Syllabus

Economic and mathematical modeling

(3 ECTS)

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Meeting Minute # ___dated _____ 20_

Course Description

Pre-requisites

Mathematics (algebra and calculus), probability theory and statistics. Good command of English.

Abstract

"Economic and Mathematical Modeling" is taken in the first module of the Master's program "Big Data Systems". This is a crash course on a mix of quantitative finance, investment management and corporate finance reviewing major quantitative methods used in finance. It covers the traditional topics such as percentage calculus, making capital budget decisions, fixed-income securities, stock valuation, portfolio management including the CAPM and APT models and financial derivatives. While providing the basic insight into each topic, we also focus on the subtleties which are usually omitted in the standard expositions to quantitative methods. For example, we discuss the use of the standard measures like IRR for mutually exclusive projects in capital budgeting, term structure of interest rates in bond valuation, the APT model, to name a few. The framework of the course is the no-arbitrage argument which is repeatedly exploited to demonstrate the pricing for an asset. The duration of the course is one module. The course is taught in English and worth 3 credits.

Learning Objectives

The course provides a review of major methods of quantitative finance.

Learning Outcomes

At the end of the course, students are supposed to:
Be aware of:

- different types of financial assets circulating in the market;
- general principles of valuation of financial assets;
- methods of hedging the financial risks;
- implications of market microstructure

Be able to:

- select the appropriate methods to evaluate cash flow streams, fixed-income securities, stocks and financial derivatives;
- manage and diversify financial risks associated with investments;

Course Plan

№	Topic	In-class hours			Self-study	Total
		Lectures	Seminars	Sub-Total		
	1st module					
1.	**Percentage calculus, time value of money**	1	2	3	12	15
2.	**Making capital budgeting decisions**	1	2	3	10	13
3.	**Fixed income securities**	2	4	6	14	20
4.	**Stock valuation**	2	2	4	10	14
5.	**Portfolio management**	2	4	6	18	24
6.	**Mathematics of derivatives**	4	6	10	18	28
	Total	**12**	**20**	**32**	**82**	**114**

Topic 1. Percentage calculus, time value of money.

Time value of money: future value and different schemes of compounding, perpetuities, annuities, effective annual rates. Present value and discounting. Cash flows. Structure of the cash flows. Effective annual costs and replacement decisions.

Topic 2. Making capital budget decisions

Investment rules: NPV, IRR, payback, discounted payback, PI. Non-standard situations (mutually exclusive projects, scale, problem, timing, etc). Incremental cash flows. Inflation and capital budgeting. Profitability of trading on margin and short sales.

Topic 3. Fixed income securities

Bond features and prices. Yield to maturity. Bond prices over time. Term structure of interest rates. Holding period returns, spot, short and future rates. Theories and implications of the term structure. Duration of a bond. Immunization against deviations of the interest rates. Managing bond portfolios.

Topic 4. **Stock valuation**

Intrinsic value versus market price. Dividend discount models. The constant-growth DDM. Convergence of price

to intrinsic value. Multistage growth models. Price-earnings ratio and its determinants. Free cash flow valuation.

Topic 5. Portfolio management

Portfolios of two risky assets. The Markowitz portfolio optimization model: security selection, capital allocation and the separation property. The power of diversification. The capital asset pricing model: expected returns on Individual securities, the security market line. The CAPM and the single-index market. Assumptions and extensions of the CAPM. The arbitrage pricing theory.

Topic 6. Mathematics of derivatives

Futures and options trading. American and European options. Values of options at expiration. Call and put options. Option versus stock. Option strategies: protective put, covered call, straddle, spreads, collars etc. The put-call parity. Option valuation: intrinsic and time values. Determinants of option prices. Binomial option pricing. Stochastic calculus (Ito's lemma etc). Security price as a random walk. Black-Scholes option valuation. The Black-Scholes formula. Impact of dividends.

Reading List

Required

1. *Vernimmen, Pierre. Corporate Finance: Theory and Practice / Pierre Vernimmen, Pascal Quiry, Maurizio Dallocchio, Yann Le Fur, Antonio Salvi.– John Wiley & Sons, Incorporated, 2017. – URL: https://ebookcentral.proquest.com/lib/hselibrary-ebooks/detail.action?docID=5061190 – ЭБС ProQuest Ebook Central - Academic Complete 2017*
2. *Härdle, Wolfgang Carl . Applied Quantitative Finance / Wolfgang Carl Härdle, Cathy Yi-Hsuan Chen, Ludger Overbeck.– Springer, 2017–URL: https://proxylibrary.hse.ru:2084/book/10.1007%2F978-3-662-54486-0 – ЭБС Springer eBooks (Complete Collection 2017)*

Optional

1. *Hull, John. Options, Futures and other derivatives.– Pearson Education Limited, 2017– URL: https://ebookcentral.proquest.com/lib/hselibrary-ebooks/detail.action?docID=5186416&query=9781292212920 – ЭБС Ebrary Purchased Textbooks 2017*
2. *Consigli, Giorgio . Handbook of recent advances in commodity and financial modeling/ Giorgio Consigli, Silvana Stefani, Giovanni Zambruno – International Series in Operations Research & Management Science book series (ISOR, volume 257), 2018– URL: https://proxylibrary.hse.ru:2084/book/10.1007%2F978-3-319-61320-8 – ЭБС Springer eBooks (Complete Collection 2018)*

Grading System

The formula for the final grade O_{fin}

$$O_{\text{fin}} = 0.6 \times O_{\text{accm}} + 0.4 \times O_{\text{exam}}$$

is made up of the grade O_{accm} accumulated over the module and the grade O_{exam} for the final exam. The accumulated grade O_{accm} is an average of three in-class tests. No blocking elements are supposed.

Examination Type

A 2-hour written exam consisting of three problems and a concept question.

Sample concept questions for the final exam

1. Compounding schemes.
2. Effective annual rates.
3. Investment rules (NPV, IRR, PI etc).
4. Use of IRR for investments with unequal life.
5. Bond prices.
6. Yield to maturity.
7. Immunization strategies.
8. Term structure of interest rates.
9. Admissible set of risky portfolios.
11. SML and CML.
12. Separation theorem.
13. The CAPM model.
14. The APT model.
15. Diversifiable and non-diversifiable risk.

16. Options – definition and basic properties.
17. Black-Scholes model.
18. Risk-neutral valuation.

Methods of Instruction

In general, lectures should give insight into the concepts and ideas underlying the topic under review. The theoretical core of presentation should be preceded and followed up by clear examples. The lecture slides may contain pieces of (quasi) code illustrating implementation of the algorithms in some programming language. It is highly recommended to provide students with the lecture slides prior to the lecture so that they could familiarize themselves with the material in advance and prepare some questions. The lecturer should refer the students for technicalities to the recommended textbooks, reviews and papers as needed throughout the presentation.

Practice classes play the key role in providing the course. The instructor should focus on the implementation of data analysis algorithms on computers. The difficult tasks should be discussed and worked out together with students. The tasks being discussed should be close to those of home assignment so as students could solve similar problems on their own. The students are supposed to prepare a report on a particular home assignment and submit it to the instructor electronically or in paper form. Some requirements for these reports may be set, e.g.:

- The questions should be addressed in the same order they appear in the assignment. The text of the question must be retained and placed before each answer. The working language is English.
- The answer to a particular question may take a form of a plot, formula etc followed by a brief explanation and a conclusion. All conclusions must be justified numerically, i.e., by some computed quantities, plots, etc. The answers do not need to be lengthy but they must be convincing in mathematical and statistical sense, i.e., in terms of some quantitative measures.
- Each student must use a unique data set. It is the student's responsibility to make sure that no one else is using the same data. To facilitate the distribution of datasets among the students, the instructor can create an editable shared check-in list on Google Drive or some other cloud resource.
- The deadlines for the reports should be clearly specified.
- The instructor should notify the students about the penalties for late submission of the reports.
- The solutions should normally contain code in R or some other language.

It is good practice to suggest the students some datasets for the home assignments. For example, a great amount of market data can be found at Yahoo Finance, Google Finance, Federal Reserve Economic Data repository http://research.stlouisfed.org/fred2/ and so on. Other possible data sources include the JSE archive http://ww2.amstat.org/publications/jse/jse_data_archive.htm, a huge repository at https://www.data.gov/ and a list of freely available sources at http://guides.emich.edu/data/free-data. Remarkably, most of these data can be downloaded in R directly by using the respective functions which should be pointed out to students.

Special Equipment and Software Support

#	Title	Terms of access
1.	Microsoft Windows 7 Professional RUS	Internal HSE network
2.	Microsoft Office Professional Plus 2010	Internal HSE network
3.	R programming language	Internal HSE network
4.	R Studio IDE	Internal HSE network