

MATHEMATICS WITH FINANCIAL ENGINEERING, MASTER STUDY PROGRAMME, SECOND BOLOGNA CYCLE

COURSE DESCRIPTIONS

BASIC COURSES

Course name: **PROBABILITY II**

Number of ECTS credits: **6**

Content:

Outcomes, events, σ -algebras

- Sample spaces.
- σ -algebras of events, probability measures.
- Systems of events, Dynkin's lemma.
- Independence of events and systems of events.

Distributions as measures

- Distribution as push-forward of measure.
- Discreteness, density of distributions.
- Functions of random variables.
- Multivariate distributions, marginal distributions, independence.

Expected value

- Expected value as an abstract integral.
- Expectation as an integral with respect to distribution.
- Variances and covariances.

Conditional expectation

- Conditioning with respect to events and discrete random variables.
- Conditioning with respect to general random variables and σ -fields, existence.
- Properties of conditional expectation.
- Conditional distribution.
- Conditional monotone and dominated convergence theorems.

Transformation of random variables

- Generating functions.
- Characteristic functions, uniqueness theorem.

Convergence of random variables

- Types of convergence, relationships between types of convergence.
- Borel-Cantelli lemmas.
- Laws of large numbers.
- Convergence in distribution.
- Approximation of distributions.

Martingales

- Definitions and properties.
- Optional sampling theorem.
- Convergence of martingales.
- Maximal inequalities.

Course name: **FINANCIAL ENGINEERING PRACTICUM**

Number of ECTS credits: **6**

Content:

- Estimating stock prices using Brownian motion
- Estimating market beta
- Optimal portfolio weights
- Stock valuation (free cash flow method)

- Bond Duration
- Neural networks in finance
- Pricing futures contracts
- Futures arbitrage
- Option pricing
- Trading

Course name: **STATISTICAL PRACTICUM**

Number of ECTS credits: **6**

Content:

Overview of the basics in programming language R:

- Expressions and objects
- Functions and arguments
- Vectors and matrices
- Factors
- Data frames
- Importing data

Examples of application:

- Probability distributions
- Descriptive statistics
- Testing hypotheses
- Regression
- D-in-D Difference in difference
- Logistic regression
- Time series

Course name: **SEMINAR I**

Number of ECTS credits: **6**

Content:

The course envisions independent study of given chapters of articles on topics determined by the instructor. The students will submit the work in written form for evaluation and will present their reports in front of students.

Course name: **GAME THEORY**

Number of ECTS credits: **6**

Content:

- The problems of decision making in strategic situations.
- Basic concepts of game theory: players, actions, payoffs, two player matrix games.
- Games in normal form: dominated moves, best response, Nash equilibrium, mixed strategies, the existence of equilibrium, main examples.
- Games in normal form in practice: modeling human decision making.
- Dynamic games, games in extended form: strategies, Nash equilibrium, backwards induction, subgames, subgame perfect equilibrium, main examples.
- Repeated games: infinite repetition, finite repetition, the folk theorem.
- Dynamic games in practice: differences between theory and evidence about human decision-making.
- Decision-making without common knowledge: dynamic games with incomplete information, sequential equilibrium.
- Evolutionary game theory.

Course name: **FISCAL POLICY ANALYSIS**

Number of ECTS credits: **6**

Content:

- The role of government in assuring macroeconomic stability, efficient and equitable resource allocation and sustainable growth
- Fiscal accounts, fiscal aggregates and their interrelations
- Fiscal challenges and fiscal sustainability
- Debt tolerance and fiscal space
- Fiscal multipliers
- Fiscal projections
- Specificities of fiscal policy in the EU - the role of the cyclically-adjusted budget balance and the fiscal stance

Course name: **SELECTED TOPICS IN FINANCIAL MATHEMATICS**

Number of ECTS credits: **6**

Content:

Market models.

- The types of securities.
- Stochastic models of markets.
- The concept of strategy.

Asset management.

- The dimensions of risk.
- The optimal strategy for one period.
- Dynamic strategies.
- CAPM model.

Options.

- The types of options
- The principle of arbitrage.
- The protection and the basic theorem of valuating options.
- European and American options.
- Exotic options.
- Practical aspects of security.

Models of interest rates.

- The importance of stochastic modeling.
- Basic models of current interest rates.
- Options on interest rates.

Course name: **SEMINAR II**

Number of ECTS credits: **6**

Content:

The course envisions independent study of given chapters of articles on topics determined by the instructor. The students will submit the work in written form for evaluation and will present their reports in front of students. The student will present the topic of their master's thesis with emphasis on improving the communication of research results, preparation of presentations in Beamer with effective presentation including graphics, tables and possibly other media tools.

Course name: **MASTER'S THESIS**

Number of ECTS credits: **24**

Content:

A comprehensive treatment of the contents of the selected subject area of the programme and/or an interdisciplinary connection to other subject areas of the same programme, or even an interdisciplinary treatment of a subject theme.

Students choose a topic according to their interests and in accordance with the supervisor as well as the subject areas that a particular student wants to deal with in detail.

The thesis' length should comply with the Instructions for writing the Master thesis.

By writing the Master thesis students develop investigative methods: suitability issues, developing their work plan, setting goals and formulating hypotheses, searching for documentary and bibliographic resources, defining the structure of research, etc. and demonstrate their knowledge of and the ability to select and apply the most appropriate methodology.

ELECTIVE COURSES

(Read the short descriptions of all elective courses of the study programme. In the table Elective courses you will find the list of the elective courses which were offered in the last two years.)

Course name: **STATISTICS**

Number of ECTS credits: **6**

Content:

The course is focused on most important current research areas in mathematical statistics. Among other things, it may include the following topics:

Sufficient estimators

- Definition of sufficient estimator.
- Factorization theorem.

Optimality in estimation of parameters

- Unbiased estimators.
- The concept of optimum estimator.
- Cramér-Rao theorem.
- Optimum estimators.

Course name: **FINANCIAL MARKETS**

Number of ECTS credits: **6**

Content:

Introduction and basic concepts in financial markets

- Types of financial markets
- Types of financial instruments (bonds, stocks, derivatives)
- Types of financial investors (hedgers, speculators, arbitrageurs)

Interest rates

- Simple and continuous compounding
- Present and future value
- Term structure of interest rates and forward rates

Pricing financial instruments

- Bond hedging
- Stock options and the put-call parity

Trading strategies with options

Binomial tree

Wiener process and Ito's lemma

Black-Scholes-Merton model

Course name: **STOCHASTIC PROCESSES**

Number of ECTS credits: **6**

Content:

- Preliminaries from analysis, Stieltjes integral, function with bounded total variation.
- Martingales, optional sampling theorem, maximal inequalities, Dood's inequality.
- Brownian motion: construction of Brownian motion, properties of trajectories, Markov property, the reflection principle, martingales related to Brownian motion.
- Itô integral, Itô isometry, properties of integral. Itô formula, localiyation theorem, local martingales, quadratic variation, generalization to martingale integrands.

Course name: **ASSET PRICING**

Number of ECTS credits: **6**

Content:

Stochastic differential equations

- Formulation and definition of solutions.
- Existence and uniqueness of solutions.

Valuation through arbitrage

- Asset price models.
- Contingent claims.
- Hedging in continuous time.
- Girsanov theorem and change of measure.
- Martingale representation theorem.
- Valuation of options in the Black-Scholes model.
- Greeks.
- American options.

Term structure models

- Models for term structure.
- Valuation of term structure options.

Course name: **VALUATION OF INSURANCE PRODUCTS**

Number of ECTS credits: **6**

Content:

Modeling of risk

- Measures of risk.
- Models of life span, modeling of longevity.
- Models for interest rate risk.
- Agregate risk for short term contracts.
- Lundberg process.
- Models for asset prices.
- Reinsurance.
- Modeling of risk in non-life insurance.
- Reserving in non-life insurance.

Life insurance

- Life contracts.
- General terms.
- Pricing.
- Reserving.
- Models for surplus distribution.
- Risk management in life insurance.

Course name: **TIME SERIES**

Number of ECTS credits: **6**

Content:

- Introduction: examples of time series, modeling, transformations of time series.
- Stationary processes: definition, autocorrelation function, forecasting in stationary processes, ARMA models.
- ARMA models: autocorrelation function, parameter estimation, diagnostics, forecasting.
- Nonstationary and seasonal time series, SARIMA models, forecasting for nonstationary time series.
- Multivariate time series: stationarity, multivariate ARIMA models, estimation, forecasting.
- Introduction to ARCH and GARCH models.