# Statistics for economics and finance

## I Modulo: Prof. Luca Fraone; II Modulo: Prof. Marco Fattore

*I Modulo: Prof. Luca Fraone*

***COURSE AIMS AND INTENDED LEARNING OUTCOMES***

The course aims at introducing statistical techniques and models widely used in Finance in general, but with particular focus on option pricing. In the course different types of options will be introduced and, for each of these, the specific complexities that modelling such derivatives entail will be analysed.

Part of the course is dedicated to the introduction of stochastic processes which can be used to model underlying assets and consequently to the problem of calibration of such stochastic models from financial data using estimation methods such as maximum likelihood estimation and method of moments. Various tests of fitting to verify the goodness of fit of each stochastic process will be carried out.

The course will then provide an in depth overview of risk neutralization methods to pass from the statistical parameters to the risk-neutral ones and the application of Monte Carlo simulations to price options (both European and American). The last part of the course is dedicated to the introduction of Multi-Asset options which, being based on more than one underlying asset, generate the further issue of modelling the dependence structure between such underlying assets.

The presentation of each topic will be accompanied by a demonstration on how to compute each problem through the use of the R statistical environment.

By the end of the course students are expected to be able to understand the complexities that evaluating different derivatives entail and to comprehend which model grants the most accurate results, based on the specific characteristics of the financial product that they have to evaluate. Students are also expected to be able to use R to set the specific problems and to reach numerical results.

***COURSE CONTENT***

– Random number generation and variance reduction techniques.

– Calibration and estimation of financial models from the data using method of moments and maximum likelihood estimation.

– The main stochastic processes used to model stock prices in finance, such as the Geometric Brownian motion and Lévy processes.

– Black and Scholes formula, implied volatility and volatility smile.

– The problems arising if we assume normality of returns.

– Girsanov theorem and the risk neutral transformation (Esscher transform and mean correcting martingale).

– Introduction to stochastic calculus.

– Monte Carlo methods with applications to (European, American and Multi-Asset) option pricing.

– Fast Fourier transform method with applications to European option pricing under different stochastic processes.

– Longstaff-Schwartz method with applications to American option pricing.

– Greeks letters.

– Multi-Asset options: how to capture the dependence between the multiple underlying assets using the Ballotta-Bonfiglioli model.

– Introduction to liquidity.

The course is highly focused on the use of the R statistical environment.

***READING LIST***

Slides and laboratory handouts will be distributed during the course and I will refer to some textbooks. These are references that are supportive information but are not required to follow:

• Stefano M. Iacus (2008), Simulation and Inference for Stochastic Differential Equations with R Examples, Springer New York.

• Stefano M. Iacus (2011), Option Pricing and Estimation of Financial Models with R, Wiley & Sons, Chichester.

• Wim Schoutens (2021), Lévy Processes in Finance: Pricing Financial Derivatives, Wiley Series in Probability and Statistics.

***TEACHING METHOD***

Lectures with computer labs and classes.

***ASSESSMENT METHOD AND CRITERIA***

Written exam: it will consist of a series of questions requiring straight to the point type of answers with limited number of rows available.

***NOTES AND PREREQUISITES***

Students are expected to have impeccable knowledge of basic statistics, such as discrete and continuous random variables, the main families of distributions and properties of distributions (density functions, probability mass functions, cumulative distribution functions, moment generation functions, characteristic functions etc.). They are expected to have a basic understanding of parameters’ estimation methods, such as method of moments, maximum likelihood and least squares method. Basic knowledge of derivatives pricing (such as the payoff of the most common options, the Geometric Brownian motion, Ito’s Lemma, Black & Scholes method and Monte Carlo simulations) is also required.

In case the medical emergency regarding the COVID-19 pandemic prevents us from meeting in class, virtual teaching will be made available and students will be informed in due course.

*Office hours*

To be arranged via email, they can be both online (on Microsoft Teams) or in person in my office (office 405, Lanzone building, 4th floor).

*II Modulo: Prof. Marco Fattore*

***COURSE AIMS AND INTENDED LEARNING OUTCOMES***

*Main goal of the course*: to give students a comprehensive knowledge of the main tools for economic time-series forecasting, using both classical inferential models and more recent deep learning algorithms. The course will cover both theoretical concepts and practical case studies.

***COURSE CONTENT***

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| Detailed programme |
| Topic | Description |
| *Time series basics* | Definition of a time series; Stationary and non-stationary time series; Univariate and multivariate time series; White noise; Level, Trend, Stagionality and erratic components of a time series; Forecasting and decomposition of time series. |
| *ARMA models* | Autoregressive (AR), Moving Average (MA) and ARMA representations of stationary time-series; Specification and estimation of ARMA models; Forecasting AR, MA and ARMA models. |
| *ARIMA and SARIMA models* | Integrated time series and ARIMA representation; Seasonal time series (SARMA and SARIMA representations). Forecasting. |
| *Unobserved Component Models* | Random walks and Random walks with drift; Building an unobserved component model in ETS form; Estimation, decomposition and forecasting. |
| *Deep learning and time series* | Essentials of neural networks; the LSTM algorithm. |
| *Methods for financial time-series (hints)* | ARCH and GARCH models. |

***READING LIST***

1. J.D. Cryer, K. Chan, “Time Series Analysis, With Applications in R”, Springer.
2. [Rob J. Hyndman](http://robjhyndman.com/)**,** [Anne B. Koehler](http://www.fsb.muohio.edu/directory/koehleab)**,** [J. Keith Ord](https://gufaculty360.georgetown.edu/s/faculty-profile?netid=ordk)**,** [Ralph D. Snyder](https://research.monash.edu/en/persons/ralph-snyder) **“**Forecasting with Exponential Smoothing: the State Space Approach”, Springer.
3. [Ian Goodfellow](https://www.amazon.it/Ian-Goodfellow/e/B01MQGN8N0/ref%3Ddp_byline_cont_book_1), [Yoshu Bengio](https://www.amazon.it/Yoshua-Bengio/e/B00IWC47MU/ref%3Ddp_byline_cont_book_2), [Aaron Courville](https://www.amazon.it/Aaron-Courville/e/B01N8XGWRL/ref%3Ddp_byline_cont_book_3) “Deep Learning”, MIT Press.

***TEACHING METHOD***

Frontal lessons and practical sessions.

***ASSESSMENT METHOD AND CRITERIA***

Individual exam on the whole program.