Università degli Studi di L'Aquila - Dipartimento di Ingegneria e Scienze dell'Informazione e Matematica

Course catalogue

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Programme of Course "Modelli e Algoritmi per la Finanza Aziendale"

- Code: DT0320
- Type of course unit: Elective (Bachelor Degree in Computer Science curriculum General), Elective (Master Degree in Computer Science curriculum NEDAS), Elective (Master Degree in Computer Science curriculum SEAS)
- Level of course unit: Undergraduate Degrees, Postgraduate Degrees
- Semester: 1

Number of ects credits: (Master Degree in Computer Science) 6 (workload 150 hours), (Bachelor Degree in Computer Science) 6 (workload 150 hours)

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1	**Course objectives**	The students quantitative and programming capabilities are applied to corporate finance modelling. To be specific, the course will focus on capital budgeting models, i.e. the choice of industrial investment projects, in both a deterministic and a stochastic framework.
2	**Course content and learning outcomes (dublin descriptors)**	Topics of the module include: • Fixed income securities valuation under the assumption of certainty: interest rates risk sensitivity: (a) Macaulay duration (b) term structure of interest rates, spot, forward and short rates; (c) Fisher Weil duration. • Shares valutation under the assumption of certainty, dividend discount model: (a) Myron Gordon's dividend growth model; (b) Modigliani Miller 1961, growth model; (c) fundamental indexes and dividend discount models, cross sectionals and longitudinal evidences; • Capital Budgeting, choosing real investments in an industrial firmunder the assumption of certainty: (a) criteria: i. Payback Period, ii. Internal Rate of Return, iii. Net Present Value, iv. Profitability Index, v. Economic Value Added (as an extension of Modigliani Miller 1961); (b) methods: i. capital rationing, uni e multiperiod cases, linear programming applied to multiperiod cases, geometric approach and Excel Solver Tool application; ii. optimal harvesting, Faustmann problem individual and repeated cycles problems solutions. (c) comparative statics and dynamic optimization: Richard Bellman's Dynamic Programming in a deterministic frameworkl: i. continuous and discrete control variables ii. application to the choice and optimal dynamic management of investment project for renewable and exhaustible resources. • Introduction to derivative securities: options (a) payo ff diagrams (b) position diagrams (c) put call parity (d) composite positions: i. spread; ii. combination; iii. hedge. • An hands on introduction to stochastic processes most used in derivatives valuation modelling: (a) time series modelling: additive shocks, multiplicative shocks. i. MA(1), AR(1) representations ii. from sufficient statistics of a normal distribution to those of the corresponding log normal; (b) Wiener process as a limit case of a random walk (c) Ito process as a generalization of a Wiener process (d) Geometric Brownian Motion: i. univariate GBM; A. Ito's lemma application: log transform process parameters derivation, Arithmetic Brownian Motion B. Monte Carlo simulation of Pde solution and of its Euler approximation C. parameters empirical estimate; D. binomial approximation through moment matching conditions: Cox, Ross, Rubinstein 1979 E. Brownian Bridge, concept and Monte Carlo Simulation; ii. multivariate GBM with correlated Wiener Processes: A. construction and simulation of a multivariate GBM with correlated Wiener processes; B. bivariate case: analytic (Cholesky) transformation of two uncorrelated shocks into two correlated ones; C. general case: Cholesky decomposition of a correlogram; D. parametric Monte Carlo study of the estimates of correlation between two time series generated by correlated GBMs. E. Boyle, Evnine, Gibbs 1989, multivariate binomial model: bivariate case programmed in Aptech Gauss; (e) Ornstein Uhlenbeck: i. original version with arithmetic shocks; ii. Ito's lemma application: derivation of Schwartz 1997 version, geometric with spring effects on logarithms; iii. OU process parameters estimates; iv. Monte Carlo simulation of processes sub i. and ii. v. Binomial approximation Sick 1995 (f) volatility

estimate for univariate processes: i. inverting Black e Scholes 1973 and deriving a volatility surface ii. equally weighted estimates; iii. ARCH(m); iv. EWMA: exponentially weighted moving average; v. GARCH(1,1): A. volatility clustering detection; B. leverage e ffect detection; C. plain vanilla GARCH(1,1) D. GARCH(1,1) as a discrete time counterpart of an Ornstein Uhlenbeck process; E. I-GARCH vi. review of some models that accommodate volatility leverage: A. A-GARCH; B. E-GARCH; C. GRJ-GARCH; D. NL-GARCH; E. Smooth Transition GARCH; F. Markov Switching GARCH; vii. GARCH(1,1) estimation: A. MLE methods in general; B. MLE methods for GARCH(1,1) numerical examples on Excel: 3 parameters estimation; 2 parameters estimation variance targeting; MLE estimate of EWMA; tness tests: Box Pierce, Ljung Box, autocorrelogram viii. Use of GARCH() models to forecast volatility: A. GARCH volatility term structure; B. GARCH average volatility. ix. GARCH models and Options Pricing: A. local risk neutrality, Duan 1995; B. numerical example: Monte Carlo simulation of a GBM with stochastic volatility generated by a GARCH(1,1) (g) Variance covariance matrix estimation for multivariate processes: i. equally weighted estimates of covariances; ii. EWMA with no cross terms. iii. modelling of variance covariance matrix, review, with speci fication of the respective LL function: iv. direct: VEC GARCH, BEKK GARCH, v. indirect: CCC GARCH, DCC GARCH.
- Martingale Pricing for derivative securities: (a) american options valuation: drift change and backward induction in the following models i. Cox, Ross, Rubinstein 1979 ii. Sick 1995 iii. Boyle, Evnine, Gibbs 1989 (b) european options valuation, in addiction to the preceding sub (a): i. derivation of Black e Scholes 1973 as a limit case for Cox, Ross, Rubinstein 1979; ii. Stultz 1982, Johnson 1987 rainbow options valuation, bivariate case programming in Aptech Gauss iii. Monte Carlo simulations for both univariate and multivariate cases;
- Real Options (a) parallelism with decision tree analysis (b) martingale pricing viability for an irregular uncertainty resolution, multiperiod securities markets di Harrison e Kreps 1979 (c) differences and analogies between real and financial options d) most frequent real options, Mickey mouse examples i. option to wait; ii. option to expand/contract iii. option to mothball/restart iv. option to switch use v. option to abandon vi. option to default vii. operating default viii. fi nancial default asset substitution moral hazard underinvestment moral hazard put call parity interpretation of bond holders equity holders wealth transfer (e) different approaches to real options valuations: (f) the general real options model of Kulatilaka-Trigeorgis: i. mickey mouse example ii. taxonomy of operating modes of an industrial plant Markov Chain states analogies; iii. binomial lattice Cox, Ross, Rubinstein 1979, Mickey Mouse example.
- Least Squares Monte Carlo, Longsta ff, Schwartz 2001 RFS: (a) general introduction to the model and comparison with Tsitsiklis Van Roy model; (b) american/bermudean put option valuation, example of Moreno Navas 2003 MF: (c) LSMC for the Kulatilaka Trigeorgis general real options model, Gamba 2011 JMF

On successful completion of this module, the student should :

- have a thorough and deep knowledge of capital budgeting models in both deterministic and stochastic frameworks, real options. In particular, he/she must be able to model any payoff of a simple and multiple underlying derivative. He/she must be able to provide a discrete time approximation of stochastic processes dealt with at lesson both in view of a lattice approximation and a Monte Carlo simulation. Finally, the student should be able to price any financial or real option within the stochastic processes and pricing algorithms provided in the course. In any case, she/he must be knowledgeable with the general themes of martingale pricing.

- be able to use her/his programming skills in simple Excel spreadsheets and/or in high programming languages such as Gauss or MatLab, not only for financial models and algorithms dealt with at lesson but also for other similar problems.

- have acquired general skills in the field of algorithms and applied programming for option pricing which enable him/her to make educated choices in a problem solving

		practice framework. To be specific, the student should be able set up Excel spreadsheets and/or high level language, GAUSS or MatLab, codes implementing univariate and multivariate lattice models, Monte Carlo Simulations as discrete time approximations of the stochastic processes deal with at lesson. Moreover, the student should be able to program univariate and multivariate underlying European Options Derivatives closed formulas. Finally, the student should be able to program backward induction algorithms both on a lattice and in a Monte Carlo simulation framework, Least Squares Monte Carlo, choosing the algorithm which suits best to the application (algorithm educated choice) The student should be able to apply methods mentioned above both to financial derivatives and to real options, Bellman's dynamic programming in a stochastic framework, impulse control. • be capable to give a presentation both in front of a general practitioners' audience and a more academic one about the models dealt within the course. • have acquired a method of study both thanks to a wide knowledge of the main streams in which financial modelling is evolving, theoretical continued learning, and a confident practice with respect to the main high level programming languages, GAUSS and MatLab, which are continually evolving, best practice continued learning.
3	**Course prerequisites**	Pre-Assessment Suggestive prerequisites are summarized by the syllabi of the following exams, namely Foundations Of Programming And Laboratory, Probability And Mathematical Statistics, Operation Research And Optimization. Actual prerequisites are not assessed at the beginning of the course and they are considered as a given when tuning the teaching approach of finance topics. A good programming ability is required for the following applications: A) any spreadsheet, e.g. Excel, Calc; B) any matrix oriented language, e.g. MatLab, Gauss, Ox, Octave, Scilab. In the computer lab classes, Gauss will be used. Univariate and multivariate calculus is applied in most of the models. A solid background in probability theory and in statistics is required.
4	**Teaching methodsand language**	lectures and practice drills in the computer lab. **Language**: Italian **Reference textbooks** • Thomas E. Copeland, J. Fred Weston, and Kuldeep Shastri, ***Financial Theory and Corporate Policy***. Addison-Wesley. 2005. • Luenberger, D, ***Investment Science***. Oxford University Press. 1998. • John C. Hull, ***Options, Futures, and Other Derivatives***. Pearson Education Inc.. 2015. • Dessislava A. Pachamanova, Frank J. Fabozzi, ***Simulation and Optimization in Finance: Modeling with MATLAB, @Risk, or VBA***. John Wiley & Sons. 2010.
5	**Assessment methods**	**Pre Assessment** A preliminary assessment of prerequisite skills is not performed in this course. **Formative Assessment** The formative assessment of this course teaching and learning process is performed through class participation during lessons: A) students may be asked to answer questions about topics dealt with at lesson; students may ask instructor questions during lessons both about the very topic dealt with at lesson and about correlated topics they are particularly interested in. B) summary of previous week lessons: a student is randomly selected to sum up topics dealt with in the previous sessions, actually introducing extant session; C) short seminars: students are required to apply their skills in Calculus, Stochastic Calculus, Numerical Analysis and Mathematical Statistics to specific problems in finance, proposing their own solutions previously prepared as homeworks. **Summative Assessment** The summative assessment of this course is performed through A) Written tests: i) during the semester module a mid term and a final test at the end of the semester are given for students attending lessons; ii) a comprehensive test is given in ordinary exam sessions for students not attending lessons and for attending students that do not pass mid term and final semester tests; B) Homeworks and take home projects: some compulsory homeworks are given on specific topics to let students delve into the subject at her/his own pace; some optional take home projects are suggested to students particularly interested in applying quantitative methods of their choice to finance problems. C) Oral exams: after achieving at least an average pass grade in written tests during the semester or, as an alternative, an equivalent valuation on a comprehensive written test in an ordinary exam session, students are required to take an oral exam

		made up of: 1) questions about mistakes in written tests; 2) one's choice topic question. **aims and formative purposes** students are evaluated with respect to three different dimensions of learning: A) Baseline theoretical knowledge provided through lessons and suggested reading list: tested through open questions to be answered through short essays; B) Problem solving involving symbolic calculus and stochastic calculus capabilities: tested through questions about model building and algorithms tuning for specific formal problems; C) Programming capabilities: tested through small (large) problems in class (at home) assignments to be programmed in a high level language, e.g. MatLab, Gauss, Ox, Scilab. **Evaluation criteria** 1) final numerical results achievement; 2) style: 2.1) in modelling – possibly new – solutions in a symbolic layout; 2.2) in writing codes for extant models; 2.3) in prose for short essays questions. **Assessment breakdown** Formative and Summative Assessment towards the definition of a final grade weights on the final grade: In class participation 5%; Summary of previous week lessons 10%; Short seminars (if given, else the weight is given to class participation) 5%; In Class written tests 50%; Home assignments (homeworks and take home projects) 25%; Oral Exam 5%.