Market analysis and dependencies exploration of the Tunisia InterBank Offered Rate

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Abstract

In this article, we consider the Tunisia InterBank Offered Rate (TUNIBOR) which is the interest rate at which Tunisian banks lend and borrow liquidity in the Tunisian interbank market. TUNIBOR is the trimmed arithmetic mean of the interest rates fixed and submitted by the Tunisian banks the most active in the InterBank Market[1]. This study focuses on exploring the dependencies of the TUNIBOR with external factors. The fist part presents the approach used by the authors to collect the dataset. In the second part, we will explore the dependencies of the *TUNIBOR* and look for potential correlations. Finally, we present the computation results that lead to the choice of the optimal parameters for the models proposed.

Keywords: *Tunisia Inter-Bank Market; Statistical tests; Financial time series; Financial machine Learning*

1 Introduction

Rational investors know that financial markets are uncertain markets characterized by volatility. The research in this field focused on exploring data trends in order to help investors predict the future movements of these markets and answer the question: *how could we use interest rates to generate an outcome?* and *how volatile are interest rates?*
The research in this field focused also on analyzing markets in order to extract indicators that could help in forecasting. The interbank market, where banks exchange liquidity in Tunisian dinar (TND) for short maturities of up to one year, is one of the most complex markets. Indeed, it is an *Over-The-Counter* that follows a *floating rate* system (The exchange rate adjusts on its own time based on the supply and demand of currency trades). It is also an unregulated and decentralized system, meaning there is no specific location where these transactions occur. In Tunisia the central bank known as *Banque Centrale de Tunisie* is one of the major actors in this market.

The circular of the *Banque Centrale de Tunisie* number $2018 - 12$ of November $28, 2018$ covers one of the four components of the modernization project of the operational framework of the monetary policy initiated by the *BCT* since 2015. The BCT aims to boost and develop the Interbank Liquidity Market through this circular which has just replaced certain provisions and completed the BCT circular number 2005-09 relating to the organization of the money market. The purpose of this circular is to define the conditions, modalities

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[1]ranking is determined by the *Banque Centrale de Tunisie*

and procedures for liquidity exchanges within the framework of the interbank market in dinars. Its provisions will be applicable from January 2019.

The *Banque Centrale de Tunisie* examined, on July 27, 2016, the proposal of the Monetary Policy Committee, meeting on July 22, 2016, concerning the creation of a new benchmark indicator of the interbank interest rate in Tunisia (**TUNIBOR**). The Council adopted TUNIBOR, which will be broadcast from September 1, 2016.

The Tunisian Interbank Offered Rate is an average indicative interest rate at which the most active banks on the money market in Tunisian Dinar intend to lend each other liquidity without guarantee. TUNIBOR has 8 maturities: 1 Week, 2 Weeks, 1 Month, 2 Months, 3 Months, 6 Months, 9 Months and 1 year Banque Centrale de Tunisie (28 November 2018).

The *Banque Centrale de Tunisie* has constituted a designated panel of banks [2] for the TUNIBOR such that only banks that have a significant role in the money market in Tunisian Dinar are considered eligible for membership as mentioned inBanque Centrale de Tunisie (28 November 2018). Each contributing bank is required to update daily before 10:45 a.m. its rate quotations displayed on its contribution pages disseminated through *Reuters* or *Bloomberg* platforms. After checking and validating the underlying contributions, the *Banque Centrale de Tunisie* proceeds at 11 a.m. to calculate the TUNIBOR by maturity as a 15% trimmed mean of the banks' responses and publishes it on its official website. The choice of the trimmed mean is no surprise as other xIBOR[3] are using the same approach.

2 Dependencies exploration

2.1 Data set

Since no database was available of the *TUNIBOR* rates was available, our first task was gathering the data needed to analyze the market. In fact, as mentionned in the introduction, the *BCT* publishes every day the TUNIBOR rates therefore Web Scrapping from centrale de Tunisie (2013) seemed the most efficient solution.

Remark 1 *The BCT website is a single-page website: our headless browser will download the HTML code, and the Javascript code, but will not be able to execute the full Javascript code, and the webpage will not be totally rendered.*

We managed to scrap from the *BCT*'s official website by inspecting the API calls that are made by the Javascript frontend and reproducing them.

Finally, the data base that we constructed contains 1766 values of *TUNIBOR* rates starting from 01/09/2016 to 01/07/2021.

Another problem was the holidays' rates; during some holidays the *BCT* published 0 during these dates but during others the *BCT* published the rates of the day just before the holidays. We managed to solve this by deleting all the holidays from our dataset.

[2] currently: ATB, BNA, ATTIJARI, BT, AMEN BANK, BIAT, STB, UBCI, UIB, BH, BTK, TSB, QNB, BTE, BTL, ABC

[3] LIBOR for example

Once the data gathered, we may take a look on evolution of the TUNIBOR for different maturities starting from 2019.

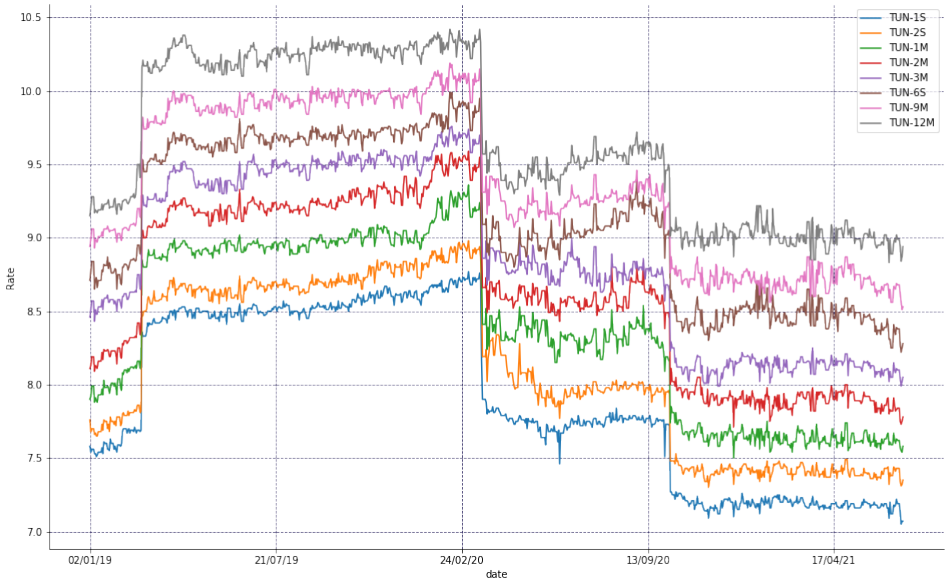


Figure 1: Tunibor rates between 2019 and 2021. We note the jump regime characterizing the Tunisian tunibor and discussed in this article Lin et al. (2017).

We encountered another major problem which is the missing values of the *TUNIBOR* rates for maturity 2 weeks between 01/09/2016 and 02/01/2019.

Remark 2 *This article proposes a machine learning approach to fill the missing values.*

To predict the previous TUN-2S rates we will build a new feature[4] as follows:
Let

- $X^{(1)}$ Tunibor rates with maturity 1 week
- $X^{(2)}$ Tunibor rates with maturity 1 month
- Y Tunibor rates with maturity 2 weeks

We will construct a feature $X^{(3)}$ such that

$$X_t^{(3)} = \alpha X_t^{(1)} + (1-\alpha) X_t^{(2)} \tag{1}$$

We will determine α via OLSE[5]. A simple calculus will give us the following formula:

$$\alpha = \frac{\sum_i (X_t^{(1)} + X_t^{(2)})(Y_t - X_t^{(2)})}{\sum_i (X_t^{(1)} - X_t^{(2)})(X_t^{(1)} + X_t^{(2)})} \tag{2}$$

[4]Computational experiments will prove afterwards that predicting using this feature is better than any other feature in the data set

[5]Ordinary Least Squared Estimation

Another simple calculation gave that the optimal value of α given by the formula below is 0.5758016032387674 therefore the new feature extracted is given by the following formula

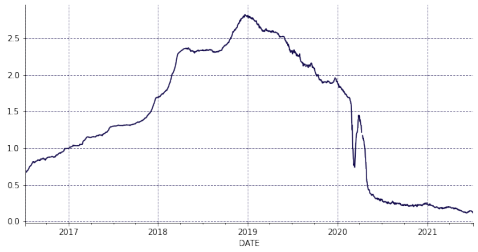
$$X_t^{(3)} = 0.5758016032387674\ X_t^{(1)} + 0.42419839676\ X_t^{(2)} \tag{3}$$

2.2 Dependencies exploration

2.2.1 Data analysis

The first thing we need to look at is the evolution of the *TUNIBOR* rates over the last 5 years. We need also to compare its evolution to another xIBOR, that is why we will plot also the evolution of the *LIBOR* for the same maturity during the same period of time.

(a) TUNIBOR rates for maturity 3 Months



(b) LIBOR rates for maturity 3 Months

Figure 2: Comparison between TUN-3M and LIB-3M in the same period

Obviously, the TUNIBOR curve has some sudden ups and downs. It also has an increasing trend over the period 2016 to 2020 but afterwards it tends to decrease. Forecasting using a time series model such as *ARMA* or *SARIMA* would be hard owing the fact we cannot predict sudden events that imply sudden increase of the rates or sudden decrease.

Therefore, we will assume that there exists external factors that could explain these "anomalies".

We will first have a look on the evolution of the spot EUR/TND and the TUNIBOR for maturity 3 Months rate in the same period of time.

(a) TUN-3M

(b) SPOT EUR/TND

Figure 3: Comparison between TUN-3S and EUR/TND in the same period

We could see that at least there exists some correlation between the TUNIBOR rates and the EUR/TND rates.

Let us explore the correlation between these[6][7] two by using a correlation matrix based on *Pearson*'s correlation coefficient.

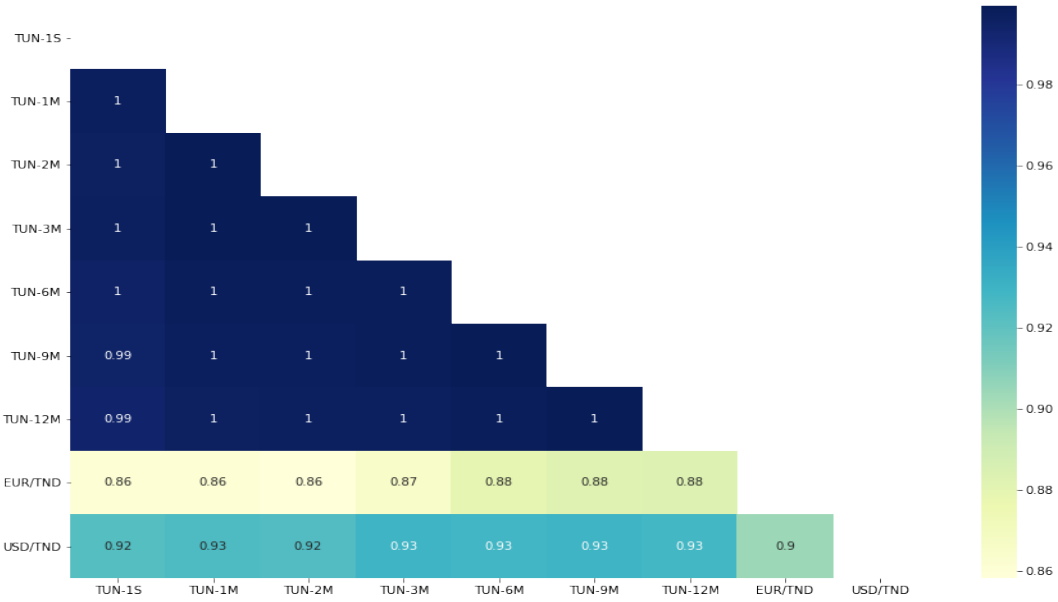
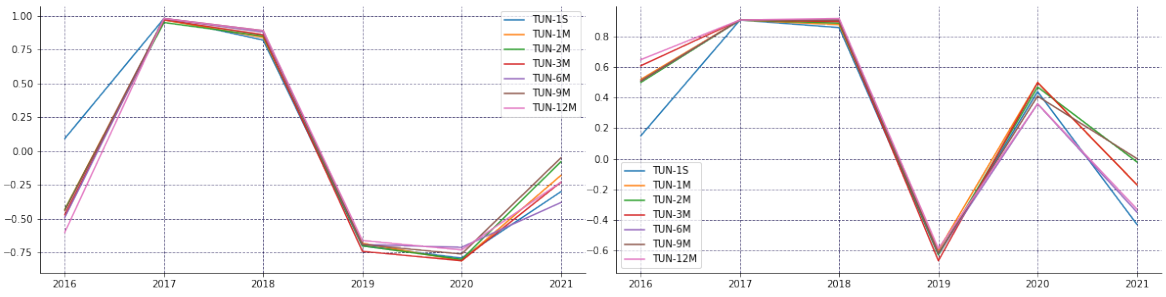


Figure 4: Correlation matrix over the 5 years

We could remark that there exists a correlation between TUNIBOR rates and EUR/TND and USD/TND. However, over the 5 years the correlation may or not be constant i.e. we may have years where it tends to increase and others where it decreases. In order to take a closer look on the dependency we consider the correlation year by year and observe its evolution.



(a) Correlation with EUR/TND evolution (b) Correlation with USD/TND evolution

Figure 5: Evolution of the correlation with foreign currencies

The dependency of the *TUNIBOR* on EUR/TND and USD/TND fluctuates over the

[6]We are not considering TUN-2S rates as it has missing values.
[7]We will explore the correlations of TUN-2S later.

years. It has reached values close to 1 in 2017. Now we need to test the significance of this correlation by performing statistical tests.

2.2.2 Statistical tests

Given the dataset, we will perform for each maturity of the *TUNIBOR* rates the following statistical test and set $\alpha = 0.05$

$\boldsymbol{H_0}$: $\rho = 0$ (no correlation)

$\boldsymbol{H_1}$: $\rho \neq 0$ (correlation exists)

where ρ is *Pearson*'s correlation coefficient.
The p-values are given in the following table:

Variable	p-value (EUR/TND)	p-value (USD/TND)
TUN-1S	0.0	0.0
TUN-1M	0.0	0.0
TUN-2M	0.0	0.0
TUN-3M	0.0	0.0
TUN-6M	0.0	0.0
TUN-9M	0.0	0.0
TUN-12M	0.0	0.0

Table 1: p-values

All p-values are less than 0.05 which indicates strong evidence against the null hypothesis, as there is less than a 5% probability the null is correct. Therefore, we reject the null hypothesis, and accept the alternative hypothesis which means that **the correlations are significant**.

3 Computational Experiments

Remark 3 *To accurately judge the performance of the different models that we will be using and the feature that we constructed, we will use the Root Mean Squared Error metric referred as RMSE*

In order to test the models on unseen data, we will use *Cross-Validation*. We will split the dataset into 5 Folds and perform the *training-testing-validation*.

3.1 Machine Learing models

Remark 4 *Hyperparameters tuning is performed by the Randomized Search*

Model	MAE	MSE	RMSE	R^2	Training Time (sec)
Huber Regressor	0.0327	0.0016	0.0396	0.9905	0.0267
Linear Regression	0.0478	0.0048	0.0591	0.9055	0.9200
Least Angle Regression	0.0478	0.0048	0.0591	0.9055	0.0133
Orthogonal Matching Pursuit	0.0478	0.0048	0.0591	0.9055	0.0167
Bayesian Ridge	0.0481	0.0048	0.0594	0.9053	0.0167
Passive Aggressive Regressor	0.0764	0.0091	0.0890	-0.5086	0.0167
Ridge Regression	0.1344	0.0474	0.1708	0.3657	0.0133
Extra Trees Regressor	0.2592	0.1609	0.3398	-0.5921	0.4567
Decision Tree Regressor	0.2671	0.1624	0.3484	-0.9563	0.0167
Gradient Boosting Regressor	0.2666	0.1633	0.3494	-0.9680	0.0467
Random Forest Regressor	0.2695	0.1659	0.3528	-1.0555	0.5267
Light Gradient Boosting Machine	0.2703	0.1684	0.3557	-0.9927	0.2400
K Neighbors Regressor	0.2736	0.1679	0.3588	-1.3063	0.0833
AdaBoost Regressor	0.2851	0.1694	0.3693	-2.1036	0.0400
Lasso Regression	0.6829	0.6205	0.7509	-66.7622	0.0200
Elastic Net	0.6829	0.6205	0.7509	-66.7622	0.0167
Lasso Least Angle Regression	0.6829	0.6205	0.7509	-66.7622	0.0167

Table 2: Different Machine Learning methods

3.2 Time series models

3.2.1 FBprophet

Criteria	Fold N°1	Fold N°2	Fold N°3	Fold N°4	Fold N°5
RMSE	1.23	1.23	1.21	1.25	1.28
Std Deviation	0.03	0.02	0.02	0.01	0.02
Normalized RMSE (%)	4516	6287	7534	8507	5727

Table 3: FBprophet models

3.2.2 SARIMAX

As we have observed no seasonnality in the time series, we will not consider the seasonal part in the models and we will choose the AIC metric to evaluate and choose the best model.
Computational experiments gave that the best model is *ARIMA(5,0,0)(0,0,0)[0] intercept*
Below you can find the table for the best parameters of the model chosen

	coefficient	Standard error	z	$\mathbf{P} > \|z\|$	[0.025	0.975]
intercept	0.0023	0.006	0.358	0.720	-0.010	0.015
drift	-6.351 10^{-6}	7.32 10^{-6}	-0.867	0.386	-2.07 10^{-5}	8 10^{-6}
$X^{(3)}$	1.0010	0.009	116.621	0.000	0.984	1.018
Y_{t-1}	0.6947	0.029	24.046	0.000	0.638	0.751
Y_{t-2}	0.0568	0.033	1.717	0.086	-0.008	0.122
Y_{t-3}	0.0370	0.054	0.680	0.497	-0.070	0.144
Y_{t-4}	0.0547	0.057	0.961	0.337	-0.057	0.166
Y_{t-5}	0.0592	0.039	1.501	0.133	-0.018	0.136
Sigma	0.0006	1.6 10^{-5}	38.827	0.000	0.001	0.001

Table 4: Sarimax Results

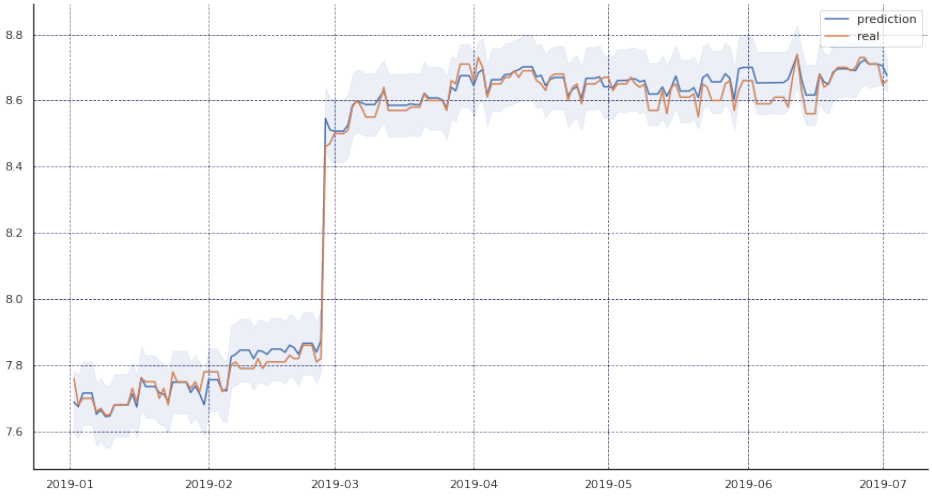


Figure 6: SARIMAX test

Figure 7: Final results

4 Conclusion

In this article, we tried to study the tunisian interbank market by modelling its interest rate and exploring its different dependecies. It turns out that the *TUNIBOR* is highly dependent on external factors namely the spot EUR/TND and USD/TND. This can explain the sudden fluctuations of the rates in the years (the sudden increase of 2017 for example). However, the authors claim that their explanation is only based on data and have studied no political factors. For further explanation, we may consider the political situation of the country and the different policies applied by the *Banque Centrale de Tunisie*. A more de-

tailed work can also include the role of the intervention of the *International Monetary Fund* and its different suggested policies, on the evolution of the interbank interest rates. Hence, a *Sentiment Analysis* will be needed nevertheless the lack of data is the factor influencing the most the research in this field.
This article proposed a method to collect the TUNIBOR dataset based on web scrapping Moreover, it provided a solution for the missing values of TUNIBOR rates. The authors constructed a new feature based on a simple interpolation between the the rates for maturities 1W and 1M.This new feature performed better than any other feature in the *TUNIBOR* dataset scrapped. Moreover, the statistical tests have proved the effectivness of this method. The best model used for the prediction was *ARIMA(5,0,0)(0,0,0)[0] intercept* based on the computational expirements that we did. We based our choice on the *AIC* criterion that we tried to minimize in order to obtain the optimal parameters for the problem given.

Remark

This article is an express version and another detailed article that provide further details to model the *TUNIBOR* using stochastic and machine learning will be published by authors.

Conflict of interest

The authors declare that they have no conflict of interest.

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