ECON 424/CFRM 462: Computational Finance and Financial Econometrics

Course Description

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Office Hours: TuTh 3:30-4:30 (after class)

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This course is an introduction to computational finance and financial econometrics - *data science applied to finance*. The course covers computer programming and data analysis in R, econometrics (statistical analysis), financial economics, microeconomics, mathematical optimization, and probability models. A free online version of this course is available on Coursera and has been taken by over 100,000 students world-wide.

The emphasis of the course will be on making the transition from an economic model of asset return behavior to an econometric model using real data. This involves: (1) exploratory data analysis; (2) specification of models to explain the data; (3) estimation and evaluation of models; (4) testing the economic implications of the model; (5) forecasting from the model. The modeling process requires the use of economic theory, matrix algebra, optimization techniques, probability models, statistical analysis, and statistical software.

Topics in financial economics that will be covered in the class include:

- asset return calculations
- risk concepts
- portfolio theory
- risk budgeting
- index (factor) models
- capital asset pricing model

Mathematical topics covered include:

- optimization methods involving equality and inequality constraints
- basic matrix algebra
- matrix differential calculus (sounds hard but it isn't)

Statistical (Econometric) topics to be covered include:

- probability and statistics with the use of calculus
    - expectation, univariate and joint distributions, covariance, normal distribution, etc.

- Monte Carlo simulation
- basic time series models
- descriptive statistics and data analysis
- estimation theory and hypothesis testing
- resampling methods (e.g., bootstrapping)
- linear regression
- data analysis using the open source R programming language

This course is an elective for the *Undergraduate Certificate in Economic Theory and Quantitative Methods* and one of the core courses for the new*Certificate in Quantitative Managerial Economics*. It is also included in the *Advanced Undergraduate Economic Theory and Quantitative Methods Courses* list for the *Bachelor of Science* degree in Economics.

ECON 424 is cross-listed with CFRM 462. Students entering the *Professional MS in Computational Finance and Risk Management* program or the*Computational Finance Certificate* program will benefit from being familiar with this ECON 424/CFRM 462 course material.

Course Requirements

- Homework and Computer labs 25%: due every Tuesday by 8 pm PST (submitted online via Canvas)
- 1 Midterm exam 25% (tentatively scheduled for)
- Class project 25% - W credit will be given if you receive a grade of 3.3 or higher on the class project (Due Friday March 11 at 8 pm via Canvas)
- Final Exam 25% ()

The homework, computer labs and project comprise the core of the course and have been weighted accordingly for grading purposes. I believe that one cannot obtain an adequate knowledge and appreciation of model building, finance and econometrics without "getting one's hands dirty" in the computer lab.

Prerequisites

Formally, the prerequisites are Econ 300 and an introductory statistics course (Econ 311 or equivalent). Econ 482 (Econometric Theory) *is not* a prerequisite. More realistically, the *ideal* prerequisites are a year of calculus (through partial differentiation and constrained optimization using Lagrange multipliers), some familiarity with matrix algebra, a course in probability and statistics using calculus, intermediate microeconomics and an interest in financial economics (Econ 422 would be helpful).

Required Texts

- *An Introduction to Computational Finance and Financial Econometrics*

with R by Eric Zivot, manuscript in preparation. Book manuscript is posted on the Canvas syllabus page. Older versions of the notes are on the notes page.

- *Statistics and Data Analysis for Financial Engineering, Second Edition* by David Ruppert and David Matteson, Springer-Verlag. Book website.The UW library has access to the UseR series of books from Springer-Verlag. If you have a UW net ID then you can get access to these ebooks through the UW library page. If you are connecting from a computer that is off campus be sure to use the Off Campus login link. A direct link to*Statistics and Data Analysis for Financial Engineering* is here.
- *A Beginner's Guide to R* by Alain Zuur, Elena Ieno and Erik Meesters, Springer-Verlag. A direct link to *A Beginner's Guide to R* is here
- *R Cookbook* by Paul Teetor, O'Reilly.

Recommended Texts

- *Introductory Statistics with R, Second Edition* (Statistics and Computing, Paperback), by Peter Dalgaard, Springer-Verlag, New York.
- *Modern Portfolio Theory and Investment Analysis*, by E.J. Elton et al., Wiley, New York. This text gives a very detailed treatment of portfolio theory.
- *Financial Modeling,* by Simon Benninga. MIT Press. This textbook covers financial modeling using Microsoft Excel.
- *Statistical Analysis of Financial data in R*, by Rene Carmona, Springer-Verlag, 2014. This is a great book but is a bit too advanced for this course It is used at Princeton in the Masters Program in Financial Engineering.

Software

The course will utilize R for data analysis and statistical modeling and Microsoft Excel for spreadsheet modeling.

Excel is included with all version of Microsoft office, and is available on all PC computers around campus.

R is a free open-source statistical modeling and graphical analysis language built upon the S language developed at Bell Labs and is available on many computers throughout the UW campus. It can be downloaded from www.r-project.org. There are versions available for the PC, Mac and various forms of LINIX. The CSSCR lab, on the 1th floor of Savery Hall, has R on most of the PCs. I highly recommend using RStudio (www.rstudio.org) as a free integrated development environment for R (runs on windows, MAC and LINUX).

We will be using several user-created packages (libraries of R functions) specifically designed for the analysis of financial time series data. R

	packages are maintained on the web and can be automatically downloaded from with R. The R package IntroCompFinR is the companion package for my book *An Introduction to Computational Finance and Financial Econometrics with R* and is available on R-Forge here. This package contains data for all of the examples in the book as well as a number of useful functions for data, portfolio and risk analysis.

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Class Syllabus

Winter 2016

Note 1: In the Reading column below, "ZLM" refers to *A Beginner's Guide to R* by Zuur, Leno and Meesters; "R Cookbook" refers to *R Cookbook* by Teetor; "EZ" refers to book chapters of *Introduction to Computational Finance and Financial Econometrics with R* by Eric Zivot; "EG" refers to *Modern Portfolio Theory* by Elton and Gruber; "Ruppert" refers to *Statistics and Data Analysis for Financial Engineering* by Ruppert and Matteson . "*" denotes optional reading.

Note 2: Recent changes to the reading list are denoted with NEW.

Note 3: My Book chapters are work in progress and are not guaranteed to be free of errors. The book manuscript is posted on the class Canvas syllabus page. As the quarter progresses I will be making changes and additions to the chapters so check the revision dates to make sure you have the most up to date set of notes. Please let me know if you find typos or other errors.

Last updated on January 11, 2016

Week	Topic	Reading	Additional Material
1	1. Course Introduction 2. Computing Asset Returns 3. Getting financial data from Yahoo! 4. Excel calculations 5. Introduction to R 6. Univariate random variables and distributions	1. Ruppert, chapter 2 (Returns). 2. EZ, chapter 1 (return calculations). 3. EZ, chapter 2 (Review of Random Variables). 4. EZ, class slides on course introduction. 5. EZ, class slides on return calculations. 6. EZ, class slides on probability review: Part I. 7. ZLM, chapters 1-3, 5. 8. R Cookbook, chapters 1 - 5, 10 (sections 1 - 15) 9. An Introduction to R, sections 1-3, 6 and 7.	1. finance.yahoo.com Check out finance/quote section 2. returnCalculations.xls 3. returnCalculations.r (R code for book chapter examples) 4. returnCalculations.Rmd (R markdown file for web-page examples) 5. returnCalculations.html (R examples in web page using R markdown - best viewed in Chrome) 6. Rintro.pdf (introduction to R covered) 7. probReview.xls 8. probReview.r (R code for book chapter examples)

		10. R for Beginners, sections 1-3. 11. *EG, chapters 1-3	
2 & 3	1. Characteristics of distributions 2. The normal distribution 3. Linear function of random variables 4. Quantiles of a distribution, Value-at-Risk 5. Bivariate distributions 6. Covariance, correlation, autocorrelation 7. Linear combinations of random variables 8. Time Series concepts 9. Matrix algebra	1. Ruppert, chapter 5 (Modeling Univariate Distributions),chapter 7 (Multivariate Statistical Models), chapter 9(Time Series Models: Basics),Appendix (sections 1-10, 12-15, 20) 2. EZ, chapter 2 (Review of random variables), chapter 3 (matrix algebra review) and chapter 4 (time series concepts) 3. EZ, class slides on probability review: Part I. 4. EZ, class slides on probability review: Part II. 5. EZ, class slides on time series concepts. 6. EZ, class slides on matrix algebra. 7. ZLM, chapters 3-7. 8. R Cookbook, chapter 8 and chapter 14 (sections 1 - 16). 9. An Introduction to R, section 8. 10. R for Beginners, section 4.	1. probReview.xls 2. probReview.r (R code for book chapter examples) 3. probabilityReview.Rmd (R markdown file used to create webpage examples) 4. probabilityReview.html (R examples in webpage created with R markdown) 5. timeSeriesConcepts.r (R code for book chapter examples) 6. timeSeriesConcepts.Rmd (R markdown file used to create webpage examples) 7. timeSeriesConcepts.html (R examples in webpage created with R markdown - best viewed in Chrome) 8. matrixReview.r (R code for book chapter examples) 9. matrixReview.Rmd (R markdown file used to create webpage examples) 10. matrixReview.html (R examples in webpage created with R markdown - best viewed in Chrome) 11. Working with time series data in R
4-5	1. Descriptive statistics: histograms, sample means, variances, covariances and autocorrelations 2. The constant expected return	1. Ruppert, chapter 4 (Exploratory Data Analysis), chapter 5sections 9 and 10 (maximum likelihood estimation), chapter 6(Resampling), Appendix(sections 11, 16 - 18) 2. EZ, chapter 5 (descriptive statistics for financial data), chapter 6 (constant	1. descriptiveStatistics.r (R code for book chapter examples) 2. descriptiveStatisticDaily.r 3. descriptiveStatistics.Rmd (R markdown file used to create webpage examples) 4. descriptiveStatistics.html (R examples in webpage created with R markdown) 5. cerModel.r (R code for book chapter examples) 6. cerModel.Rmd (R markdown file used to create webpage

	model. 3. Monte Carlo simulation 4. Standard errors of estimates 5. Confidence intervals 6. Bootstrapping standard errors and confidence intervals 7. Hypothesis testing 8. **Midterm exam:** 9. Midterm solutions 10. Grade distribution econ 424	expected return model), chapter 7 (estimation of the CER model), chapter 8 (bootstrapping), chapter 9 (hypothesis testing in the CER model) 3. EZ, class slides on descriptive statistics. 4. EZ, class slides on CER model. 5. EZ, class slides on bootstrapping 6. EZ, class slides on hypothesis testing in the CER model. 7. EZ, class slides on maximum likelihood estimation. **Note: will not cover this material this term.** 8. Bootstrap Methods and Permutation Tests, by Tim Hesterberg. Read sections 1 - 5. 9. R Cookbook, chapter 9 (General Statistics) chapter 10 (Graphics), chapter 13 (Beyond Basic Numerics and Statistics, section 8 on Bootstrapping). 10. An Introduction to R, section 12.	examples) 7. cerModel.html (R examples in webpage created with R markdown - best viewed in Chrome) 8. cerModelEstimation.r (R code for book chapter examples) 9. cerModelEstimation.Rmd (R markdown file used to create webpage examples) 10. cerModelEstimation.html (R examples in webpage created with R markdown - best viewed in Chrome) 11. bootstrap.Rmd (R markdown file used to create webpage examples) 12. bootstrap.html (R examples in webpage created with R markdown - best viewed in Chrome) 13. bootStrap.r (R code examples) 14. rollingCerModel.Rmd (R markdown file used to create webpage examples) 15. rollingCerModel.html (R examples in webpage created with R markdown - best viewed in Chrome) 16. hypothesisTestingCER.r 17. hypothesisTestingCerModel.Rmd (R markdown file used to create webpage examples) 18. hypothesisTestingCerModel.html (R examples in webpage created with R markdown - best viewed in Chrome) 19. maximumLikelihood.r 20. maxLike R package vignette.
6-7	1. Introduction to portfolio theory 2. Optimization 3. Markowitz algorithm 4. Markowitz algorithm using the solver and matrix algebra	1. Ruppert, chapter 11 (Portfolio Theory). 2. EZ, chapter 10 (introduction to portfolio theory), and chapter 11 (portfolio theory with matrix algebra) 3. Notes on using Excel's solver. 4. EZ, class slides on Introduction to Portfolio	1. introPortfolioTheory.xls 2. 3firmExample.xls 3. introductionToPortfolioTheory.r 4. introductionToPortfolioTheory.Rmd (R markdown file used to create webpage examples) 5. introductionToPortfolioTheory.html (R examples in webpage created with R markdown - best viewed in Chrome) 6. portfolioTheoryMatrix.r 7. portfolioTheoryMatrix.Rmd (R

	5. Markowitz algorithm with no short sales constraints	Theory. 5. EZ, class slides on portfolio theory with matrix algebra. 6. R Cookbook, chapter 13 (Beyond Basin Numerics and Statistics, sections 1 - 2) 7. *EG, chapters 5 and 6	markdown file used to create webpage examples) 8. portfolioTheoryMatrix.html (R examples in webpage created with R markdown - best viewed in Chrome)
8 & 9	1. Portfolio risk budgeting 2. Statistical Analysis of Efficient Portfolios 3. Beta as a measure of portfolio risk	1. Ruppert, chapter 12 (Regression: Basics), chapter 13 (Regression: Troubleshooting), chapter 16 (CAPM) 2. EZ, chapter 12 (portfolio risk budgeting), chapter 13 (statistical analysis of portfolios), and chapter 14 (single index model) 3. EZ, class slides on portfolio theory with no short sales. 4. EZ class slides on statistical properties of efficient portfolios. 5. EZ, class slides on portfolio risk budgeting 6. R Cookbook, chapter 11 (Linear Regression and ANOVA) 7. *EG, chapters 6, 7 and 9	1. portfolioTheoryNoShortSales.r 2. portfolioTheoryNoShorts.html (R examples in webpage created with R markdown - best viewed in Chrome) 3. portfolioTheoryNoShorts.Rmd (R markdown file used to create webpage examples) 4. statisticalAnalysisPortfolios.Rmd (R markdown file used to create webpage examples) 5. statisticalAnalysisPortfolios.html (R examples in webpage created with R markdown - best viewed in Chrome) 6. riskBudgeting.Rmd (R markdown file used to create webpage examples) 7. riskBudgeting.html (R examples in webpage created with R markdown - best viewed in Chrome) 8. rollingPortfolios.r 9. bootstrapPortfolio.R 10. singleIndex.r 11. singleIndexPrices.xls (added May 22, 2006) 12. testCAPM.r
10	1. The Single Index Model 2. Estimating the Single Index Model using simple linear regression 3. Capital Asset Pricing	1. EZ, chapter 14 (single index model) and chapter 15 (CAPM) 2. EZ class slides on the single index model. 3. EZ class slides on estimating single index model using regression. 4. EZ class slides on the	

	Model (CAPM)	Capital Asset Pricing Model	
Finals week	**Final Exam: Tuesday March 15 Smith 304.** **Final Project: Due Friday March 11 by 8 pm via Canvas**		