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Estimation Of Benchmark Treasury Bills Curve

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ABSTRACT

Treasury Bills (TB) are issued on a weekly basis based on an issuance calendar for 91days, 182days and 364 days by the Reserve Bank of India. Secondary market trading is either on the electronic NDS-OM platform or concluded bilaterally and reported on NDS-OM. Generally T-Bills are traded for the first few days after issuance. In the construction of a T-Bill curve, as a first step they were categorized into 7 tenor buckets, each representing a key benchmark tenor. Analysis of the trading in T-Bills shows that trading is unevenly distributed across the tenors, with the 3 month tenor bucket accounting for around 60% of the trading value. Trades of value Rs. 5 crore and above and a threshold of at least 3 trades in each tenor was considered in the calculation for data robustness. Constituent trades, which are generally traded away from the market prices, are excluded. Outstanding executable orders from the NDS-OM order book, with a bid-ask spread of 10bps at market close are considered for augmentation in case the criteria of minimum 3 trades is not fulfilled for a tenor bucket.

The design of the methodology for the computation of the TB curve takes into account four parameters: Distance, Volume, Amount and Rate. The final rate for each traded tenor is the weighted average rate taking into account the weight of all these 4 parameters. The weighted average rate for each Tenor bucket is calculated considering the traded T-bills and executable orders, if available after meeting the required criteria and removing outliers beyond 3 standard deviations. In case it is not feasible to calculate the traded rates, then the missing rate for that tenor is calculated by adding the spread of the adjacent tenors to the previous day's rate for that day and as a last measure repeating the T-Bill rate of the previous day. There is minimal deviation from the traded rates and the rates calculated using the aforementioned methodology. T-Tests between the T-Bill rates so computed and the weighted average yield of the auctions for 91 days, 182 days and 364 days, suggests that the means and variances of these two samples do not significantly differ from each other and both these rates are closely aligned. Analysis of the 3 month T-bill rate, the most liquid tenor suggests that around 50% of the total trading values lie within this rate, indicating that the traded rates are on an average symmetrical around the benchmark rate.

JEL Classification: G1, G12, G0, E430,

Keywords: T-Bills, Spread, Tenors, Regression, Efficiency

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SECTION 1

1. INTRODUCTION

Treasury Bills in India are regularly issued and follows an Issuance Calendar released every three months by RBI. The 91-day T-Bills are issued every Wednesday and 182-day and 364-day T-Bills are issued every alternate week along with 91-day T-Bills. This implies that every week there are two T-bills are issued by RBI on behalf of the Government: 91 Day and 182 Day or 91 Day and 364 Day T-Bills. Since October 2017, the 182-day and 364-days T-bills auction has been switched over to a weekly basis. The RBI typically follows a multiple price Auction for issuance of T-Bills. The bids are submitted electronically. These T-Bills are regularly traded in the secondary market. The trades happen either through the electronic platform (NDS-OM) or directly among participants or through a Broker who helps to find a counter party for a deal. There has been no T-Bills curve though valuation of T-Bills prices are issued by FIMMDA on regular basis. Theoretically, there are many short term credit products which are linked to the T-Bills through a credit risk premia. Certificate of Deposits issued by banks are typically linked to appropriate T-Bills rate through a spread to take care of the credit risk for an issuer Bank. RBI also issues Cash Management Bills (CMB) to manage excess liquidity in the system under Market Stabilization Scheme. These are unstructured T-Bills issued by RBI. The T-Bills and CMBs are traded in secondary market regularly and these trades are captured at CCIL as all settlement is carried out by CCIL as a Qualified Central Counterparty (QCCP). Since these trades are available easily, an attempt is made to carve out a T-Bills curve out of the traded data.

1.1. Bucketing

Typically trading is more for a particular ISIN T-Bill at the time of issuance. After issuance it is traded for next few days till the buy side entities put it in their “Hold” category. Hence trading for a particular ISIN can be sporadic. We may not have a pattern of trading for a particular maturity on a daily basis. Hence, to make a meaningful analysis of trading structure of T-Bills, we need to create various buckets and put the trading of the T-Bills into these buckets if they satisfy the maturity criteria. We created acceptable and market practiced data points like 14-days, 1-month, 2-month, 3-month, 6-month, 9-month and 12 month. To analyze the trading activity in the T-Bills market, we classified the trades into buckets based on their residual maturity. The buckets have been decided on the basis of an optimization, to ensure optimal distribution of traded points across the curve so that each bucket has a representative amount of trading points. As explained above, we derived 7 buckets as illustrated in *Table 1* to represent a benchmark tenor. These buckets were selected after doing data crunching and to ensure the maximum data points are available in each bucket.

Table 1: Classification on the basis of Residual maturity		
Bucket	***Residual maturity (days)***	***Benchmark Tenor***
1	1 to 16	14 Days
2	17 to 45	1 Month
3	46 to 71	2 Months
4	72 to 115	3 Months
5	116 to 200	6 Months
6	201 to 300	9 Months
7	>300	12 Months

Table 2 illustrates the tenor wise break up of number of days during which DTBs have been traded. T-Bills are regularly issued and traded irrespective of liquidity conditions in the market. Money market participants target T-bills issuances to achieve the success ratio applicable for PDs.

Table 3, highlights the daily average number of trades and value (` Crores) of DTBs across tenor buckets. We find an unevenly distributed trading activity across tenors. Three month maturity bucket account for nearly 30% of entire trading activity and upto 3 months tenor account for 70% of the trading in terms of number of deals and 60% in terms of value.

Further, we looked at minimum number of trades with trade value of Rs.5 crores and above to be used for basic computation of benchmark rates. We looked at minimum threshold criteria of 3 and 5 trades in a day for each tenor to compute the benchmark rate. For T-Bills, we also discarded constituent trades from the data for robustness. Constituent trades are not considered because constituent trades have prices/yields which are away from the market as a spread is charged for such trades in the market as a normal market practice. Since T-bills are also traded with an anonymous order-book system, we also looked at the outstanding executable orders with a Bid-Ask spread of 10bps at the close of the market to augment the number of deals in case the minimum criteria of 3 or 5 trades is not met for particular day for a particular tenor. *Table 4 and Table 5* present the number of days the DTB rate can be computed for a given day after taking into consideration minimum 3 and minimum 5 trades in each tenor bucket respectively.

From the data, we can see that considering minimum of 5 trades for computation of T-Bills Curve may not be a good idea as the days of computation using the trade information drops significantly. Hence we decided to use the Minimum 3 trades criteria for computation of T-Bills Rates for the Benchmark T-Bills curve.

The computation of Benchmark Rates are illustrated in Section 2.

SECTION 2

2. METHODOLOGY FOR COMPUATION OF BENCHMARK RATES OF T-BILL CURVES

For the purpose of computation of the benchmark rates, secondary market transactions have been considered. The trades are classified based on their residual maturity. These trades will represent the benchmark tenors of 14 days, 1 month, 2 months, 3 months, 6 months, 9 months and 12 months. The trades in each of these buckets will serve as a medium for computation of a benchmark rate to represent a particular benchmark tenor.

For the purpose of illustration we consider the transactions to be used for computation of the 14 Day benchmark Tenor. These transactions are categorized on the basis of their residual tenor and are aggregated to arrive at a cumulative Amount and Weighted Value (WV) for each residual maturity as indicated in *'Panel A of Table 6'*. The number of trades, Amount and WV are then aggregated for those transactions with the same residual tenor as indicated in *'Panel B of Table 6'*.

The outliers are removed using a +/-3 standard deviation criteria from the mean weighted average rate in each bucket. Only trades of 5 crores and above are used for computation and constituent deals were ignored for T-Bills.

As stated above, for T-Bills Rate, we used both trading information as well as possible executable day end outstanding orders with a spread upto 10bps on those days when the minimum criteria is not met. The lower of the order values (of Buy and Sell orders) which satisfy the above criteria of 10bps spread is considered. The mid quote is considered as the applicable rate. This helped in augmenting the T-Bills data across the curve. The rates so computed can be easily used as T-Bills benchmark rates.

For the purpose of computation of the benchmark rate, the methodology takes into consideration four parameters, namely, the *Distance*, *Volume, Amount and Rate*. The computation of these parameters is illustrated in *'Table 7'* and is explained as follows:

a. Distance: To calculate the *Distance* we follow steps i to v as under*:*

i. Calculate the difference between the residual tenor of a given trade with its respective benchmark tenor. For example, in case of trades with a residual tenor of 15 days, this difference is computed as 15 minus 14 which equals -1.

ii. Calculate the absolute value of this difference. This is done to ensure that positive and negative values will have the same impact on the tenor point rate. Following our example, |-1| is equal to 1.

iii. Calculate the sum of these absolute differences, for all trades in the relevant maturity bucket. This is the sum of 12, 8, 6 and 1 which equals to 27.

iv. Each tenor is then assigned a weight, based on its percentage share in the sum of these absolute differences in that relevant bucket. In our case, this is equal to 0.0370 i.e. 1 (calculated from Step ii) divided by 27 (calculated from Step iii).

v. *Distance* is then calculated as the inverse of this percentage share. In our example, this equals to 27 i.e. 1 divided by 0.0370.

Thus, the parameter of *Distance* will vary depending upon the proximity of the residual tenor of a given trade to its benchmark tenor. Indeed, given the benchmark tenor of 14 Days, trades with a residual tenor of 15 days will have a greater weight (i.e. a weight of 27) vis-à-vis trades with a residual tenor of 2 days (i.e. a weight of 2.25), as it lies closer to our benchmark tenor. Trades which will have the exact residual maturity as the benchmark tenor point will be given the maximum weight by assigning a standard non-zero value of 0.5 (for example, a trade with an exact 14 days maturity will be assigned 0.5 to obtain the impact of 1/0)

b. Volume: The volume is computed as the percentage share of the number of trades (frequency), for a given residual tenor, in the total number of all the trades within that respective maturity bucket. As an example, there has been only one trade with a residual maturity of 15 days, within the 14 Days maturity bucket which consists of a cumulative of 5 trades. Hence the weight assigned to this trade is 0.20 (i.e. 1 divided by 5). Thus, larger the number of trades at a given tenor, greater would be its influence on the benchmark rate. This factor will be taking care of liquidity impact on rate for the tenor.

c. Amount: For a given maturity bucket, the third parameter used in computation is the *Amount* (value in Rs. Crores) of all the trades which have a residual maturity that fall within that maturity bucket. The greater the value of the trades, the larger would be its weight in the computation process. For example, in case of the 1st maturity bucket, the trades with a residual maturity of 8 days and an amount of Rs. 70 crores will play a larger role in influencing the 14-Days benchmark rate vis-à-vis trades with a residual maturity of 15 days and an amount of Rs. 5 crores.

Having computed the parameters, three alternative computation methodologies that has been considered to arrive at the weighted average rate (WAR) for each benchmark Tenor of the Curve:

$$\boldsymbol{WAR3} = \boldsymbol{WAR}(\boldsymbol{Amount}, \boldsymbol{Distance}, \boldsymbol{Volume}) = \frac{\sum(\boldsymbol{Rate} \times \boldsymbol{Amount} \times \boldsymbol{Distance} \times \boldsymbol{Volume})}{\sum(\boldsymbol{Amount} \times \boldsymbol{Distance} \times \boldsymbol{Volume})} \quad \textbf{(1)}$$

$$\boldsymbol{WAR2} = \boldsymbol{WAR}(\boldsymbol{Amount}, \boldsymbol{Distance}) = \frac{\sum(\boldsymbol{Rate} \times \boldsymbol{Amount} \times \boldsymbol{Distance})}{\sum(\boldsymbol{Amount} \times \boldsymbol{Distance})} \quad \textbf{(2)}$$

$$\boldsymbol{WAR1} \quad = \boldsymbol{WAR(Amount)} \qquad = \frac{\sum(\boldsymbol{Rate} \times \boldsymbol{Amount})}{\sum \boldsymbol{Amount}} \qquad \textbf{(3)}$$

For all the tenor buckets, the WAR computed under the three methodologies appear to closely replicate the properties of the traded rate closest to the applicable tenor such as 14 days, 30 days, 60 days etc.

An analysis of the auction weighted average yield[3] vis-a-vis the three alternative traded weighted average rates indicates that Root Mean Squared Error (Annexure 1) is the lowest in case of WAR3. Hence, among the three methodologies, WAR3 has been chosen, as it appears to be stable over time and accounts for characteristics of the amount, distance and volume of the T-Bills transactions.

SECTION 3

3. PROCESS FOR COMPUTATION OF BENCHMARK T-BILLS FOR TENORS ON THE BENCHMARK CURVE

Once the traded T-Bills and the executable orders are available, the Weighted Average Rate for a particular Tenor is calculated subject to threshold criteria explained in Section 2. The above process is followed to finalize the Rates for various Tenors in the Curve for the Day. The following process is followed to compute the benchmark rate:

a) Use the computed T-Bills Rates from trades and orders wherever available subject to conditions such as removal of outliers using 3 SD, minimum trade value of 5 crores and above, minimum 3 trades for each tenor, no constituent trades, etc.;
b) If the T-Bills Rate is not available for a day, T-Bills Rate would be computed using the previous day's T-Bills Rate for the relevant Tenor plus the average spread of two adjacent buckets for the day (Rate(t+1) –Rate(t) when two adjacent spread points are available otherwise use the nearest spread available for the Tenor. This will result in having T-Bills Rates for almost all tenors on all days.
c) In case all attempts fail to estimate a Rate for a Tenor on the Curve, previous day's Rate for the appropriate Tenor will be repeated.

Using the above methodology, we could construct a TB curve upto 1 year. The order book augmented the construction of the curve but on many occasions, we have found that the T-Bills rate of the previous day plus the average adjacent spread has to be used to compute the rate, specifically for longer maturities. The liquidity in longer maturity buckets like 9 months and 12 months is very low for which we have to use the previous day's rates and spread of adjacent tenors. *Table 8,* elucidates the break-up of the number of days DTB rate

[3] The auction weighted average yield is implied from the weighted average price announced at the time of the treasury bills auction.

has been computed from trades, augmented by order book and days when the previous days rate along with adjacent tenor spread is used.

Table 9, illustrates the comparison of the DTB rate calculated as per the aforementioned methodology with the traded DTB Rate.

SECTION 4

4. TESTING THE EFFICIENCY OF THE BENCHMARK T-BILL CURVE

The robustness and reliability of a benchmark plays a critical role in its acceptability in the market. An ideal benchmark rate should mirror the levels at which participants deal in the market. To test for efficiency, we compared the computed Benchmark rate with rates prevailing in the primary market. This section further provides an analysis of how the benchmark T-bill rate is placed in the distribution of market trades.

4.1. Comparison with the Primary Market Treasury Bills Rate:

To test the efficiency of the T-Bills Curve constructed using the methodology specified above; we compared these T-Bill rates with the weighted average yield (WAY)[4] announced during every auction for the tenors of 91 days, 182 days and 364 days. The WAY is comparable to the benchmark T-bill rate as both are volume weighted average rates. A two sample T-Test was conducted in order to analyze the equality of the means and the variances of the T-bill rate with the auction WAY, for the period of April 2012 to March 2018. The T-test results are provided in Annexure 2.

The results suggest that the difference in the Mean of the two samples (as indicated by the Pooled T-value) is not significantly different from zero. The spread between the average benchmark T-bill rate and the auction WAY was found to be close to 0. Further, the variances of the two samples (as indicated by the Folded F Statistic) do not significantly differ from each other. The descriptive statistics of the difference (in %) between the Benchmark T-bill rate and the auction WAY is provided in Table 10.

A Cross correlation analysis (Table 11) of the rates under consideration also indicates that the benchmark rate, whether traded or calculated, is closely aligned to rates prevalent in the primary market.

[4] RBI announces the weighted average price (WAP) at the time of the auction. The weighted average yield was implied from this weighted average price using the following equation: $\left(\left(\frac{100}{WAP}\right)-1\right)\times\left(\frac{365}{Tenor}\right)\times 100$

4.2. Distribution Analysis of Trades from the Benchmark T-bill Rate

The distribution of rates in an ideal market should reflect the normal distribution i.e. the rates should be symmetric around the mean. To test the efficiency of the benchmark rate we conducted a distribution analysis for the 3 month benchmark tenor- the most liquid tenor on the curve. Trades with a residual maturity starting from 72 days and upto 115 days for the period of 23rd August 2017 to 30th April 2018 were analyzed. We calculated the daily rate at the 10th, 25th, 50th, 75th and 90th percentiles for all trades reported during the period and the cumulative value at each of these percentiles. In addition to this, the cumulative value of the trades' upto the computed FBIL Benchmark rate was also estimated. The summary statistics of the results for each month is shown in Table 12.

The results suggest that around 50% of the total trading value of trades lie within the FBIL T-bill rate. This suggests that the traded rates are on an average symmetrical around the published benchmark rate.

SECTION 5

5. CONCLUSION AND SUGGESTIONS

1. T-Bills curve (TBCURVE) may be generated by computing the rates for 7 tenors of 14-day, 1, 2, 3, 6, 9 and 12 months. Trades reported and executed on NDS-OM will be captured in tenor buckets, as explained in the methodology document.
2. First the trade data is divided into two categories while allocating trades to various maturity tenors – (a) less than 3 trades and (b) 3 or more trades.
3. For the data set where there are less than 3 trades, we move to include order book information with a bid-offer spread of 10bps to augment the data. Then Weighted Average rate and SD is computed to remove outliers from the data using +/-3SD. Final Weighted Average rate and SD may be computed after removal of such outliers.
4. For the data set where we have more than or equal to 3 trades, we compute the Weighted Average Rate and Standard Deviation and remove the outlier using +/-3SD. After removal of outliers, if a dataset is falling short of minimum 3 trades criteria, then the tenor data set may be augmented by order book data with a spread of 10bps. The Weighted Average Rate for the Tenor and standard deviation may be computed from the said augmented dataset.
5. In general, for construction of the TBCURVE, the computed T-Bills rates from trades and orders whenever available may be used subject to certain conditions, namely removal of outliers outside +/- 3SD range, minimum trade size of `5crores, minimum 3 trades for each of the 7 tenor and no constituents trades.

6. If the T-Bills rate for any particular tenor is not available on any working day, it may be computed using the previous working day's T-Bills rate for that tenor plus the average spread of two adjacent tenors for the day ($TBRate_t$ - $TBRate_{t-1}$) when two adjacent spread points are available. Otherwise the closest tenor spread available will be added to the previous day's TB Rate to give the TB Rate for the Day for the missing Tenor.
7. In case all attempts fail to estimate the rates for all tenors, previous working day's rates for relevant tenors may be repeated. This procedure may be followed for a maximum of two more working days.

ANNEXURE 1

The Root Mean Squared Error (RMSE) was computed using the following equation:

$$RMSE = \sqrt{\frac{(Auction\ WAY - WAR)^2}{N}}$$

where,

- *Auction WAY stands for the weighted average yield that is implied from the weighted average price announced at the time of the Treasury bill auction.*
- *WAR stands for the weighted average rate computed from trades during the day. WAR is computed under three alternative methodologies specified in equation (1), (2) and (3) stated above.*
- *N is the number of days in the period of 2012-2016 on which the auction WAY as well as the traded WAR is available, subject to the threshold criteria.*

Tenor	N	RMSE		
		WAR3	WAR2	WAR1
3M	245	0.0223	0.0241	0.0364
6M	116	0.0186	0.0179	0.0232
12M	108	0.0226	0.0226	0.0235
Average		0.0212	0.0215	0.0277

ANNEXURE 2

Two Sample T Test between the FBIL Rate and the Auction WAY for the period of -2012-2018

Tenor=91

Type	Method	N	Mean	Std Dev	Std Err	Min	Max
FBIL_RATE		314	7.5653	1.1460	0.0647	5.8015	11.7306
Auction_WAY		314	7.5646	1.1472	0.0647	5.7776	11.7667
Diff (1-2)	Pooled		0.0007	1.1466	0.0915		
Diff (1-2)	Satterthwaite		0.0007		0.0915		

Type	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
FBIL_RATE		7.5653	7.4381	7.6926	1.1460	1.0629	1.2434
Auction_WAY		7.5646	7.4372	7.6920	1.1472	1.0640	1.2447
Diff (1-2)	Pooled	0.0007	-0.1790	0.1804	1.1466	1.0865	1.2139
Diff (1-2)	Satterthwaite	0.0007	-0.1790	0.1804			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	626	0.0100	0.9937
Satterthwaite	Unequal	626	0.0100	0.9937

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	313	313	1.0000	0.9853

Tenor=182

Type	Method	N	Mean	Std Dev	Std Err	Min	Max
FBIL_RATE		171	7.4786	1.0939	0.0837	5.9612	11.5256
Auction_WAY		171	7.4848	1.0954	0.0838	5.9471	11.5600
Diff (1-2)	Pooled		-0.0061	1.0947	0.1184		
Diff (1-2)	Satterthwaite		-0.0061		0.1184		

Type	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
FBIL_RATE		7.4786	7.3135	7.6438	1.0939	0.9889	1.2239
Auction_WAY		7.4848	7.3194	7.6501	1.0954	0.9903	1.2257
Diff (1-2)	Pooled	-0.0061	-0.2390	0.2267	1.0947	1.0182	1.1836
Diff (1-2)	Satterthwaite	-0.0061	-0.2390	0.2267			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	340	-0.0500	0.9588
Satterthwaite	Unequal	340	-0.0500	0.9588

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	170	170	1.0000	0.9851

Tenor=364							
Type	**Method**	**N**	**Mean**	**Std Dev**	**Std Err**	**Min**	**Max**
FBIL_RATE		173	7.4511	0.9910	0.0753	5.9356	10.1646
Auction_WAY		173	7.4537	0.9896	0.0752	5.9598	10.1114
Diff (1-2)	**Pooled**		-0.0026	0.9903	0.1065		
Diff (1-2)	**Satterthwaite**		-0.0026		0.1065		

Type	**Method**	**Mean**	**95% CL Mean**		**Std Dev**	**95% CL Std Dev**	
FBIL_RATE		7.4511	7.3024	7.5998	0.9910	0.8964	1.1080
Auction_WAY		7.4537	7.3052	7.6022	0.9896	0.8951	1.1065
Diff (1-2)	**Pooled**	-0.0026	-0.2120	0.2068	0.9903	0.9215	1.0703
Diff (1-2)	**Satterthwaite**	-0.0026	-0.2120	0.2068			

Method	**Variances**	**DF**	**t Value**	**Pr > |t|**
Pooled	Equal	344	-0.0200	0.9806
Satterthwaite	Unequal	344	-0.0200	0.9806

Equality of Variances				
Method	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Folded F	172	172	1.0000	0.9854

Table 2: Tenor Wise Trading Frequency (No. of Days Traded) in DTB market*								
Year	**14D**	**1M**	**2M**	**3M**	**6M**	**9M**	**12M**	**Total Trading Days**
2012	145 *80%*	160 *88%*	140 *77%*	175 *96%*	126 *69%*	87 *48%*	108 *59%*	182 *100%*
2013	157 *64%*	206 *84%*	191 *78%*	237 *97%*	214 *88%*	144 *59%*	175 *72%*	244 *100%*
2014	220 *93%*	215 *91%*	199 *84%*	231 *98%*	212 *90%*	175 *74%*	179 *76%*	236 *100%*
2015	201 *83%*	223 *93%*	207 *86%*	236 *98%*	207 *86%*	156 *65%*	151 *63%*	241 *100%*
2016	195 *81%*	216 *90%*	190 *79%*	236 *98%*	203 *84%*	147 *61%*	150 *62%*	241 *100%*

**Trades of Rs. 5 Cr. and above have been considered. Constituent deals have been excluded.*

Table 3: Tenor-Wise Analysis of DTB Trades and Value (Rs. Cr.)*														
Year	**14D**	**1M**	**2M**	**3M**	**6M**	**9M**	**12M**	**14D**	**1M**	**2M**	**3M**	**6M**	**9M**	**12M**
	DTB													
	Daily Average No. of Trades							**Tenor Wise Percentage of Total Trades**						
2012	7	8	6	15	5	4	6	13%	18%	11%	36%	8%	5%	9%
2013	4	7	7	17	6	3	6	7%	14%	13%	38%	13%	5%	11%
2014	9	7	6	17	7	4	6	16%	13%	11%	33%	13%	7%	8%
2015	6	7	7	18	7	4	5	11%	14%	12%	39%	12%	6%	6%
2016	5	6	5	20	8	5	5	10%	12%	9%	42%	14%	7%	7%
	Daily Average Value (Rs. Crore)							**Tenor Wise Percentage of Total Traded Value**						
2012	299	363	224	596	308	247	318	13%	18%	9%	31%	12%	6%	10%
2013	165	319	347	870	359	302	422	5%	12%	12%	37%	14%	8%	13%
2014	396	308	338	1039	416	327	336	13%	10%	10%	36%	13%	9%	9%
2015	340	372	422	1221	482	435	370	9%	11%	12%	38%	13%	9%	7%
2016	426	381	298	1533	484	442	375	10%	10%	7%	45%	12%	8%	7%

***Trades of Rs. 5 Cr. and above have been considered. Constituent deals have been excluded.*

Table 4: Number of Days DTB WAR is computed under Minimum 3 Trades Criteria														
Panel A: No. of Days DTB WAR has been computed using Trade Book														
	Minimum 3 Trades Criteria													
Period	**14D**		**1M**		**2M**		**3M**		**6M**		**9M**		**12M**	
2012	109	*(60%)*	131	*(72%)*	90	*(49%)*	155	*(85%)*	80	*(44%)*	48	*(26%)*	72	*(40%)*
2013	90	*(37%)*	173	*(71%)*	142	*(58%)*	219	*(90%)*	157	*(64%)*	70	*(29%)*	119	*(49%)*
2014	180	*(76%)*	170	*(72%)*	148	*(63%)*	216	*(92%)*	165	*(70%)*	103	*(44%)*	109	*(46%)*
2015	132	*(55%)*	178	*(74%)*	155	*(64%)*	225	*(93%)*	142	*(59%)*	90	*(37%)*	86	*(36%)*
2016	133	*(55%)*	163	*(68%)*	123	*(51%)*	224	*(93%)*	157	*(65%)*	79	*(33%)*	90	*(37%)*
2012-2016	644	*(56%)*	815	*(71%)*	658	*(58%)*	1039	*(91%)*	701	*(61%)*	390	*(34%)*	476	*(42%)*
Panel B: No. of Days DTB WAR has been augmented using Order Book														
	Minimum 3 Trades Criteria													
Period	**14D**		**1M**		**2M**		**3M**		**6M**		**9M**		**12M**	
2012	8	*(4%)*	6	*(3%)*	13	*(7%)*	11	*(6%)*	10	*(5%)*	6	*(3%)*	8	*(4%)*
2013	6	*(2%)*	7	*(3%)*	6	*(2%)*	8	*(3%)*	10	*(4%)*	7	*(3%)*	12	*(5%)*
2014	4	*(2%)*	13	*(6%)*	16	*(7%)*	10	*(4%)*	16	*(7%)*	12	*(5%)*	36	*(15%)*
2015	11	*(5%)*	12	*(5%)*	28	*(12%)*	7	*(3%)*	19	*(8%)*	18	*(7%)*	12	*(5%)*
2016	11	*(5%)*	12	*(5%)*	29	*(12%)*	7	*(3%)*	17	*(7%)*	16	*(7%)*	15	*(6%)*
2012-2016	40	*(3%)*	50	*(4%)*	92	*(8%)*	43	*(4%)*	72	*(6%)*	59	*(5%)*	83	*(7%)*
Panel C (A+B) : No. of Days DTBs WAR has been computed using Trade and Order book combined														
	Minimum 3 Trades Criteria													
Period	**14D**		**1M**		**2M**		**3M**		**6M**		**9M**		**12M**	
2012	117	*(64%)*	137	*(75%)*	103	*(57%)*	166	*(91%)*	90	*(49%)*	54	*(30%)*	80	*(44%)*
2013	96	*(39%)*	180	*(74%)*	148	*(61%)*	227	*(93%)*	167	*(68%)*	77	*(32%)*	131	*(54%)*
2014	184	*(78%)*	183	*(78%)*	164	*(69%)*	226	*(96%)*	181	*(77%)*	115	*(49%)*	145	*(61%)*
2015	143	*(59%)*	190	*(79%)*	183	*(76%)*	232	*(96%)*	161	*(67%)*	108	*(45%)*	98	*(41%)*
2016	144	*(60%)*	175	*(73%)*	152	*(63%)*	231	*(96%)*	174	*(72%)*	95	*(39%)*	105	*(44%)*
2012-2016	684	*(60%)*	865	*(76%)*	750	*(66%)*	1082	*(95%)*	773	*(68%)*	449	*(39%)*	559	*(49%)*
**Parenthesis indicate Percentage Share of Total Trading Days)*														

Table 5: Number of Days DTB WAR is computed under Minimum 5 Trades Criteria

Panel A: No. of Days DTB WAR has been computed using Trade Book

Period	*Minimum 5 Trades Criteria*													
	14D		1M		2M		3M		6M		9M		12M	
2012	82	*(45%)*	105	*(58%)*	63	*(35%)*	142	*(78%)*	51	*(28%)*	26	*(14%)*	51	*(28%)*
2013	56	*(23%)*	127	*(52%)*	106	*(43%)*	201	*(82%)*	115	*(47%)*	34	*(14%)*	81	*(33%)*
2014	150	*(64%)*	135	*(57%)*	99	*(42%)*	198	*(84%)*	126	*(53%)*	63	*(27%)*	72	*(31%)*
2015	95	*(39%)*	120	*(50%)*	109	*(45%)*	205	*(85%)*	97	*(40%)*	48	*(20%)*	53	*(22%)*
2016	83	*(34%)*	109	*(45%)*	76	*(32%)*	204	*(85%)*	122	*(51%)*	45	*(19%)*	60	*(25%)*
2012-2016	466	*(41%)*	596	*(52%)*	453	*(40%)*	950	*(83%)*	511	*(45%)*	216	*(19%)*	317	*(28%)*

Panel B: No. of Days DTB WAR has been augmented using Order Book

Period	*Minimum 5 Trades Criteria*													
	14D		1M		2M		3M		6M		9M		12M	
2012	8	*(4%)*	8	*(4%)*	8	*(4%)*	6	*(3%)*	9	*(5%)*	6	*(3%)*	6	*(3%)*
2013	3	*(1%)*	10	*(4%)*	5	*(2%)*	7	*(3%)*	10	*(4%)*	11	*(5%)*	11	*(5%)*
2014	3	*(1%)*	10	*(4%)*	23	*(10%)*	16	*(7%)*	15	*(6%)*	14	*(6%)*	22	*(9%)*
2015	7	*(3%)*	25	*(10%)*	28	*(12%)*	17	*(7%)*	9	*(4%)*	9	*(4%)*	10	*(4%)*
2016	12	*(5%)*	21	*(9%)*	19	*(8%)*	11	*(5%)*	15	*(6%)*	14	*(6%)*	11	*(5%)*
2012-2016	33	*(3%)*	74	*(6%)*	83	*(7%)*	57	*(5%)*	58	*(5%)*	54	*(5%)*	60	*(5%)*

Panel C (A+B) : No. of Days DTBs WAR has been computed using Trade and Order book combined

Period	*Minimum 5 Trades Criteria*													
	14D		1M		2M		3M		6M		9M		12M	
2012	90	*(49%)*	113	*(62%)*	71	*(39%)*	148	*(81%)*	60	*(33%)*	32	*(18%)*	57	*(31%)*
2013	59	*(24%)*	137	*(56%)*	111	*(45%)*	208	*(85%)*	125	*(51%)*	45	*(18%)*	92	*(38%)*
2014	153	*(65%)*	145	*(61%)*	122	*(52%)*	214	*(91%)*	141	*(60%)*	77	*(33%)*	94	*(40%)*
2015	102	*(42%)*	145	*(60%)*	137	*(57%)*	222	*(92%)*	106	*(44%)*	57	*(24%)*	63	*(26%)*
2016	95	*(39%)*	130	*(54%)*	95	*(39%)*	215	*(89%)*	137	*(57%)*	59	*(24%)*	71	*(29%)*
2012-2016	499	*(44%)*	670	*(59%)*	536	*(47%)*	1007	*(88%)*	569	*(50%)*	270	*(24%)*	377	*(33%)*

**Parenthesis indicate Percentage Share of Total Trading Days)*

Table 6: T-Bills Transaction for computation of 14 Days Benchmark Rate

Panel A				*Panel B*				
Residual Tenor	*Amount (Rs. Cr.)*	*Yield*	*WV*	*Residual Tenor*	*Number of Trades*	*Amount (Rs. Cr.)*	*WV*	*Rate*
	(a)	*(b)*	*(a) x(b)*			*(a)*	*(b)*	*(c)= (b)/(a)*
2	10.00	6.6089	66.089	2	2	20.00	132.18	6.6089
2	10.00	6.6089	66.089	6	1	50.00	330.08	6.6015
6	50.00	6.6015	330.08	8	1	70.00	458.64	6.5520
8	70.00	6.5520	458.64	15	1	5.00	32.50	6.4997
15	5.00	6.4997	32.50					

Table 7: Computation of 14 Days Weighted Average Rate					
Variable	**Notation**	**14 Day WAR**			
Panel A: Tenor-Wise Information					
Residual Tenor$	*(a)*	2	6	8	15
Benchmark Tenor@	*(b)*	14			
Days	*(c) = (a) – (b)*	12	8	6	-1
ABS(Days)	*(d) = |(c)|*	12	8	6	1
Sum of ABS(Days)	*(e) = ∑(d)*	27			
Share in ABS(Days)	*(f) = (d)/(e)*	0.4444	0.2963	0.2222	0.0370
Distance	*(g) = 1/(f)*	2.2500	3.3750	4.5000	27.0000
No. of trades$	*(h)*	2	1	1	1
Sum of No. of Trades	*(i) = ∑(h)*	5			
Volume	*(j) = (h)/(i)*	0.4000	0.2000	0.2000	0.2000
Amount (Rs. Cr.) $	*(k)*	20.00	50.00	70.00	5.00
Rate$	*(l)*	6.6089	6.6015	6.5520	6.4997
***Panel B: Computed* Weighted Average Rate**					
WAR3	$\frac{\sum(l)\cdot(k)\cdot(g)\cdot(j)}{\sum(k)\cdot(g)\cdot(j)}$	6.5610			
WAR2	$\frac{\sum(l)\cdot(k)\cdot(g)}{\sum(k)\cdot(g)}$	6.5792			
WAR1	$\frac{\sum(l)\cdot(k)}{\sum(k)}$	6.5751			
Rate to Closest Applicable Tenor$		6.4997			
Notes: $Figures from Panel B of Table 2. @Figures from Table 1.					

Table 8: DTB Trading Analysis using Minimum 3 Trades Criteria							
Period	**14D**	**1M**	**2M**	**3M**	**6M**	**9M**	**12M**
Panel A: No. of Days DTB WAR is computed from Trades							
2012	109	131	90	155	80	48	72
2013	90	173	142	219	157	70	119
2014	180	170	148	216	165	103	109
2015	132	178	155	225	142	90	86
2016	133	163	123	224	157	79	90
Panel B: No. of Days DTB WAR is augmented from DTB Order Book							
2012	8	6	13	11	10	6	8
2013	6	7	6	8	10	7	12
2014	4	13	16	10	16	12	36
2015	11	12	28	7	19	18	12
2016	11	12	29	7	17	16	15
Panel C: No. of Days DTB WAR is computed from Adjacent Tenor Spreads							
2012	64	45	79	16	90	127	100
2013	148	64	96	17	77	167	114
2014	52	53	72	10	55	121	91
2015	98	51	58	9	80	133	143
2016	97	66	89	10	67	146	136

Table 9: Deviations of Calculated DTB WAR from Traded DTB WAR							
Traded DTB rates							
Year	**14D DTB**	**1M DTB**	**2M DTB**	**3M DTB**	**6M DTB**	**9M DTB**	**12M DTB**
2012	8.12	8.20	8.24	8.23	8.19	8.13	8.04
2013	8.32	8.57	8.54	8.57	8.50	8.21	8.41
2014	8.28	8.42	8.50	8.61	8.65	8.67	8.66
2015	7.28	7.51	7.58	7.64	7.67	7.66	7.65
2016	6.52	6.56	6.61	6.67	6.69	6.76	6.77
2012-2016	7.69	7.85	7.90	7.92	7.93	7.90	7.96
Calculated DTB Rates using the suggested methodology							
Year	**14D DTB**	**1M DTB**	**2M DTB**	**3M DTB**	**6M DTB**	**9M DTB**	**12M DTB**
2012	8.14	8.19	8.21	8.22	8.19	8.14	8.06
2013	8.39	8.53	8.56	8.58	8.50	8.43	8.31
2014	8.28	8.43	8.53	8.61	8.66	8.66	8.64
2015	7.27	7.49	7.60	7.64	7.65	7.64	7.63
2016	6.51	6.55	6.63	6.68	6.73	6.75	6.75
2012-2016	7.70	7.82	7.89	7.93	7.93	7.91	7.87
Deviation							
Year	**14D DTB**	**1M DTB**	**2M DTB**	**3M DTB**	**6M DTB**	**9M DTB**	**12M DTB**
2012	2	-1	-3	-1	0	1	2
2013	7	-4	2	1	0	22	-10
2014	0	1	3	0	1	-1	-2
2015	-1	-2	2	0	-2	-2	-2
2016	-1	-1	2	1	4	-1	-2
2012-2016	1	-3	-1	1	0	1	-9

Table 10: Difference (%) between the Auction WAY and the Benchmark T-bill Rate			
	3M Difference	*6M Difference*	*12M Difference*
Mean	-0.0007	0.0061	0.0026
Standard Error	0.0012	0.0017	0.0020
Median	0.0022	0.0022	0.0015
Standard Deviation	0.0206	0.0218	0.0258
Sample Variance	0.0004	0.0005	0.0007
Kurtosis	5.2637	4.8091	13.7896
Skewness	-0.0733	1.5889	-0.8665
Range	0.2243	0.1487	0.2710
Minimum	-0.1057	-0.0449	-0.1642
Maximum	0.1186	0.1039	0.1068
Count	314	171	173

Table 11: Cross-Correlation of the Auction WAY with the FBIL Benchmark Rate

	91D Auction WAY	182D Auction WAY	364D Auction WAY	FBIL 3M	FBIL 6M	FBIL 12M
91D Auction WAY	1					
182D Auction WAY	0.9974	1				
364D Auction WAY	0.9863	0.9496	1			
FBIL 3M	0.9998	0.9974	0.9863	1		
FBIL 6M	0.9972	0.9998	0.9269	0.9972	1	
FBIL 12M	0.9866	0.9603	0.9997	0.9867	0.9403	1

Table 12: Distribution Analysis of Rate in the 3-Month Tenor Bucket

	Percentage Share in Total Volumes Upto						Rates at						Difference between the Median and FBIL T-bill Rate
Month	10th Pctl.	25 Pctl.	50 Pctl.	75 Pctl.	90 Pctl.	FBIL T-bill Rate	10th Pctl.	25th Pctl.	50th Pctl.	75th Pctl.	90th Pctl.	FBIL T-bill Rate	
Aug-2017	6	17	38	76	95	41	6.0940	6.0976	6.1071	6.1240	6.1383	6.1117	-0.0046
Sep-2017	25	46	82	93	98	49	6.0643	6.0779	6.0864	6.1005	6.1157	6.0856	0.0008
Oct-2017	18	35	55	88	97	43	6.0572	6.0692	6.0770	6.0836	6.0903	6.0743	0.0027
Nov-2017	15	29	62	87	97	50	6.0879	6.0979	6.1116	6.1192	6.1264	6.1081	0.0035
Dec-2017	8	39	55	93	98	46	6.1319	6.1474	6.1570	6.1653	6.1706	6.1588	-0.0018
Jan-2018	7	25	50	79	94	43	6.2395	6.2770	6.2978	6.3110	6.3160	6.3084	-0.0106
Feb-2018	32	40	69	89	99	47	6.2948	6.3132	6.3276	6.3339	6.3391	6.3383	-0.0107
Mar-2018	15	28	50	94	99	66	6.1265	6.1494	6.1698	6.1879	6.1985	6.1838	-0.0140
Apr-2018	17	35	61	79	96	55	6.0566	6.0770	6.0954	6.1090	6.1265	6.1048	-0.0094
Full Period	16	34	60	87	97	49	6.1303	6.1486	6.1627	6.1739	6.1832	6.1675	-0.0048
Inter-Quartile Analysis								0.0184	0.0141	0.0112	0.0093		
									0.0325	0.0253	0.0205		
										0.0437	0.0346		
											0.0529		

Pctl. stands for percentile