The Capital Markets Research Based on the Financial Quantitative Models,

Ciprian ALEXANDRU,
Nicoleta CARAGEA

Ciprian ALEXANDRU, Ph.D., associate professor, Ecological University of Bucharest - Faculty of Economics

Nicoleta CARAGEA, Ph.D., associate professor, Ecological University of Bucharest - Faculty of Economics

Abstract

In last period of time, progress in statistics has been marked by the increasing availability of software, such as the most known and open source R system. This has the potential to continue the transformation from a set of techniques used and developed by statisticians and computer scientists to an essential system of analysis tools for a much larger community. This paper aims to expose a small part of the capability of R to use mix-and-match models and quantitative modelling in order to build an alternative way to analyze capital markets based on a scientific scope beyond commercial purposes. For those that wish to use R for making Trading decisions, this paper is a short introduction which one can pursue in order to make trade on capital market using different response variables, signal thresholds, technical indicators and classifiers. Applying testing methods should be used to assess the performance of each model which the trading strategy is based on. The paper also provides a description of various packages in R that includes all necessary functionality for generating signals, extracting precision/recall metrics of generated models, performing estimates and evaluating trading strategies.

Keywords: financial modeling, R, quantmod, capital market, trading models

JEL Classification: C13, C15, C18, C53, C58, C87.

Introduction

The R software is increasingly accepted by so-called ‘quants’ as the basic infrastructure for financial applications. Forecast the financial asset prices has become a challenge in the more unpredictable and volatile world. The use of software have become very extensive in the financial field, most of the econometric models focuses on time series generated on the capital market.

A large area of new and improved software packages has facilitated the implementation burden for many statistical analysis methods. R itself may not be very friendly, but on the other hand, the econometrics is the most friendly science field? To answer at this question, we should take into account a famous quote from the R community by Greg Snow which describes the correct approach to R: "R is a four wheels drive SUV (though environmentally friendly) with a bike on the back, a kayak on top, good walking and running shoes in the passenger seat, and mountain climbing and spelunking gear in the back".

With the argument of growing recognition of the statistical computational methods using R as a powerful tool with important practical applications across a number of research areas, this statistical application development environment merges many forms of innovation, even if initially it belongs, as intrinsic value, of innovation itself by introducing a new concept analysis tools market data.

In this study, the authors expose a small part of the capability of R to use econometric models and cutting-edge methods in statistics and quantitative modelling in order to build an alternative way to analyse capital market in Romania based on a scientific scope beyond commercial purposes. For those that wish to use R for making Trading decisions, this paper is a short introduction which one can pursue in order to make trade on capital market using different response variables, signal thresholds, technical indicators and classifiers. This paper aims to present an overview of what is going on in modern finance and how this can be rapidly implemented in a general computational framework like R. The choice of the R in order to analyse the capital market data and its signals is motivated both by the fact that the authors of this paper are some of the promoters of the R Project in Romania but also because R, being open source, is free and transparent ensuring that it is always possible to see how numerical results are obtained without having the barriers of by a 'black-box' of a commercial product.

In the Romanian context, the quantitative modelling of capital market is available only for clients of trading brokers because the time series data are collected for the commercial purpose; in that circumstance, the statistical computing tools meet the inertia to change.

1. Literature review

There are many scientific publications on the fields of financial and capital market. Some of them consider only mathematical aspects of the matter at different level of complexity. Other books that mix theoretical results and software applications are usually based on copyright protected software. These publications touch upon the problem of model calibration only incidentally and in most cases the focus is on discrete time models mainly (ARCH, GARCH, etc.) with notable exceptions. Modern mathematical finance originated from the doctoral thesis of Bachelier (1900, pp. 21-86), but was formally proposed in a complete financial perspective by Black and Scholes and Merton (1975, pp. 637–654). In the last decade, there are more numerically oriented publications and more oriented books to the statistical analysis of financial times series are Carmona (2004), Tsay (2005) and Ruppert (2006), Bliznyuk and Shoemaker (2011).

In terms of software, the finance issues have traditionally been one of the two key users of the S language, and this constituency has moved from S+ to R. In recent years, R has grown tremendously both in terms of capabilities and users, being also increasing use in Finance field. Hence, R provides an excellent platform for academic research and teaching - as well as investment research and trading. R is used for statistical analysis, data manipulation, visualization and exciting applications in various fields like: statistics, economy, financial, business, genetics, engineering, biology and many more.

Currently fighting with the three giants of the statistical computing – SAS, SPSS and Stata, R is in a continuous release and upgrade of component-based software. Some experts [12] have already forecasted that year 2015 will be the beginning of the end for SAS and SPSS. This continuous process of evolving and improving raised better alternatives to the R base installation: RStudio, Deducer, Revolution Analytics, Red-R, JGR (Java GUI for R), SciViews-R. These GUIs (Graphical User Interfaces) are really user-friendly. The capabilities of R are extended through packages, user-created add-on programs, which allow specialized statistical techniques, reporting tools, data-mining techniques etc.

One of its big advantages of R is the linkage with the way statisticians think and work (e.g.: keeping the track of missing values). The wide area of use - statistics, mapping, finance, forecasting, social networking, computational biology and many more – makes R a common language for all the researchers and data analysts. The most recently used R packages for modelling the quantitative data on capital market was started to develop in 2008 and upgraded in 2013 (Ryan). Besides these packages, a very wide variety of functions suitable for empirical work in Finance is provided by both the basic R system (and its set of recommended core packages), and a number of other packages on the Comprehensive R Archive Network (CRAN).

Although there are many books on finance across the world, being a very new statistical tool to explore quantitative data on capital market, few deal with the statistical aspects of modern data analysis as applied to financial problems. This paper is the first step in filling this gap by addressing some of the most challenging issues facing any financial analysis.

2. Overview of quantitative financial econometric models

In quantitative finance, financial modelling entails the development of a sophisticated mathematical models that deal with analyse and forecast asset prices, market movements, portfolio returns and the like. These problems are often stochastic and continuous in nature, and models thus require complex algorithms, entailing computer simulation and/or advanced numerical methods, such as numerical differential equations, numerical linear algebra, dynamic programming. This section of the paper provides a general but comprehensive overview of the most popular econometric model and modelling techniques among academics and practitioners.

In the table 1 there are briefly introduced the most common known econometric models with application on time series analysis generated by capital market. The usual notations given in the formulas included into the table below are the followings: X_t – the value of the variable X at the moment t (e.g. short term rate), B_t – price at the moment t and alpha, beta, gamma, sigma– parameters/functions of the various models.

Table 1. The family of econometric models used on capital market analysis

Reference	Model
Models based on one-factor time-invariant processes	
Merton (1973)	$dX_t = \alpha dt + \sigma dB_t$
Vasicek (1977)	$dX_t = (\alpha + \beta X_t)dt + \sigma dB_t$
Cox, Ingersoll, Ross (1985b)	$dX_t = (\alpha + \beta X_t)dt + \sigma \sqrt{X_t} dB_t$
Models based on one-factor time-varying (fitted) processes	
Hull, White (1990)	$dX_t = (\alpha_t + \beta_t X_t)dt + \sigma_t X_t^{\gamma} dB_t$
Vasicek (1977) in the framework of Hull, White (1990)	$dX_t = (\alpha_t + X_t)dt + \sigma dB_t$
Lognormal models	
Black, Derman, Toy’s (1987, 1990)	$d\ln X_t = (\alpha_t + \beta \ln X_t)dt + \sigma dB_t$

Reference	Model
Black, Karasinski (1991)	$d\ln X_t = (\alpha_t + \beta_t \ln X_t)dt + \sigma_t dB_t$
Other single factor models	
Dothan (1978)	$dX_t = \alpha X_t dB_t$
Brennan, Schwarts (1980)	$dX_t = (\alpha + \beta X_t)dt + \sigma X_t dB_t$
Rendleman, Bartter (1980)	$dX_t = \alpha X_t dt + \sigma X_t dB_t$
Cox, Ingersoll, Ross (1980)	$dX_t = \sigma X_t^{3/2} dB_t$
Extensions to a multi-dimensional space models	
Langetieg (1980)	$dx_t = \alpha_i dt + \sigma_i dB_t$ where $X_t = \sum_{i=1}^{n} x_{it}$
Chan (1992)	$dX_t = (\alpha + \beta X_t)dt + \sigma X_t^{\gamma} dB_t$
Extensions to an infinite dimensional space models	
Ho, Lee (1986) – lattice model, continuous time limit model	
Heath, Jarrow, Morton (1992) extended model of Ho, Lee (1986)	
Goldstein (1997), Kennedy (1997) extended model of Heath, Jarrow, Morton (1992)	

Despite the fact that over time many econometric models have been developed in the financial and capital markets, relatively little work has been done to investigate how these models have comparable results in terms of ability to capture the profile of investors.

3. Modelling financial data with R

This paper aims to supplies for academic research area an accessible approach to financial econometric models and their applications to real-world empirical research. Econometric models can be used to predict values for next period of time. For that, many model systems in R use the same function, conveniently called predict. Predict is a generic function for predictions from the results of various model fitting functions. The function invokes particular methods which depend on the class of the first argument. Most prediction methods which are similar to those for linear models have an argument newdata specifying the first place to look for explanatory variables to be used for prediction. Some considerable attempts are made to match up the columns in newdata to those used for fitting, for example that they are of comparable types and that any factors have the same level set in the same order. Building a quantmod model with a given specified fitting method currently uses some function as the followings: lm, glm, loess, step, ppr, rpart, tree, randomForest, mars, polymars, lars, rq, lqs, rlm, svm, and nnet. Additional methods wrappers can be created to allow for modelling using custom functions. The only requirements are for a wrapper function to be constructed taking parameters quantmod, training.data. The function return the fitted model object and have a predict method available.

3.1. Data source

Extraction of financial time series from available Internet sources is a highly discussed topic lately, both in academia and in the specific brokers. For this there are at least two solutions. The most common are commercial solutions, but have both financial and technical barriers. Financial barriers are taxes connecting to databases or even the cost of a software environment that provides access to such databases. Technical barriers consist of dependency that we have from the software provided by the broker or the entity through which we access to these data sets. In recent years more and more available open access database and access them are designed for a variety of software environments. In this paper we have chosen to present some packages available in R, and the most used are quantmod and Quandl (Table 2). The authors of the present study did the computation of data, but the ensuring the quality and correctness of statistical or scientific software constitutes the responsibilities of scientific software developers and scientists who provide the codes to solve a specific computational task.

Table 2. Source of financial data accessible from R

Source	R package
Yahoo, FRED, Oanda, Google	Quantmod
Quandl	Quandl
TrueFX	TFX
Bloomberg	Rbbg
Interactive Broker	IBrokers
Datastream	rdatastream
Penn World Table	pwt
Yahoo, FRED, Oanda	fImport
ThinkNum	Thinknum
DataMarket	rdatamarket

Source: The R Trader, "Financial Data Accessible from R – part IV", December 2013, [Online], Available: http://www.r-bloggers.com/financial-data-accessible-from-r-part-iv/ [Accessed Jan. 15, 2014]

The package quantmod has capability of downloading stock and index prices from Yahoo Finance and Google Finance and contains plotting and charting functionality. The Quandl package is a bit different in that it is tied in with the Quandl website, a source of financial data itself, as well as a portal to economic and social science data (Ryan, 2013). In our analysis we used version 3.0.2. R software with different packages explained adequately before running code.

3.2. Quantmod package

The quantmod package is a Quantitative Financial Modelling & Trading Framework for R, designed like an environment to assist the quantitative trader in the development, testing, and deployment of statistically based trading models. The quantmod has been created to have functions which could easily use to replicate in R data modelling, so that we could access that functionality using a function with defaults and naming consistent with common usage in the finance literature.

As with any other R package, one must install the quantmod package in the usual way. The installation of the xts package for time series data is presented in the Annex 1.a.

The traders are quite familiar with the finance sites on Yahoo and Google as sources for tracking stock, mutual fund, and exchange traded fund (ETF) prices and returns. With quantmod, we can easily load this data into R by specifying the same ticker symbol that is used in these two web sources. Also, an important data series provider is Oanda.com trader, especial for Romanian users. The variable used is RONEUR quotations with daily frequency.

The data set is returned to the R session in the form of an xts object with the name RONEUR. To check the contents we use the head(.) and tail(.) R functions, Annex 1.b.

We can have access to any stock price history available on Yahoo or Google Finance, as another example; for that example we need to download Apple's stock price data series.

3.3. Using quantmod package to forecast buy/sell/hold signals for the RON/EUR Pair

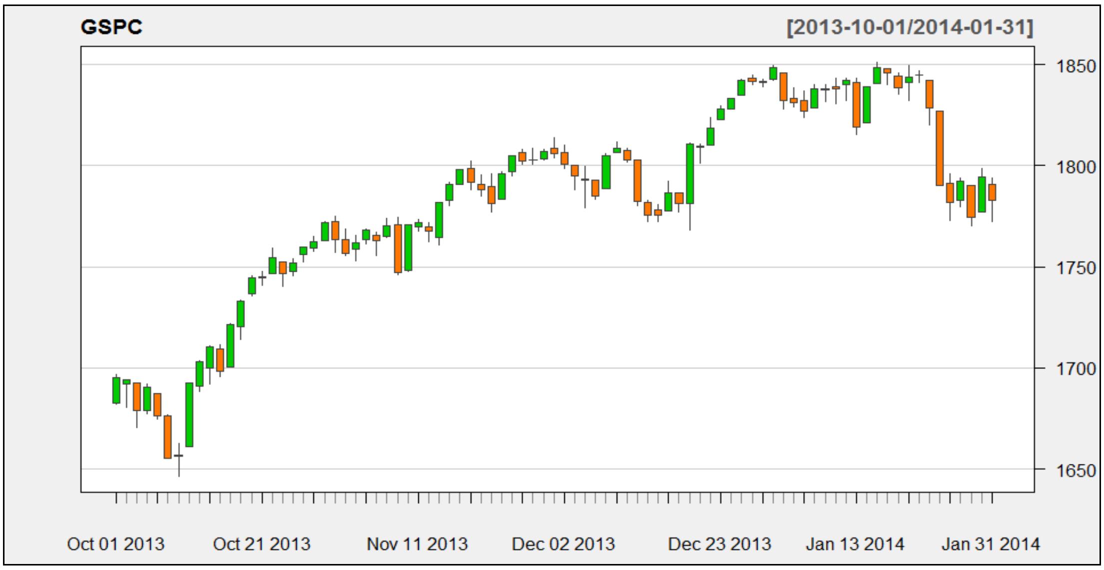
We also use the quantmod for uploading the index or stock prices and generate various types of graphics, see Annex 1.c.

The data set is returned to the R session in the form of an xts object with the name GSPC. To check the contents we use the head(.) and tail(.) R functions.

One of the most used chart is candle type and we are be able to plot the uploaded data with the function candleChart.

For data interval October 2013 - January 2014 the candleChart is presented below. The R codes used could be seen in the Annex 1.d.

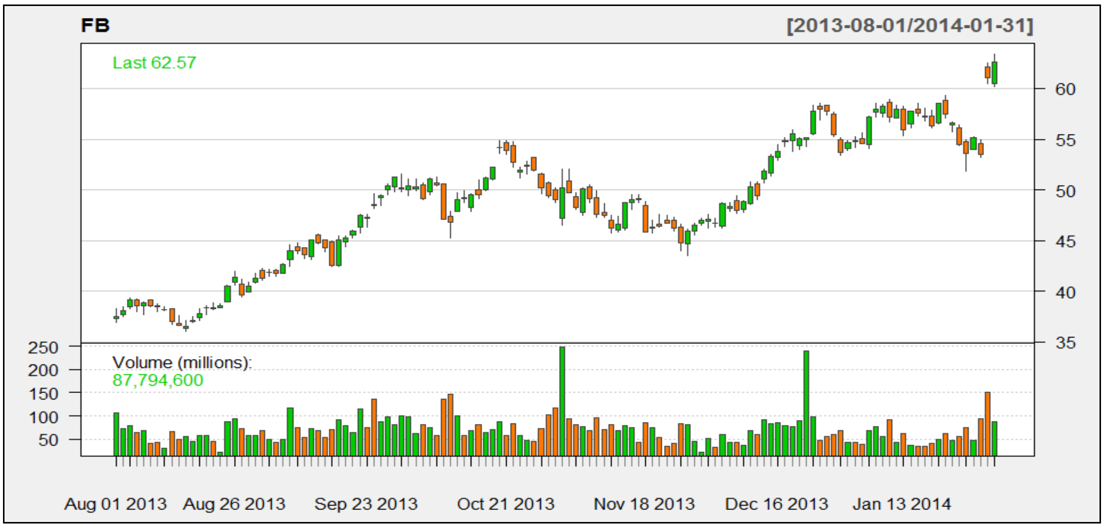
Fig. 1: Output plot for ^GSPC, Oct 2013- Jan 2014



Source: Author's calculation based on ^GSPC, Oct 2013- Jan 2014

Also, we can have on our chart the volume of transactions as an indicator of interest of investors on these financial instruments. For exemplifications we upload the stock history price for the newest big company listed on New York Exchange, Facebook Inc.The source code for ploting the serial data of Facebook is presented in Annex 1.e.

Fig. 2: Output plot for FB, Aug 2013- Jan 2014

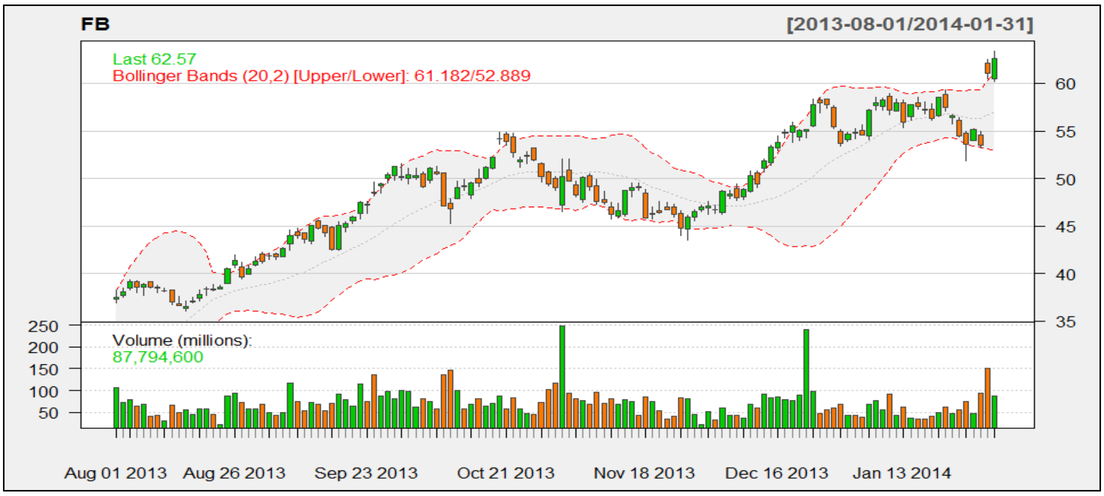


Source: Author's calculation based on FB, Aug 2013- Jan 2014

The Bollinger Bands provide a picture of prices intervals showing that the price are high at the upper band and low at the lower band

.

Fig. 3: Output plot for FB, with Bollinger Bands (20,2), Aug 2013- Jan 2014



Source: Author's calculation based on FB, with Bollinger Bands (20,2), Aug 2013- Jan 2014

The figure 3 illustrates the Bollinger Bands for price of Facebook, Inc. During August to January 2013.

Another way to analyze the volatility of prices of financial instruments is the technique named MACD (Moving Average Convergence/Divergence) created by Gerald Appel.

Fig. 4: Output plot for FB, with MACD (32,50,12), Aug 2013- Jan 2014

Source: Author's calculation based on FB, with MACD (32,50,12), Aug 2013- Jan 2014

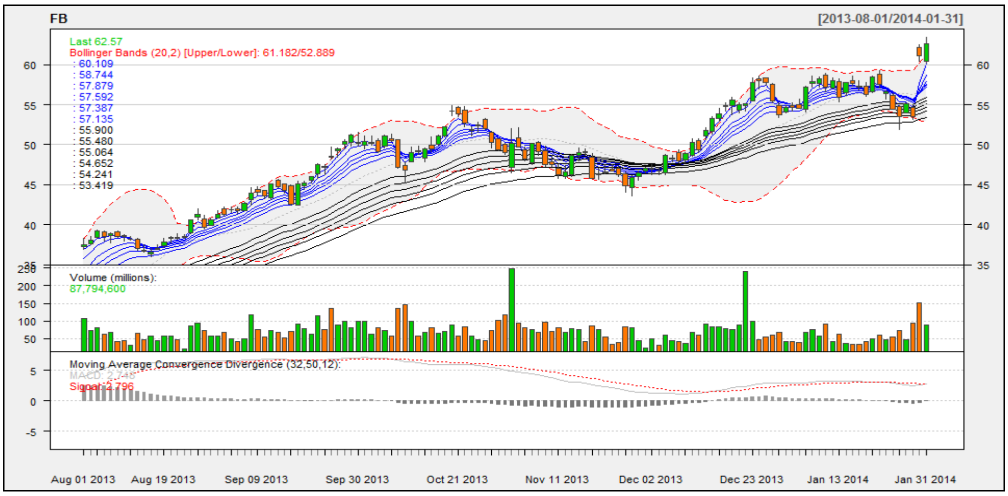
The indicator is generally used to show changes in the strength, direction, momentum, and duration of a trend in a stock's price.

The MACD is a set of three signals calculated from historical price data, most often the closing price. These three signal lines are: the MACD line, the signal line (or average line), and the difference (or divergence).

The period for the moving averages on which an MACD is based can vary. The parameters (in days) for MACD (faster, slower, signal) are in this case, MACD(32,50,12).

Like of above indicators, we create a new indicator named NC in order to spot fast and slow moving average in the same time (figure 5). The source code is shown in Annex 1.f.

Fig. 5: Output plot for FB, with NC function, Aug 2013- Jan 2014



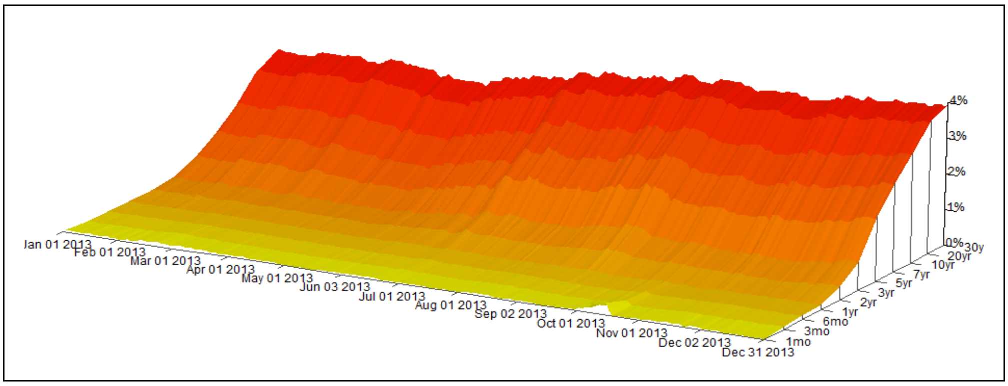
Source: Author's calculation based on FB, with NC, Aug 2013- Jan 2014

In the following part of the paper we analyse the yield curve of Treasury Constant Maturity Rate (DGS) showing the relation between the level of interest rate (or cost of borrowing) and the time to maturity, known as the "term", of the debt for a given borrower in a given currency.

The indicator Treasury Constant Maturity Rate has average values calculated for the following periods of time: months (DGS1MO; DGS3MO; DGS6MO) and years (DGS1; DGS2; DGS3; DGS5; DGS7; DGS10; DGS20; DGS30).

The frequency aggregation feature converts higher frequency data series into lower frequency data series (e.g. converts a monthly data series into an annual data series). The highest frequency data is daily, and the lowest frequency data is annual. There are three aggregation methods available - average, sum and end of period. The source code is shown in Annex 1.e.

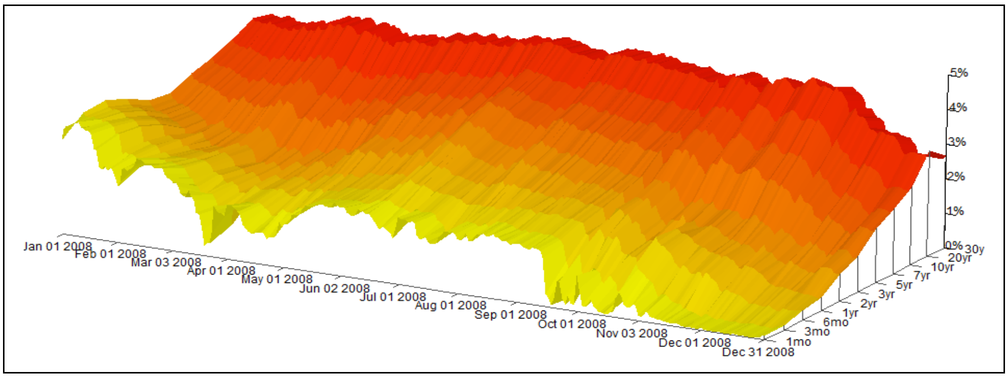
Fig. 6: Yield Curve 2013 – Daily



Source: Author's calculation based on DGS, 2013

In the figure 6 presented above it is illustrated the yield curve of Treasury Constant Maturity Rate (data published by FRED – Federal Reserve Economic Data). During 2013, it can be observed that the interest rate was very stable at monthly level (1 month, 3 months, 6 months), but having large variations at yearly level (from 3 years forward). For a better understaning of the dynamics of that indicator, we had a look back in what happend during the year 2008 (figure 7).

Fig. 7: Yield Curve 2008 – Daily



Source: Author's calculation based on DGS, 2013

In the period January – September 2008 the Treasury Constant Maturity Rate registered a large volatility because of the turbulences generated by the financial crisis. The rates published after September 19, 2008, reflect the direct or indirect effects of the new temporary programs of Federal Reserve – the central bank of the US and, accordingly, are not comparable for some purposes to rates published prior to that period.

4. Conclusions

Using a set of R packages developed at the level of international R community we applied econometric models in order to generate estimation for the behaviour of the capital markets. To achieve that objective, we focused on the quantmod R-package that is designed like an environment to assist the quantitative analysts in the development, testing, and deployment of statistically based trading models. Data used in this study were mostly extracted from financial time series from available Internet sources like Yahoo Finance and Google Finance, Quandl website and Federal Reserve Economic Data. Also, an important data series provider is Oanda, especially for Romanian capital market data.

On the other hand, this paper is based on research developed in the frame of the idea to promote the using R environment in academic fields in Romania. The overall aim of this research was to enable an informed answer to the question of how could be used R environment to generate a better understanding of the estimation of capital market.

In the next future we are planning to continue to have more contributions to implement the R environment in order to provide free and open source software for data analysis in various research and academic fields in Romania and among the individual persons, investors, financial institutions and commercial and non-commercial organizations (www.r-project.ro).

Acknowledgement

The present paper is part of the research project of Romanian R-userRs Team. The authors are thankful to their team for the great collaboration. Also, the authors of this paper would like to express the special thanks to Jeffrey Ryan, the author of the R package Quantitative Financial Modelling Framework. He is perhaps best known in the R community as one of the primary organizers of the annual R/Finance conference. In addition to his efforts on the R/Finance organizing committee, he has also developed a number of popular R packages for financial analysis. The statements and opinions expressed in this study represent authors own ideas.

References

Alexandru, A.C., 2013, *Modele de analiza a volatilității pieței de capital din Romania*, Editura Mustang, Bucharest, pp. 3-212.

Alexandru, A.C., 2013, Diversificarea instrumentelor specific pieței de capital utilizate pentru cresterea stabilitatii economic-financiare ca factor determinant al dezvoltarii sociale in spatial european, Editura Expert, Bucharest, pp. 7-220.

Alexandru, A.C., Caragea, N., Dobre, A.M., 2013, Innovative methods to analyze the stock market in Romania. Studying the volatility of the Romanian stock market with the ARCH and GARCH models using the “R” software, Theoretical and Applied Economics, Asociatia Generala a Economistilor din Romania - AGER, vol. 0(11(588)), pp. 83-100.

Bachelier, L., 1900, *Theorie de la speculation*, Analles Scientifique de l’Ecole Normale Superieure, pp. 21–86.

Black, F., Scholes, M., 1973, *The pricing of options and corporate liabilities*, Journal of Political Economy, pp. 637–654.

Bliznyuk, N., Ruppert, D., Shoemaker, C., 2011, Bayesian Inference Using Efficient Interpolation of Computationally Expensive Densities with Variable Parameter Costs, JCGS, 20, 636—655.

Brennan M., Schwartz E., 1982, *An Equilibrium model of Bond Pricing and a Test of Market Efficiency*, Journal of Financial and Quantitative Analysis, 17, 3, 301-29.
Carmona, R., 2004, Statistical Analysis of Financial Data in S-Plus, Springer, New York.
Carroll,R.J, Ruppert,D., Stefanski, L.A., Crainiceanu,C., 2006, *Measurement Error in Nonlinear Models: A Modern Perspective*, Second Edition, ISBN: 158-488-633-1.
Caragea, N., Alexandru, A.C., Dobre, A.M., 2012, *Bringing New Opportunities to Develop Statistical Software and Data Analysis Tools in Romania*, The Proceedings of the VIth International Conference on Globalization and Higher Education in Economics and Business Administration, ISBN: 978-973-703-766-4, pp. 450-456.
Di, C., Crainiceanu, C., Caffo, B. S. Punjabi, N., 2009, *Multilevel functional principal component analysis*, Ann. Appl. Statist. 3, 458–488.
Greven, S., Crainiceanu, C., Caffo, B., Reich, D., 2010, *Longitudinal functional principal component*. Electronic J. Statist. 4, 1022–1054.
Iacus, S., 2011, *Option Pricing and Estimation of Financial Models with R*, First Edition., Ltd. Published 2011 by John Wiley & Sons, Ltd. ISBN: 978-0-470-74584-7.
Kane, D., 2004, *[R-sig-finance] R vs. S-PLUS*, [Online], Available: https://stat.ethz.ch/ pipermail/ r-sig-finance/2004q4/000186.html/[Accesed Dec, 20, 2013].
Muenchen, R., 2012, *The Popularity of Data Analysis Software*, [Online], Available: http://r4stats.com/articles/popularity/[Accesed Dec, 20, 2013].
Rickert, J., December 2013, *Quantitative Finance Applications in R*,, [Online], Available: http://www.r-bloggers.com/quantitative-finance-applications-in-r/ [Accessed Jan. 15, 2014].
Ryan, J.R., Aug, 2013, *Quantitative Financial Modelling Framework*,, [Online], Available: http://cran.r-project.org/web/packages/quantmod/quantmod.pdf/[Accesed Dec, 20, 2013].
Ruppert, D., 2006, *Statistics and Finance: An Introduction*, Springer, New York.
Ruppert, D., 2011, Statistics and Data Analysis for Financial Engineering, Springer, New York.
Scherer, B., Martin, D., 2005, *Introduction to Modern Portfolio Optimization with NuOPT, S-Plus and S+Bayes*, Springer Science Media Business, Inc., New York.
Tsay, R. S., 2005, *Analysis of Financial Time Series. Second Edition*, John Wiley & Sons, Inc., Hoboken, N.J..
Xiao, Luo., Li, Y., Ruppert, D., 2013, *Fast Bivariate P-splines: the Sandwich Smoother*, JRSS-B, 75, 577-599.
* * * http://www.r-project.ro/
* * * http://lifeanalytics.blogspot.ro/2011/01/forex-trading-with-r-part-1.html
* * * FRED, Federal Reserve Economic Data, from the Federal Reserve Bank of St. Louis

Annexes

Annex 1.a. Instaling the R xts package

To install the package xts we run the following code:

```
> install.packages("quantmod")
```

Then, we load the package:

```
> library(quantmod)
```

Annex 1.b. Uploading and visualisation of RONEUR serial data from Oanda data proveder

```
> getSymbols("RONEUR", src="oanda")
[1] "RONEUR"
> head(RONEUR)
           RON.EUR
2012-09-14   0.2224
2012-09-15   0.2222
2012-09-16   0.2224
2012-09-17   0.2224
2012-09-18   0.2226
2012-09-19   0.2224
> tail(RONEUR)
           RON.EUR
2014-01-10   0.2215
2014-01-11   0.2204
2014-01-12   0.2202
2014-01-13   0.2202
2014-01-14   0.2208
2014-01-15   0.2211

> # use single quotes and specify data source:
> getSymbols("AAPL", src = "yahoo")  # but src = "yahoo" is the default

> # Visualizing data with head(.) and tail(.) R functions:
> head(AAPL)
            Open   High    Low  Close    Volume Adjusted
 2007-01-03 86.29  86.58  81.90  83.80  44225700    81.03
 2007-01-04 84.05  85.95  83.82  85.66  30259300    82.83
 2007-01-05 85.77  86.20  84.40  85.05  29812200    82.24
 2007-01-08 85.96  86.53  85.28  85.47  28468100    82.64
 2007-01-09 86.45  92.98  85.15  92.57 119617800    89.51
 2007-01-10 94.75  97.80  93.45  97.00 105460000    93.79
> tail(AAPL)
             Open   High    Low  Close   Volume Adjusted
 2014-01-08 538.81 545.56 538.69 543.46  9233200   543.46
 2014-01-09 546.80 546.86 535.35 536.52  9969600   536.52
 2014-01-10 539.83 540.80 531.11 532.94 10892000   532.94
 2014-01-13 529.91 542.50 529.88 535.73 13517600   535.73
 2014-01-14 538.22 546.73 537.66 546.39 11877200   546.39
 2014-01-15 553.52 560.20 551.66 557.36 13987100   557.36
# We can then extract the closing prices to an R vector:
# coerce from an xts object to a standard numerical R vector:
> AAPL_vector <- as.vector(AAPL[, "AAPL.Close"])
```

Annex 1.c. Uploading and visualisation of GSPC Index

```
> # uploading the data for GSPC index
> getSymbols("^GSPC")
[1] "GSPC"
> head(GSPC)
```

```
                Open    High     Low   Close     Volume Adjusted
2007-01-03  1418.03  1429.42  1407.86  1416.60  3429160000  1416.60
2007-01-04  1416.60  1421.84  1408.43  1418.34  3004460000  1418.34
2007-01-05  1418.34  1418.34  1405.75  1409.71  2919400000  1409.71
2007-01-08  1409.26  1414.98  1403.97  1412.84  2763340000  1412.84
2007-01-09  1412.84  1415.61  1405.42  1412.11  3038380000  1412.11
2007-01-10  1408.70  1415.99  1405.32  1414.85  2764660000  1414.85
> tail(GSPC)
                Open    High     Low   Close     Volume Adjusted
2014-01-24  1826.96  1826.96  1790.29  1790.29  4618450000  1790.29
2014-01-27  1791.03  1795.98  1772.88  1781.56  4045200000  1781.56
2014-01-28  1783.00  1793.87  1779.49  1792.50  3437830000  1792.50
2014-01-29  1790.15  1790.15  1770.45  1774.20  3964020000  1774.20
2014-01-30  1777.17  1798.77  1777.17  1794.19  3547510000  1794.19
2014-01-31  1790.88  1793.88  1772.26  1782.59  4059690000  1782.59
```

Annex 1.d. Chart of the GSPC Index

```
> # plot the uploaded data for interval Oct 2013 - Jan 2014
> candleChart(GSPC, subset='201310/', theme='white', TA=NULL)
```

Annex 1.e. Plot the serial data of Facebook

```
> # upload data for Facebook, FB-symbol
> getSymbols("FB")
> # plot the uploaded data for interval Aug 2013 - Jan 2014
> chartSeries(FB, subset='201308/', theme='white')
> # adding Bollinger Bands for default 20,2 parameters
> addBBands()
> # adding MACD for default 32,50,12 parameters
> addMACD(32,50,12)
```

Annex 1.f. Output plot for FB, with NC function

```
> # create a function that returns our myMMA
> myMMA <- function(x) {
>  +  fastMA <- c(3,5,8,10,12,15)
>  +  slowMA <- c(30,35,40,45,50,60)
>  +  x <- sapply(c(fastMA,slowMA),
>  +  function(xx) EMA(x,xx))
>  +  return(x)
>  +  }
> # create an addNC function with newTA
> addNC <- newTA(FUN=myMMA,
>  +  preFUN=Cl,
>  +  col=c(rep(3,6),
>  +  rep("#333333",6)),
>  +  legend="myMMA")
> class(addNC)
> # adding NC function for specific parameters
> addNC(on=-1, col=c(rep("blue",6), rep("black",6)))
```

Annex 1.e. Illustration of the yield curve of Treasury Constant Maturity Rate

```
> getSymbols("DGS1MO;DGS3MO;DGS6MO;DGS1;DGS2;DGS3;
> + DGS5;DGS7;DGS10;DGS20;DGS30",
> + src="FRED")
> TR <- merge(DGS1MO,DGS3MO,DGS6MO,DGS1,DGS2,DGS3,DGS5,
> + DGS7,DGS10,DGS20,DGS30, all=FALSE)
colnames(TR) <- c("1mo","3mo","6mo","1yr","2yr","3yr","5yr",
> + "7yr","10yr","20yr","30yr")
> TR <- na.locf(TR)
> chartSeries3d0(TR["2013"])
```