	87.34	92.86	75.47	85.53	84.41	58.41	10.11	81.63	40.35	61.84	82.39	2.35	61.53

Note: All columns in the table except column titled 'Current' indicate cumulative values. The interpretation of the contribution of the individual factors in the total variation can be highlighted using the example of the CD-TB spread of 14D, wherein the contribution of factor 1 is 31.19% and that of factor 2 is 0.43% (31.62-31.19).

Table 18: Factor Weights Profile												
	Predictor Variable Weights									**Response Variable Weights**		
Number of Extracted Factors	**CD TBill 14D**	**CD TBill 1M**	**CD TBill 3M**	**TB - OIS Fx Spread 14D**	**TB - OIS Fx Spread 1M**	**TB - OIS Fx Spread 3M**	**OIS Fx. - OIS Fl. Spread 14D**	**OIS Fx. - OIS Fl. Spread 1M**	**OIS Fx. - OIS Fl. Spread 3M**	**Risk Premia 14D**	**Risk Premia 1M**	**Risk Premia 3M**
1	**0.34**	**0.50**	**0.60**	-0.02	0.02	0.42	0.13	0.23	0.36	0.31	**0.64**	**0.70**
2	-0.07	-0.27	-0.04	**0.62**	**0.66**	**0.40**	-0.02	-0.17	0.13	**0.89**	0.36	0.29
3	0.28	-0.28	-0.43	-0.08	0.04	0.04	**0.87**	**0.45**	**0.18**	0.84	-0.16	-0.51
4	0.66	0.35	-0.47	0.03	0.10	0.18	-0.22	-0.07	-0.42	0.12	0.05	-0.99

spread was relatively low (around 9 to 18%). The second factor however was more suitable in explaining the variation in the TBill-OISFx spread (around 69% to 84%). While, these two factors were able to explain around 56% of the variation in the response model as a whole, these factors alone accounted for nearly 73% of the entire variation in the 3 month term premia. The third and fourth factors together accounted for around 5.46% of the variation in the term premia.

Attribution of Weights in Factor Score Computation:

Each factor is computed by assigning a weight to the individual variables (predictor or response as the case may be). The higher the weight associated with the individual variable the greater would be the contribution of that variable in the computation of the factor. The weights are provided in *Table 18*. The first factor did not seem to indicate a very significant relationship (or even a consistent in term of sign) with the TBill-OISFx spreads. However, it was observed that the first factor had a higher weight associated to the CD-TBill spread. The weight was also found to be positive for all the three tenors considered. A unique and positive relationship of the first factor with these variables indicates that the first factor could be a representation of credit risk in money market.

The second factor had a positive and significant weight with the TBill-OISFx spreads for all the tenors considered (with the weights ranging between 0.40 and 0.66). It did not seem to have a prominent weight associated with the CD-TBill spreads. It was therefore interpreted that the second factor could be a representation of liquidity risk[19]. As the third and fourth factor did not seem to provide tenor-wise consistent results in terms of either the size of the weight or the direction (+/-), these factors could represent idiosyncratic risk factors.

Factor Loadings:

The factor loadings are determined by individually regressing the tern premia for 14 days, 1 month and 3 month on the extracted factors. The results are highlighted in T*able 19*. The results indicate that the a unit change in the credit risk (Factor 1) results in the term premia widening by around 3.86 bps for the 14 days, 9.86 bps for the 1 month and 19.40 bps for the 3 month tenors respectively. The liquidity risk (Factor 2) had a marginally higher impact on the 14 days term premia in comparison to that in the 1 month and 3 month. A unit change to the liquidity risk resulted in an increase in the term premia by 4.55 bps, 2.27 bps and around 3.30 bps respectively.

The plot of the tenor-wise decomposition of the term premia into credit and liquidity risk is presented in Annexure 11. The values in the graph represent a deviation of the term premia, credit and liquidity factors from its mean value. It can be observed that any deviations of the term premia from its mean value were driven by the change in either the liquidity risk and/or credit risk factor. For the 1M and 3M tenor, the deviation of the term premia from its mean value could be better explained by the credit risk factor, while that for the 14 days was primarily influenced by the liquidity risk factor.

Table 19: MPLS Regression Model Results

Variable	*Loadings*	*Standard Error*	*t Stat*	*F-Stat*	*RMSE*	*Adjusted R^2*
14D						
Intercept	26.4419	0.4153	63.6703*	149.1816*	12.3336	0.4008
Factors 1	3.8672	0.2723	14.2022*			
Factors 2	4.5552	0.2651	17.1809*			
Factors 3	3.2072	0.3233	9.9193*			
Factors 4	0.5245	0.4357	1.2040			
1M						
Intercept	39.0936	0.4098	95.4010*	357.2692*	12.1699	0.6166
Factors 1	9.8634	0.2687	36.7103*			
Factors 2	2.2708	0.2616	8.6801*			
Factors 3	-0.7594	0.3190	-2.3804**			
Factors 4	0.2785	0.4299	0.6478			
3M						
Intercept	63.9324	0.4965	128.7712*			

[19] To validate these results, the inputs used as predictor and response variables in MPLS were modelled endogenously using a principal component analysis. The results were found to be consistent with the MPLS regression. Details are provided in *Annexure 10*.

Factors 1	19.3951	0.3255	59.5806*	1031.8583*	14.7447	0.8231
Factors 2	3.3003	0.3170	10.4124*			
Factors 3	-4.2759	0.3865	-11.0619*			
Factors 4	-9.6992	0.5208	-18.6227*			
Note: * , **and *** indicate significance at 1%,5% and 10% respectively.						

These results are in line with the finding in empirical literature that attribute liquidity and credit as key drivers of the LIBOR-OIS spread, a measure often perceived as an indicator of term premia in international money markets. While literature in the international context has generally quantified credit risk by using the CDS spread as a proxy and obtained liquidity risk as a residual risk, in the paper an attempt has been made to extract credit and liquidity risk as unique latent factors driving interest rates of closely related money market instruments.

7. ROBUSTNESS CHECKS

Robustness testing helps to analyze whether estimated parameters of a baseline model are sensitive to any omitted variables in model specifications. Robustness tests also help to increase the validity of inferences drawn from the original specification. Such checks help to examine how certain core regression coefficient estimates behave when the regression specification is modified by adding or removing regressors (*Lu and White, 2014*). Hence, while estimating the model for decomposition of term premia, it is imperative to test whether the hypothesis presented in this paper holds under alternative specifications determined by including a few possible explanatory variables which control for other factors with possible impact on the daily changes in term premia.

7.1. Additional control variables

The following control variables have been used to test the validity of the regression specification:

- ***Alternate for OIS fixed and OIS floating spread:*** In the equations (5) and (6), the (OISFx – OISFl) spread was used as a representative measure of expectations errors derived from a (near) risk free curve. This variable was found to be statistically insignificant in explaining the variations in the term premia. This variable indicated the spread between the fixed rate for a tenor and compounded floating rate for the corresponding tenor. The same is validated by including alternate specification of term premia, defined as the difference between the long rate and the short rate.
    - Changes in the spread between the 3 month OIS Fixed Rate and the O/N MIBOR Rate[20]. This variable represents the term premia of in the money markets (near risk-free curve).

[20] *McAndrews, Sarkar and Wang (2017)* use the OIS (Fixed Leg) Rate minus the O/N Federal Fund Rate as a representation of the money market term premia.

- Changes in the spread between the 3 month zero coupon rate and the O/N zero coupon rate as observed in the bond market. These rate are estimated from the zero coupon yield curve derived from traded Government of India dated securities and treasury bills using the Nelson-Siegel-Svensson model[21].

- ***O/N Call Market Volatility:*** It is observed in empirical literature that differently shaped yield curves can be a result of different combinations of volatility and expectations about future spot rates. In particular, the premium component is of more importance relative to the expectation component when volatility is very high (*Engle and Ng, 1993*). Hence a measure of volatility is introduced as a control variable in the model, to account for the possible impact of volatility of the underlying call money market on the term premia. The volatility in the underlying overnight call money market was estimated as :

$$CallVol = High - Low$$

A positive coefficient for this variable would suggest that the term premia increases with an increase in volatility of the call money market.

- ***Changes in Term LAF Spread (in bps):*** The Term LAF (Liquidity Adjustment Facility) spread defined as the difference between the mid-term LAF rate and the O/N market repo rate[22] is also added as a control variable in the model. The mid-term LAF Rate is computed as the average of the LAF Term repo and LAF Term reverse repo rates[23]. The Term LAF rate is a collateralized variable rate which was introduced as a measure of managing funding liquidity in the money markets for a period greater than one day. The O/N market repo rate is a weighted average transaction based rate of basket repo transactions undertaken during the first hour of trading. Since both the Term LAF rate and the O/N market repo rate are collateralized rates, the spread would serves as a useful measure of the term premia in the collateralized money market.

- ***Net LAF/TTMV:*** The Net LAF is a measure of funding liquidity in the money markets and is defined as the net liquidity injection/absorption via the RBI LAF window. In times of liquidity shortages (deficit scenario), ideally market participants would require a greater compensation in the form of a higher interest rate (adding a higher premium) to part with their funds. Hence, the term premia should increase in a liquidity deficit scenario (i.e. when O/N plus Term Repo volumes are greater than the O/N plus Term Reverse Repo volumes). A decline in term premia would ideally be associated with a liquidity surplus. TTMV represents the Total Money Market Value which includes the day's traded value in the O/N Call, Repo and TREP markets used as a scaling variable. One can interpret a positive coefficient for this variable an increase in the term premia for every increase in the Net LAF/TTMV (i.e. liquidity injection) and vice-versa.

[21] NSS model estimates as provided by CCIL

[22] The FBIL MROR rate has been used as a representative O/N collateralized money market rate.

[23] The LAF Term Repo rate is the rate at which the RBI lends funds to the counterparty bank by borrowing collateral. The LAF Term Reverse repo rate is the rate at which the RBI would borrow funds from the counterparty bank by lending the collateral. The rate is available on a consistent basis for the 14 Day term only.

- **G-Sec Value:** An estimate of the extent of liquidity in the fixed income markets as a whole is best captured by the total traded GSEC volume for the day. An increase in liquidity would provide for better price discovery and reduce the uncertainty risk and hence the associated term premia. Hence the natural logarithm of the total traded G-Sec value for the day is introduced as a control variable.

The descriptive statistics of the variables in consideration are presented in *Table 16* and results are highlighted in *Table 20*[24]. It was found that the Δ(3M OISFx –O/N MIBOR) and Δ(3M Spot Rate –O/N spot rate), introduced in Model 1 and Model 2 respectively, were not statistically significant predictors at 5% level of significance. This suggests that the term premia derived from either the OIS curve or g-sec short term spread do not significantly influence the term premia captured in the uncollateralised money market.

Table 20: Descriptive Statistics of Control Variables in OLS Model[$]

	Δ3M Spot Rate – O/N Spot Rate	**Δ3M OISFx – O/N MIBOR Spread**	**Δ14D TermLAF* –O/N MROR Spread**	***Call_vol***	***Δ NetLAF/TTM***	***ln_Gsec***
Mean	-0.0014	-0.0036	0.3876	1.1902	-0.0002	10.7164
Median	0.0200	0.0000	0.0000	0.8300	-0.0031	10.6756
Standard Deviation	1.3664	6.6818	10.4654	1.1148	0.2212	0.4394
Kurtosis	8.9356	6.3174	67.4450	12.1933	143.5699	0.4544
Skewness	-0.1646	-0.1628	5.4954	2.3922	7.2828	0.4431
Minimum	-8.6100	-43.0000	-49.5400	0.0000	-1.2401	9.3956
Maximum	8.6900	33.0000	140.3500	11.1100	4.1560	12.2311
Count	878	878	878	879	878	879

Notes:$ Financial Year end points have been eliminated from the sample.* the 14D Term LAF spread series was backfilled upto 3 days in case of missing data points.

Models 3 through *Model 6* present the results from the introduction of control variables (*Table 21*). While no relationship was found between the call money market volatility, the state of the systemic liquidity (Δ *NetLAF/TTM*) and the increase in the volumes in the G-sec market (*ln_Gsec*) were found to be statistically significant predictors of the uncollateralised money market term premia when the full sample period was analyzed. Additionally, the CD-TBill Spread and TBill-OISFx Spread were found to be statistically significant at 1% when such control variables were introduced in the model. A sub-sample analysis however suggests that consistent results for the control variables of ***Δ*** *NetLAF/TTM* and the *ln_Gsec* could not be established.

[24] For comparison, key findings from *Table 14.2* are reproduced in *Table 21* under the heading 'Baseline Model'.

Table 21: Robustness Check: Implementation of Alternate Model Specifications and Control Variables														
			Alternate Control Variables											
	Baseline Model		Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Total R^2	0.1517		0.0708		0.0625		0.1540		0.3164		0.1737		0.1859	
Root MSE	2.7512		2.8794		2.8923		2.7490		3.4688		2.7169		2.6982	
Parameter	***Estimate***	***t-stat***	***Estimate***	***t-stat***	***Estimate***	***t-stat***	***Estimate***	***t-stat***	***Estimate***	***t-stat***	***Estimate***	***t-stat***	***Estimate***	***t-stat***
Intercept	-0.0967	-0.9300	-0.0766	-0.7100	-0.0821	-0.7500	0.0493	0.3200	-0.2295	-1.7700**	-0.0979	-0.9700	8.2289	2.9100*
Δ(3M CD-TBill Spread)	0.0297	3.9800*	0.0197	2.6600*	0.0219	2.8500*	0.0296	3.9600*	0.0444	4.6300*	0.0299	4.1100*	0.0288	3.9300*
Δ(3M TBill-OIS Spread)	0.2056	5.1500*	0.0988	2.9700*	0.1145	3.4600*	0.2049	5.1500*	0.1546	2.7500*	0.1845	4.9400*	0.2002	5.0600*
Dummy Year End	0.9815	4.3500*	0.9191	3.8800*	0.9395	3.9600*	0.9885	4.4000*	1.0772	4.1200*	0.9859	4.3600*	0.8125	3.5900*
Δ(3M OISFx -OISFl Spread)	0.3275	5.3300*	-	-	-	-	0.3259	5.5000*	0.1755	1.5500	0.2979	4.7200*	0.3116	5.1600*
Δ(3M OISFx –O/N MIBOR spread)			-0.0539	-1.93***	-	-	-	-	-	-	-	-	-	-
Δ(3M Spot Rate – O/N Spot Rate)					-0.1590	-1.4900	-	-	-	-	-	-	-	-
Call_vol							-0.0194	-1.2200	-	-	-	-	-	-
Δ(14D Term LAF–O/N MROR Spread)									-0.2017	-3.4900*	-	-	-	-
Δ(NetLAF/TTM)											2.0533	3.0400*	0.1619	1.6600***
Ln(Gsec Volumes)													-0.7687	-2.8800*
Notes: *,** and *** indicate statistical significance at 1%,5% and 10% respectively. Term LAF rates was backfilled upto 3 days in case of missing tenors in Model 4.														

8. CONCLUSION

This paper is one among the few attempts made to test for the pure expectations theory in the Indian uncollateralised money markets under a no-arbitrage framework. Additionally, it attempts to quantify the money market term premia and decompose the same into credit and liquidity risk factors by using information from related money market instruments. While literature on advanced economies have often proxied credit risk by using CDS spreads, this paper has provided for an alternative method to capture a credit risk in money markets of emerging economies like India that still do not have an actively traded CDS market.

To empirically test the pure expectation hypothesis, the annualized returns from investing in the term money market rate were compared with the annualized returns obtained from sequentially reinvesting in a series of the overnight uncollateralised money market rate for the same time period. In this study, the Term Rates were found to be persistently higher than the Compounded O/N Rate, computed on an ex-ante and ex-post basis. Empirically analyzing the Term Rates and the O/N Rate using a VECM framework revealed that the pure expectations theory was valid in case of a 14 days tenor, but not for the tenors of 1 month and 3 months. The results revealed that the term premia associated with the 1 month and 3 month tenors were found to vary with time.

To quantify and decompose the term premia, the paper used an OLS as well as a latent factor analysis to identify the key factors that drive the term premia. The term premia was deconstructed into 4 components- the payoff of an OIS swap contract, a spread of the Treasury bill rate over the OIS Fixed rate, a spread of the CD rate over Treasury bill rate and a spread of the Term Rate over the CD Rate. The analysis of the changes in the term premia indicated that it exhibited a positive and significant relationship with TBill-OIS and the CD-TBill spread. A latent factor approach to decompose the term premia support these results, and identified credit and liquidity risk factors as the key underlying drivers.

This paper has put in place a framework that can allow market participants as well as regulators to quantify a daily indicator of term premia in the Indian money markets, based on transaction based data from OIS, TBill, and CD markets. The proposed methodology would enable them to easily forecast and monitor the perception of risk in the term money markets. This paper further provides a mechanism to decompose this term premia, which could aid market regulators to identify if this risk is due to a widening of credit and/or liquidity factor and allow them to take preemptive policy measures to manage the factor specific risk.

References:

1. Browne, F. and P. Manasse (1989), The Information Content of the Term Structure of Interest Rates: Theory and Practice, OECD Economics Department Working Papers, No. 69, OECD Publishing, Paris, https://doi.org/10.1787/748671027822.
2. Brunnermeier, M. (2009). Deciphering the Liquidity and Credit Crunch 2007–2008. Journal of Economic Perspectives, 23(1), pp.77-100.
3. Carpenter, S. and Demiralp, S. (2011). Volatility, Money Market Rates, and the Transmission of Monetary Policy. Finance and Economics Discussion Series, 2011(22), pp.1-35.
4. Cook T. and. Hahn T. (1990), Interest Rate Expectations and the Slope of the Money Market Yield Curve, Federal Reserve Bank of Richmond, Economic Review, Sep/Oct-1990, pp.11-24.
5. Engle, R. and Granger, C. (1987). Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*, 55(2), p.251-276.
6. Engle, R. and Ng, V. (1993). Time-Varying Volatility and the Dynamic Behavior of the Term Structure. Journal of Money, Credit and Banking, 25(3), pp.336.
7. Epskamp and Fried (2018). A Tutorial on Regularized Partial Correlation. http://dx.doi.org/10.1037/met0000167.pp.1-15.
8. Filipovic, D. and Trolle, A. (2012). The Term Structure of Interbank Risk. SSRN Electronic Journal.
9. Gefang, D., Koop, G. and Potter, S. (2011). Understanding liquidity and credit risks in the financial crisis. Journal of Empirical Finance, 18(5), pp.903-914.
10. Gladchun M. (2018). Is the Widening Libor-OIS Spread Cause For Concern? Research & Perspectives Loomis, Sayles & Company.
11. Grahame Johnson (2003). Measuring Interest Rate Expectations in Canada, Bank of Canada Review, Bank of Canada, vol. 2003 (Summer), pp. 17-27.
12. Guidolin and Thornton (2008). Predictions Of Short-Term Rates And The Expectations Hypothesis Of The Term Structure Of Interest Rates. European Central Bank, Working Paper Series No. 977/December 2008, pp. 1-32.
13. Hui, C., Chung, T. and Lo, C. (2012). Using Interest Rate Derivative Prices to Estimate LIBOR-OIS Spread Dynamics and Systemic Funding Liquidity Shock Probabilities. Asia-Pacific Financial Markets, 20(2), pp.131-146.
14. Johnson G. (2003). Measuring Interest Rate Expectations In Canada. Bank of Canada Working Paper 2003-26, pp. 1-54.
15. Jondeau, E. and Ricart, R. (1999). The expectations hypothesis of the term structure: tests on US, German, French, and UK Euro-rates. Journal of International Money and Finance, 18(5), pp.725-750.
16. Kapur M., John J. and Mitra P. (2018). Monetary Policy and Yields on Government Securities. Reserve Bank of India-Mint Street Memo No. 16, pp.1-11.
17. King R. and Kurmann A. (2002). Expectations and the Term Structure of Interest Rates: Evidence and Implications. Federal Reserve Bank of Richmond Economic Quarterly, Fall Volume 88/4, pp.49-95.

18. King, T. and Lewis, K. (2015). Credit Risk, Liquidity and Lies. Finance and Economics Discussion Series, pp.1-41.
19. Lu, X. and White, H. (2014). Robustness checks and robustness tests in applied economics. Journal of Econometrics, 178, pp.194-206.
20. McAndrews J., Sarkar A. and Wang Z. (2017). The effect of the term auction facility on the London interbank offered rate. Journal of Banking & Finance, 83, pp.135-152.
21. Michaud F. and Upper C. What drives interbank rates? Evidence from the Libor panel. (2008). International banking and financial market developments. BIS Quarterly Review. pp. 47-57.
22. Sengupta, R. and Tam, Y. (2008). The LIBOR-OIS Spread as a Summary Indicator. Economic Synopses, Federal Reserve Bank of St. Louis, 2008(25).
23. Smith, Josephine (2010). The Term Structure of Money Market Spreads During the Financial Crisis, working paper, New York University Stern School of Business
24. Sundaresan, S., Wang, Z. and Yang, W. (2017). Dynamics of the Expectation and Risk Premium in the OIS Term Structure. SSRN Electronic Journal.
25. Taylor, J. and Williams, J. (2008). A Black Swan in the Money Market. Federal Reserve Bank of San Francisco, Working Paper Series, pp.1-38.
26. Thornton, D. (2004). Testing the Expectations Hypothesis: Some New Evidence for Japan. Federal Reserve Bank of St. Louis Review, 86(5), pp.21-39.
27. Tronzano M. (2018). Does The Expectations Hypothesis Of The Term Structure Hold In Korea After The Asian Financial Crisis? Some Empirical Evidence (1999-2017). Economia Internazionale. Volume 71, pp.191-226.
28. Van der Voet, H. (1994). Comparing the predictive accuracy of models using a simple randomization test. Chemometrics and Intelligent Laboratory Systems, 25(2), pp.313-323.

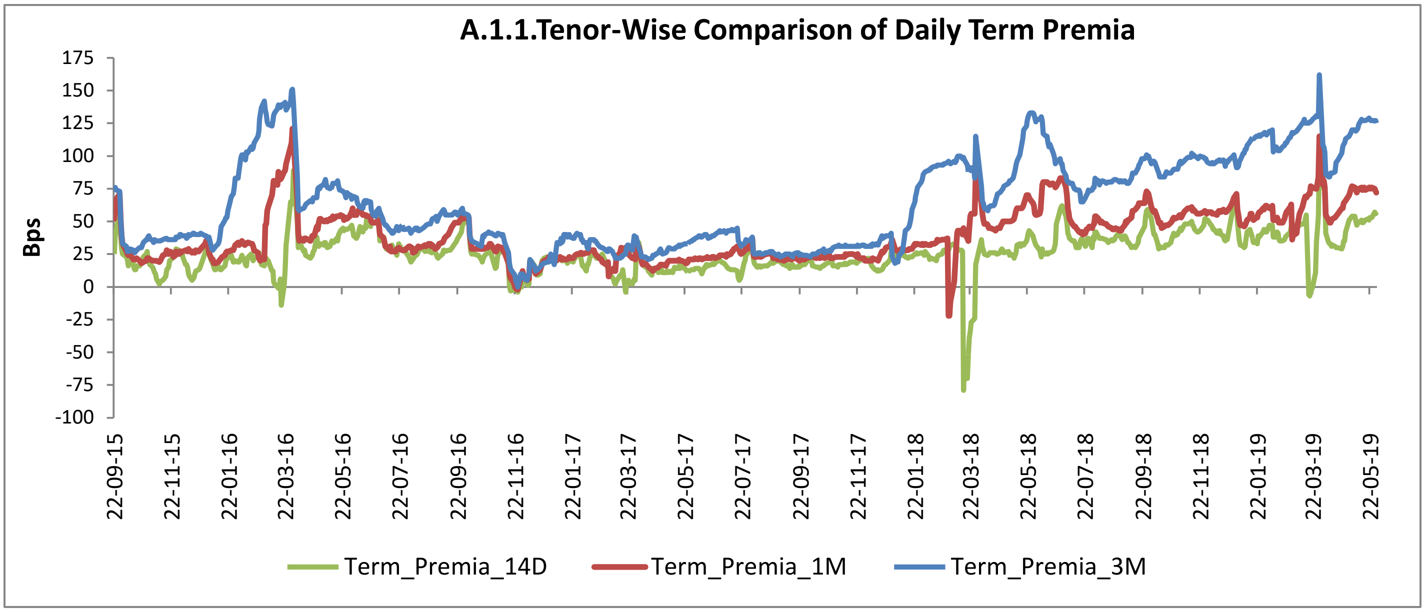
Websites:

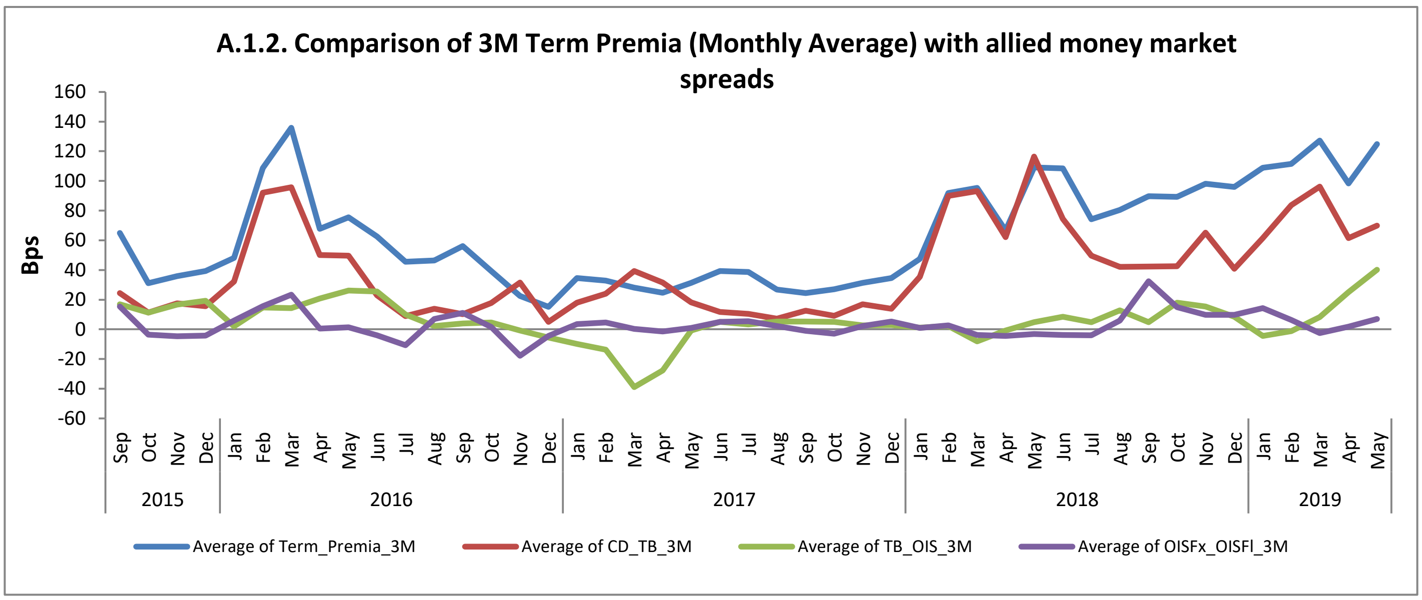
1. Support.sas.com. (2019). PROC AUTOREG: PROC AUTOREG Statement :: SAS/ETS(R) 9.2 User's Guide. [online] Available at: http://support.sas.com/documentation/cdl/en/etsug/60372/HTML/default/etsug_autoreg_sect011.htm [Accessed 5 Apr. 2019].
2. Support.sas.com. (2019). PROC PLS: PROC PLS Statement :: SAS/STAT(R) 9.2 User's Guide, Second Edition. [online] Available at: https://support.sas.com/documentation/cdl/en/statug/63033/HTML/default/statug_pls_sect006.htm [Accessed 5 Apr. 2019].
3. Rbi.org.in. (2019). Reserve Bank of India - Database. [online] Available at: https://www.rbi.org.in/Scripts/bs_viewcontent.aspx?Id=3638 [Accessed 5 Apr. 2019].
4. Wicklin, R. and Wicklin, R. (2019). Fisher's transformation of the correlation coefficient. [online] The DO Loop. Available at: https://blogs.sas.com/content/iml/2017/09/20/fishers-transformation-correlation.html [Accessed 30 Sep. 2019].

Report:

1. *Reserve Bank of India (1997)*, Internal Working Group to Examine the Development of Call Money Market.
2. *Reserve Bank of India (2007)*, Report of Currency and Finance 2005-06.
3. *Narasimham Committee (1998)*, Report of the Committee on Banking Sector Reforms.

ANNEXURE 1


A.1.1.Tenor-Wise Comparison of Daily Term Premia
Bps
175
150
125
100
75
50
25
0
-25
-50
-75
-100
22-09-15
22-11-15
22-01-16
22-03-16
22-05-16
22-07-16
22-09-16
22-11-16
22-01-17
22-03-17
22-05-17
22-07-17
22-09-17
22-11-17
22-01-18
22-03-18
22-05-18
22-07-18
22-09-18
22-11-18
22-01-19
22-03-19
22-05-19
Term_Premia_14D
Term_Premia_1M
Term_Premia_3M


A.1.2. Comparison of 3M Term Premia (Monthly Average) with allied money market spreads
Bps
160
140
120
100
80
60
40
20
0
-20
-40
-60
Sep Oct Nov Dec
2015
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2016
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2017
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2018
Jan Feb Mar Apr May
2019
Average of Term_Premia_3M
Average of CD_TB_3M
Average of TB_OIS_3M
Average of OISFx_OISFl_3M

ANNEXURE 2

Illustration of an Arbitrage Opportunity between the Term Rate and Compounded O/N Rate

In the first scenario, we considered an example of a 14 day period starting 29/09/2015, for a notional principal of Rs. 100, wherein the 14 day Term rate quoted on 29/09/2018 at 6.77% was compared with the O/N Compounded MIBOR rate for 14 calendar days ending 13-10-2018[25]. The Compounded O/N Rate was found to be 6.86%. Hence, one could make an arbitrage profit by:

1. Borrowing funds of Rs. 100 in the term market at 6.77% on Day 0.
2. Sequentially re-investing the borrowed funds for a period of 14 calendar days at the O/N Rate to obtain Rs. 100.2630.
3. Repaying the amount borrowed with interest of Rs. 100.2597 on Day 9.
4. Arbitrage profit =100.2630-100.2597=0.0033 paise (8.68 bps in percentage terms)

We also considered a second scenario, wherein the term rate was higher than the O/N compounded rate. In such a case an arbitrage profit is possible by:

1. Borrowing funds of Rs. 100 in the O/N market and investing the same in the Term market on Day 0.
2. Repaying the borrowed funds (with interest) by refinancing the amount borrowed at the new O/N Rate on Day 1. This continues until Day 8.
3. Repaying the amount borrowed on Day 8 amounting to Rs. 100.2740 with the proceeds from the term money investment of Rs. 100.2835.
4. Arbitrage profit = 100.2835-100.2740 = 0.0095 paise (25 bps in percentage terms).

[25] In case the maturity date falls on a Saturday, Sunday or a public holiday, the compounding was carried forward to the next working day.

Scenario 1: When O/N Compounded Rate> Term Rate										
Day	**Date**	**Tenor**	**Invest=O/N Market**				**Borrow= Term Market**			
			Invest	O/N Rate	Receive	Formula	At initiation	Term Rate	At maturity	Formula
Day 0	09-29-2015	1	-100.0000	7.3300			100.00	6.77		
Day 1	09-30-2015	1	-100.0201	7.0400	100.0201	100*((7.33/100)*(1/365))+100				
Day 2	10-01-2015	1	-100.0394	6.8800	100.0394	100.0201*(1+((7.04/100)*(1/365)))				
Day 3	10-05-2015	4	-100.0582	6.7500	100.0582	100.0394*(1+((6.88/100)*(1/365)))				
Day 4	10-06-2015	1	-100.1322	6.7000	100.1322	100.0582*(1+((6.75/100)*(4/365)))				
Day 5	10-07-2015	1	-100.1506	6.7500	100.1506	100.1322*(1+((6.7/100)*(1/365)))				
Day 6	10-08-2015	1	-100.1691	6.7600	100.1691	100.1506*(1+(((6.75/100)*(1/365))))				
Day 7	10-09-2015	1	-100.1877	6.8500	100.1877	100.1691*(1+((6.76/100)*(1/365)))				
Day 8	10-12-2015	3	-100.2065	6.8600	100.2065	100.1877*(1+((6.85/100)*(1/365)))				
Day 9	10-13-2015		-100.2630		100.2630	100.2065*(1+((6.86/100)*(3/365)))			-100.2597	100+(100*(6.77/100)*(14/365))
Compounded Rate					6.86	((100.263/100)-1)*(365/(14)*100)		6.77		
Arbitrage Profit (Bps)					8.68	(6.86-6.77)*100				
Arbitrage Profit (paise)					0.0033	(100.263-100.2597)				

Scenario 2: When Term Rate> O/N Compounded Rate												
Day	**Date**	**Tenor**	**Borrow =O/N Market**				**Invest= Term Market**			
			Borrow	O/N Rate	Repay	Formula	At initiation	Term Rate	At maturity	Formula
Day 0	09-22-2015	1	100.0000	7.2800			-100.0000	7.39		
Day 1	09-23-2015	1	100.0199	7.2600	-100.0199	100.00*(1+(7.28/100)*(1/365))				
Day 2	09-24-2015	4	100.0398	7.3500	-100.0398	100.0199*(1+(7.26/100)*(1/365))				
Day 3	09-28-2015	1	100.1204	7.3200	-100.1204	100.0398*(1+(7.35/100)*(4/365))				
Day 4	09-29-2015	1	100.1405	7.3300	-100.1405	100.1204*(1+(7.32/100)*(1/365))				
Day 5	09-30-2015	1	100.1606	7.0400	-100.1606	100.1405*(1+(7.33/100)*(1/365))				
Day 6	10-01-2015	4	100.1799	6.8800	-100.1799	100.1606*(1+(7.04/100)*(1/365))				
Day 7	10-05-2015	1	100.2555	6.7500	-100.2555	100.1799*(1+(6.88/100)*(4/365))				
Day 8	10-06-2015				-100.2740	100.2555*(1+(6.75/100)*(1/365))			100.2835	100+(100*(7.39/100)*(14/365))
Compounded Rate					7.14	((100.2740/100)-1)*(365/14)*100			7.39	
Arbitrage Profit (Bps)					25.00	(7.39-7.14)*100				
Arbitrage Profit (paise)					0.0095	(100.2835-100.2740)				

ANNEXURE 3

Derivation of the Equality of the Mean and Variance in Two Sample T-Test and Wilcoxon Scores (Rank Sums) Test

3.1 Two Sample T-Test:

The computation of the test statistic depends on whether the variances of the two rates in consideration are equal or unequal. Hence, to test if the variances are equal, a Folded F-Statistic is first computed as:

$$F = \frac{\max(s_1^2, s_2^2)}{\min(s_1^2, s_2^2)}$$

where, s_1^2, s_2^2 are the variances of the Term rate and the Compounded O/N Rate respectively. An insignificant F-stat would imply that the variances are equal, in which case, the means of the Term Rate ($\overline{x_1}$) and the Compounded O/N rate ($\overline{x_2}$) are statistically compared by calculating a pooled *t*-stat :

$$t = \frac{(\overline{x_1} - \overline{x_2}) - 0}{s\sqrt{\left(\frac{1}{n_1}\right) + \left(\frac{1}{n_2}\right)}}, \quad where \quad s = \sqrt{\frac{\left((n_1 - 1)s_1^2 + (n_2 - 1)s_2^2\right)}{n_1 + n_2 - 2}}$$

However, in case the variances are unequal, the Satterthwaite approximation *t*-stat is computed as:

$$t = \frac{(\overline{x_1} - \overline{x_2})}{s\sqrt{w_1 + w_2)}}$$

where, $w_1$and w_2 are standard deviation weight computed as $w_1 = \frac{s_1^2}{n_1}$ and $w_2 = \frac{s_2^2}{n_2}$.

3.2 Wilcoxon Scores (Rank Sums) Test:

In the Wilcoxon's scores test, the Term rates, the Compounded O/N rate and the dataset containing the both these rates are ranked. The rank is assigned from the lowest rate (with a rank of 1) to the highest rate (with a rank of *n*). The sum of the ranks (Wilcoxon Scores) for each dataset is computed as:

$$S_{term} = \sum_{j=1}^{n_1} R_j \; , \quad S_{Overnight} = \sum_{j=1}^{n_2} R_j \; , \quad S_{total} = \sum_{j=1}^{n} R_j$$

To compare if the Term Rate is significantly different from the Compounded O/N Rate, a standardized test statistic Z is computed, which has an asymptotic standard normal distribution:

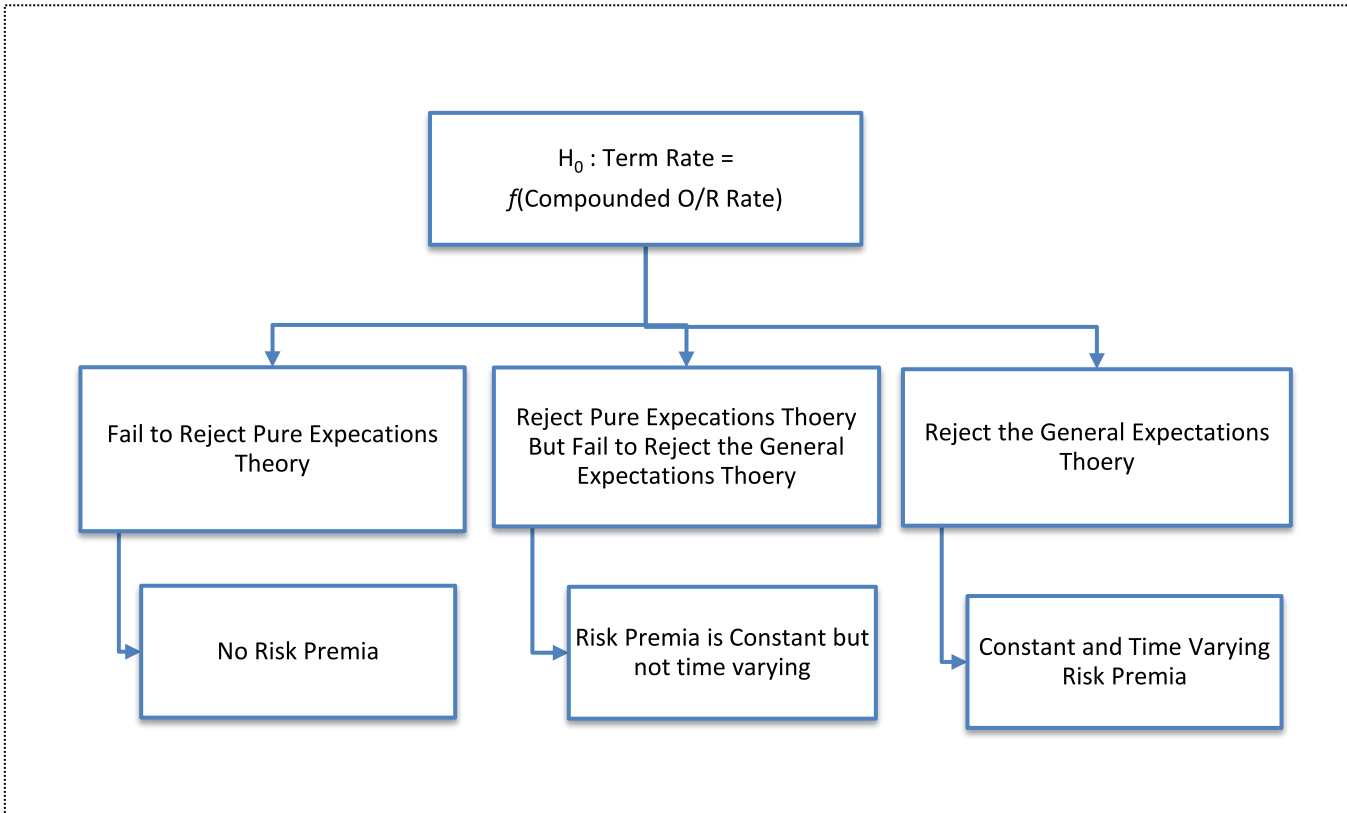
$$Z = \frac{S_{term} - E_0(S)}{\sqrt{Var_0(S)}} \qquad \text{where, } E_0(S) = \frac{n_1}{n} . S_{total},$$

$$Var_0\,(S) = \frac{n_1 n_2}{n(n-1)} \sum_{j=1}^{n} \left(R_j - \bar{a}\right)^2 \text{ and}$$

$\bar{a}$ is the average score for the full sample.

ANNEXURE 4

Rationale for the Existence of Term Premia in Indian Uncollateralised Money Markets



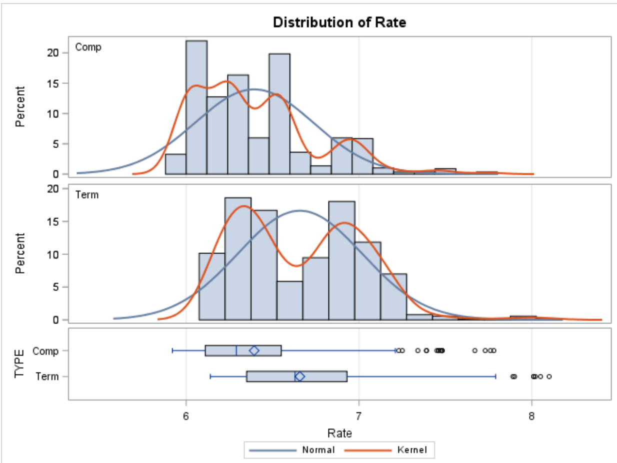
ANNEXURE 5

Illustration for Year End Dummy Variable in case of the 3 Month Term Premia

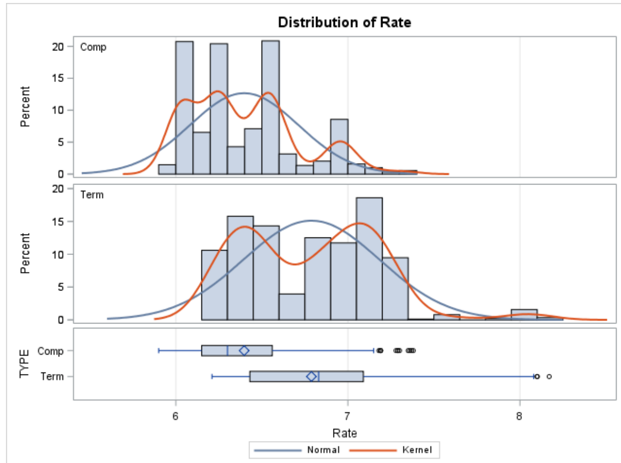
Day Count	Term MIBOR Initiation Date	Term MIBOR Maturity Date	Year End Dummy Variable	Day Count	Term MIBOR Initiation Date	Term MIBOR Maturity Date	Year End Dummy Variable
1	30-Dec-2015	29-Mar-2016	0	33	15-Feb-2016	16-May-2016	1
2	31-Dec-2015	30-Mar-2016	0	34	16-Feb-2016	16-May-2016	1
3	01-Jan-2016	31-Mar-2016	1	35	17-Feb-2016	17-May-2016	1
4	04-Jan-2016	04-Apr-2016	1	36	18-Feb-2016	18-May-2016	1
5	05-Jan-2016	04-Apr-2016	1	37	22-Feb-2016	23-May-2016	1
6	06-Jan-2016	05-Apr-2016	1	38	23-Feb-2016	23-May-2016	1
7	07-Jan-2016	06-Apr-2016	1	39	24-Feb-2016	24-May-2016	1
8	08-Jan-2016	07-Apr-2016	1	40	25-Feb-2016	25-May-2016	1
9	11-Jan-2016	11-Apr-2016	1	41	26-Feb-2016	26-May-2016	1
10	12-Jan-2016	11-Apr-2016	1	42	29-Feb-2016	30-May-2016	1
11	13-Jan-2016	12-Apr-2016	1	43	01-Mar-2016	30-May-2016	1
12	14-Jan-2016	13-Apr-2016	1	44	02-Mar-2016	31-May-2016	1
13	15-Jan-2016	18-Apr-2016	1	45	03-Mar-2016	01-Jun-2016	1
14	18-Jan-2016	18-Apr-2016	1	46	04-Mar-2016	02-Jun-2016	1
15	19-Jan-2016	18-Apr-2016	1	47	08-Mar-2016	06-Jun-2016	1
16	20-Jan-2016	20-Apr-2016	1	48	09-Mar-2016	07-Jun-2016	1
17	21-Jan-2016	20-Apr-2016	1	49	10-Mar-2016	08-Jun-2016	1
18	22-Jan-2016	21-Apr-2016	1	50	11-Mar-2016	09-Jun-2016	1
19	25-Jan-2016	25-Apr-2016	1	51	14-Mar-2016	13-Jun-2016	1
20	27-Jan-2016	26-Apr-2016	1	52	15-Mar-2016	13-Jun-2016	1
21	28-Jan-2016	27-Apr-2016	1	53	16-Mar-2016	14-Jun-2016	1
22	29-Jan-2016	28-Apr-2016	1	54	17-Mar-2016	15-Jun-2016	1
23	01-Feb-2016	02-May-2016	1	55	18-Mar-2016	16-Jun-2016	1
24	02-Feb-2016	02-May-2016	1	56	21-Mar-2016	20-Jun-2016	1
25	03-Feb-2016	03-May-2016	1	57	22-Mar-2016	20-Jun-2016	1
26	04-Feb-2016	04-May-2016	1	58	23-Mar-2016	21-Jun-2016	1
27	05-Feb-2016	05-May-2016	1	59	28-Mar-2016	27-Jun-2016	1
28	08-Feb-2016	09-May-2016	1	60	29-Mar-2016	27-Jun-2016	1
29	09-Feb-2016	09-May-2016	1	61	30-Mar-2016	28-Jun-2016	1
30	10-Feb-2016	10-May-2016	1	62	31-Mar-2016	29-Jun-2016	1
31	11-Feb-2016	11-May-2016	1	63	04-Apr-2016	04-Jul-2016	0
32	12-Feb-2016	12-May-2016	1	64	05-Apr-2016	04-Jul-2016	0

ANNEXURE 6

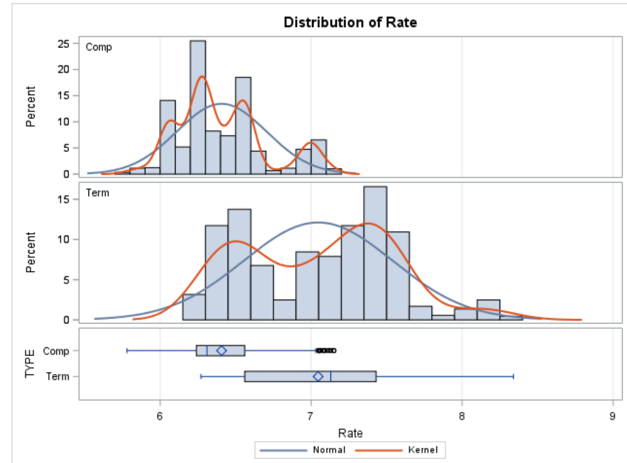
Distribution of 14 Day Rates



Distribution of 1 Month Rates

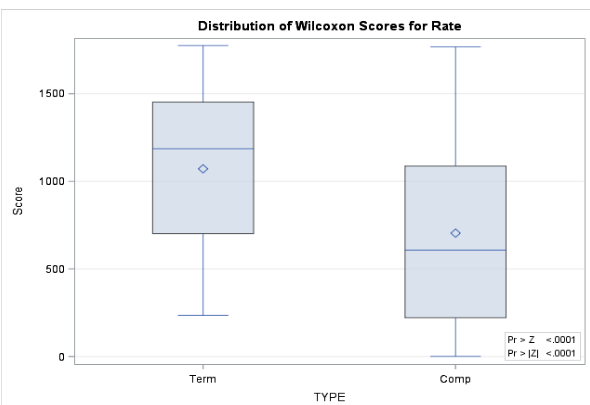


Distribution of 3 Month Rates

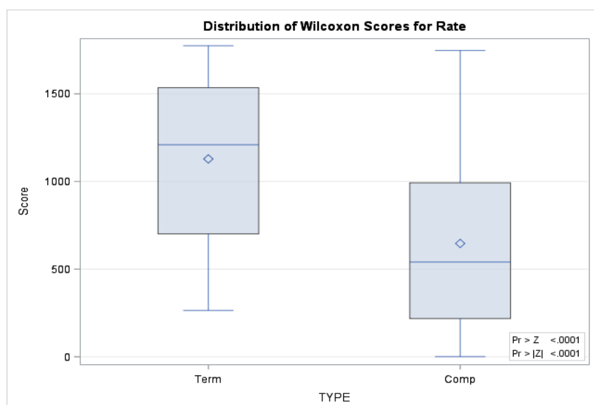


ANNEXURE 7

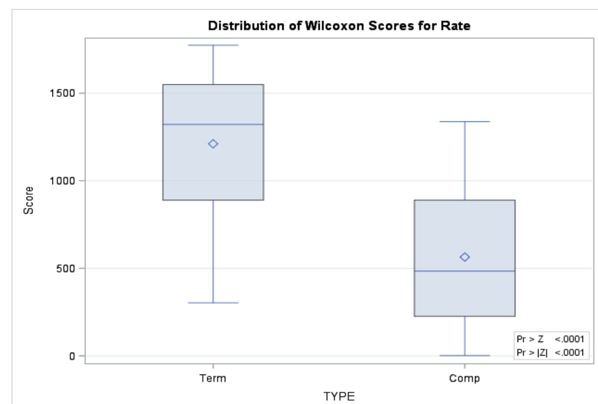
Distribution of Scores for 14 Day Rates



Distribution of Scores for 1 Month Rates

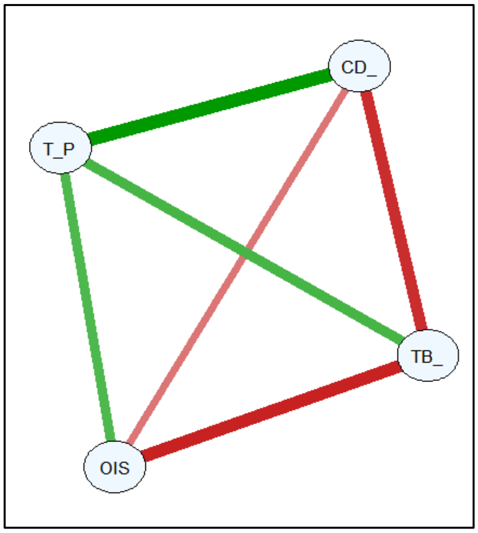


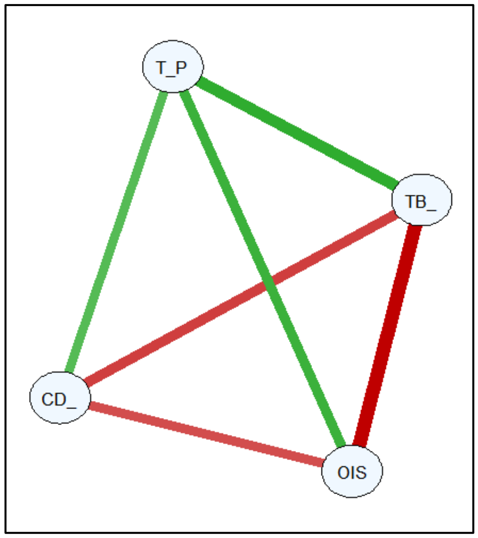
Distribution of Scores for 3 Month Rates

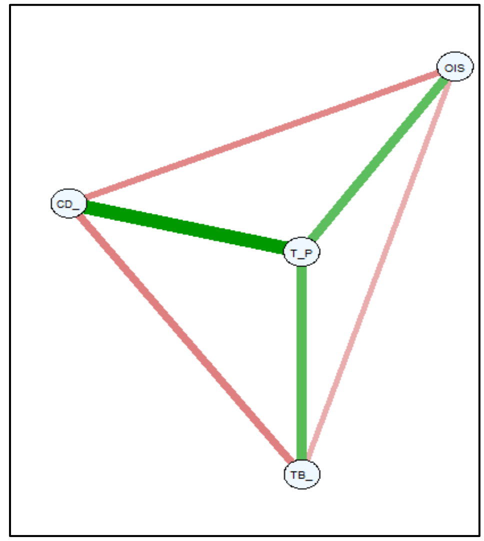


ANNEXURE 8

Network Analysis of 14 Days **Network Analysis of 1-Month** **Network Analysis of 3-Months**



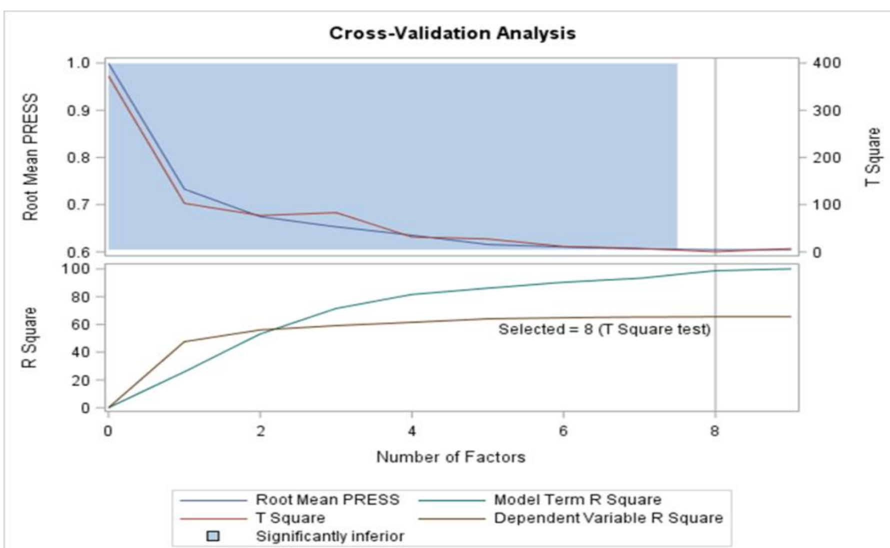




Legends:

- **T_P** stands for Term Premia, **CD** Stands for the CD-Tbill Spread, **TB** stands for the Tbill-OIS Fixed Leg Spread and **OIS** stands for the OIS Fixed Leg minus the OIS Floating Leg Spread

ANNEXURE 9



ANNEXURE 10

The eigenvalues of the correlation matrix of the variables used in the PCA framework, depict the proportion of variation that is explained by each Principal component (PC). It is observed that nearly 80% of the variation in the all the spreads used in the model can be explained by the first four components.

A.10.1.Eigenvalues of the Correlation Matrix

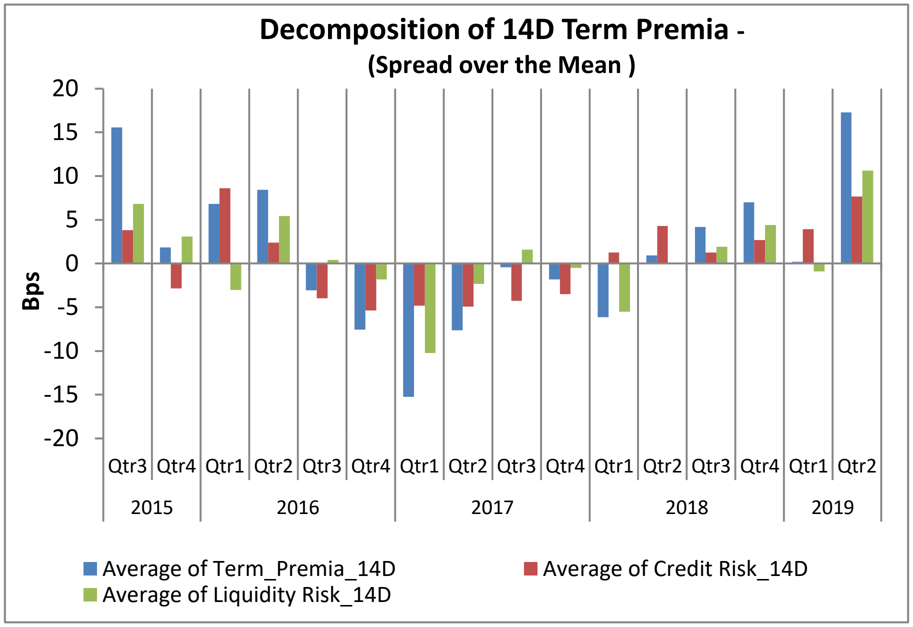
Components	Eigenvalue	Difference	Proportion	Cumulative
PC1	4.0812	1.1258	0.3401	0.3401
PC2	2.9554	1.1464	0.2463	0.5864
PC 3	1.8090	1.0053	0.1508	0.7371
PC 4	0.8037	0.1056	0.0670	0.8041
PC 5	0.6981	0.1156	0.0582	0.8623

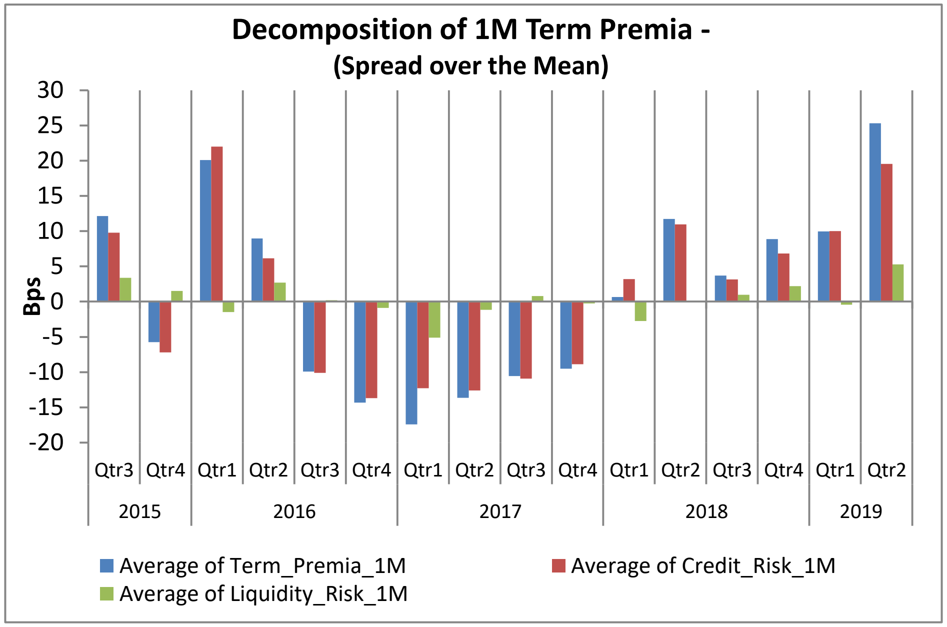
The eigenvectors of the first component indicate a positive relationship with the CD-TBill spread for all the tenors considered and can hence be interpreted as a credit risk. The eigenvectors of the second component indicate a positive relationship with the T-Bill-OIS spreads and can therefore support the earlier interpretation of a measure of liquidity risk.

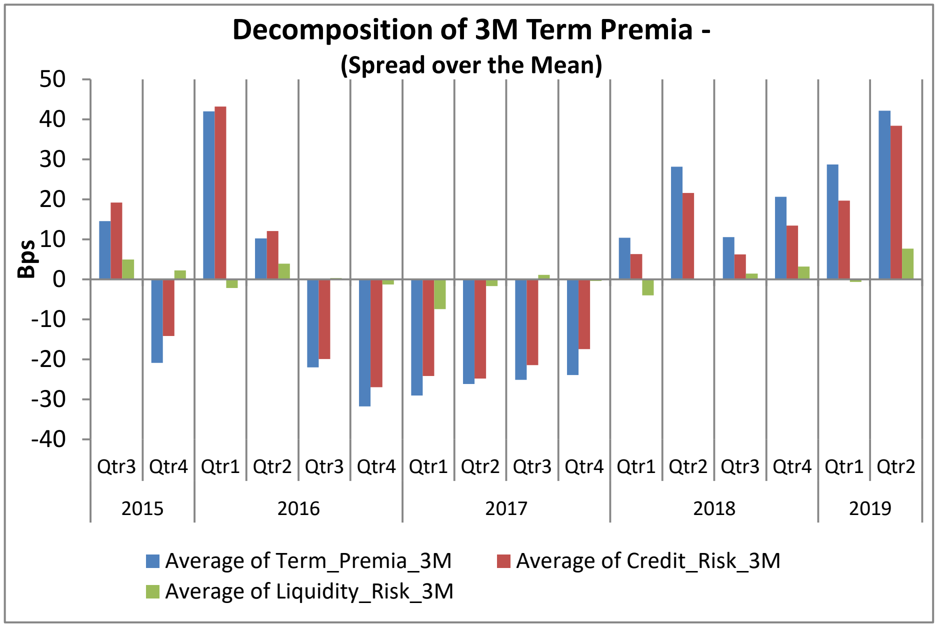
A.10.2.Eigenvectors

	PC1	PC2	PC3	PC4	PC5
Term Premia 14D	**0.2212**	**0.3127**	0.3209	0.1947	0.0024
Term Premia 1M	**0.4093**	**0.2317**	0.0243	0.0084	0.0692
Term Premia 3M	**0.4288**	**0.1948**	-0.0240	-0.3209	-0.0528
CD TB 14D	**0.2348**	0.1144	-0.3756	0.5823	0.4114
CD TB 1M	**0.3541**	0.0364	-0.3864	0.0616	-0.0578
CD TB 3M	**0.3628**	0.0720	-0.2269	-0.4788	-0.2620
TB OIS 14D	-0.2177	**0.4536**	0.1530	-0.2041	0.0354
TB OIS 1M	-0.1953	**0.4761**	0.2068	0.0285	0.0562
TB OIS 3M	0.1375	**0.3864**	0.1908	0.3473	-0.3823
OISFx OISFl 14D	0.2160	-0.3223	0.3964	0.1854	-0.3943
OISFx OISFl 1M	0.2783	-0.3169	0.3577	0.1517	0.0262
OISFx OISFl 3M	0.2428	-0.0697	0.4078	-0.2579	0.6666

ANNEXURE 11


Decomposition of 14D Term Premia -
(Spread over the Mean)
Bps
20
15
10
5
0
-5
-10
-15
-20
Qtr3
Qtr4
Qtr1
Qtr2
Qtr3
Qtr4
Qtr1
Qtr2
Qtr3
Qtr4
Qtr1
Qtr2
Qtr3
Qtr4
Qtr1
Qtr2
2015
2016
2017
2018
2019
Average of Term_Premia_14D
Average of Credit Risk_14D
Average of Liquidity Risk_14D


Decomposition of 1M Term Premia -
(Spread over the Mean)
Bps
30
25
20
15
10
5
0
-5
-10
-15
-20
Qtr3
Qtr4
Qtr1
Qtr2
Qtr3
Qtr4
Qtr1
Qtr2
Qtr3
Qtr4
Qtr1
Qtr2
Qtr3
Qtr4
Qtr1
Qtr2
2015
2016
2017
2018
2019
Average of Term_Premia_1M
Average of Credit_Risk_1M
Average of Liquidity_Risk_1M


Decomposition of 3M Term Premia -
(Spread over the Mean)
Bps
50
40
30
20
10
0
-10
-20
-30
-40
Qtr3
Qtr4
Qtr1
Qtr2
Qtr3
Qtr4
Qtr1
Qtr2
Qtr3
Qtr4
Qtr1
Qtr2
Qtr3
Qtr4
Qtr1
Qtr2
2015
2016
2017
2018
2019
Average of Term_Premia_3M
Average of Credit_Risk_3M
Average of Liquidity_Risk_3M