Online Research Seminar Syllabus

1. Overview

<table>
<tr><td>Title</td><td colspan="3">Time Series Modeling with Applications in Economics and Public Health</td></tr>
<tr><td>Mode</td><td colspan="3">Online instructor sessions and teaching fellow sessions</td></tr>
<tr><td>Targeted Students</td><td colspan="3">The course is aimed at high school and undergraduate students studying mathematics, and business management, economics, or public health.</td></tr>
<tr><td rowspan="2">Prerequisites</td><td rowspan="2">High School and College Students</td><td>Recommended course/Knowledge</td><td>Elementary probability theory for random variables: expectation, variance, normal distributions, correlation.</td></tr>
<tr><td>Recommended Materials for preparing for the course</td><td>Web-based articles on these topics</td></tr>
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2. Program Introduction and Objectives

Course Description	Introduction to fundamental methods and models of time series analysis with applications in economics, finance, and public health. Important models of trend and seasonality are developed andapplied, using multi-stage exponential smoothing. Box-Jenkins models for stationary time series (auto-regressions, moving averages) are covered including methods for estimation, order selection, and forecasting. Real-world time series data are collected from the internet and analyzed with the methods covered in the course.
Texts/Software	Required Texts: (NIST) Engineering Statistics Handbook NIST/SEMATECH e-Handbook of Statistical Methods (https://www.itl.nist.gov/div898/handbook/) (BD) Brockwell, P.J., and Davis, R.A. “Introduction to Time Series and Forecasting, Third Edition”, Springer 2016. Suggested Text (for advanced students): Tsay, R.S. “Analysis of Financial Time Series, Third Edition,” Wiley 2010. Software: R and RStudio

3. Program Schedule

Week		Lecture	Teaching fellow Session (lab/case study, etc.)	Assignment	Reading Materials
1	**Topic**	Introduction to Time Series Analysis	Install R/RStudio; importing time series data, plotting time series, computing and plotting smoothed series.	Using R as a calculator; R exercises based on NIST: 6.4.1-6.4.3; importing real-world time series from the Federal Reserve or the World Bank	NIST: 6.4.1-6.4.3.2 BD: 1.1-1.2
	Detail	Definitions and applications; Smoothing techniques (averaging and exponential smoothing methods)	Case study importing financial/economic time series and importing public health data. Applying smoothing methods to time series (simple moving average, centered moving average, exponential smoothing).		
2	**Topic**	Simple Time Series Models; financial time series	Simulating time series models; computing and using autocorrelations, estimating trend and seasonal components.	R exercises computing autocorrelations, simple smooths of series, and applying Holt-Winters exponential smoothing.	NIST: 6.4.3.3 – 6.4.3.7 BD: 1.3-1.4 T: 1.1-1.2.2
	Detail	Zero-mean models; models with trend and seasonality; autocorrelation	Case study evaluating simple time series models with economic time series; using Holt-Winters exponential smoothing to estimate trend and seasonality		
3	**Topic**	Testing estimated noise sequences for time series dependence; stationary processes.	Review test concepts and definitions; work sample problems; discuss case study	Using R to conduct auto-correlation and the Ljung-Box test; appling normal qq plots to evaluate time series for symmetry and normality verus asymmetry and heavy-tails.	BD: 1.6, 2.1-2.4 NIST: 6.4.4.2 T: 2.1-2.2
	Detail	Auto-correlation tests; Ljung-Box test, turning point and difference sign tests, normal qq plots	Case study applying tests and methods to real-world time series and their fitted models.		

<table>
<tr><td rowspan="2">4</td><td>Topic</td><td>Autoregression (AR), moving average (MA), and ARMA models</td><td>Review definitions and concepts; work sample problems; discuss case study</td><td rowspan="2">Exercises using R functions to compute time series statistics, identify models, and forecast</td><td rowspan="2">BD: 3.1-3.2

NIST: 6.4.4.4-6.4.4.6

T: 2.4 -2.6</td></tr>
<tr><td>Detail</td><td>The autocorrelation and partial autocorrelation of AR, MA, and ARMA processes; model selection and forecasting</td><td>Identifying AR models; identifying MA models; model estimation and forecasting</td></tr>
<tr><td rowspan="2">5</td><td>Topic</td><td colspan="4">Research Workshop I</td></tr>
<tr><td>Detail</td><td colspan="4">A) Final Project Milestone: Students are required to meet the following objectives before attending the session in Week 5:
Prepare well-written draft of introduction section for final project; include topic description, motivation, detailed outline of proposed sections in paper/presentation
Explicitly detail resources for the project (e.g., sections/pages of reference books; internet articles/pages
Prepare a few slides for a mini presentation of project
B) Things to do during the class and arrangement: Please fill in what you are going to do during the class and the format (e.g conversation, mini presentation and etc.)
Mini presentation of Project Phase I results with few slides prepared
Review/discussion of resources for project
Critique of written draft introduction section
Review/discussion of section outline of project</td></tr>
<tr><td rowspan="2">6</td><td>Topic</td><td colspan="4">Research Workshop II</td></tr>
<tr><td>Detail</td><td colspan="4">A) Final Project Milestone: Students are required to meet the following objectives before attending the session in Week 6:
✓ Prepare draft slides for entire project presentation
✓ Prepare well-written draft of two or three main sections of final project paper.
B) Things to do during the class and arrangement:
✓ Present the result of Project Phase II in form of conversation using breakout rooms.</td></tr>
<tr><td>7</td><td colspan="5">Final Oral Presentation and Written Reporting</td></tr>
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4. Problem Sets/Written Assignments/Quizzes

Total Number of Assignments	4 times	
Weekly Assignment Submission Deadlines	TBD Days after the distribution/announcement	
teaching fellow needed to review and grade assignment	Yes (X)	No ( )
A standard answer be provided	Yes (X)	No ( )
Quizzes or Assignment	No quizes	
Other Requirements (if any)	None	

5. Final Oral and Written Project

Students can work on the final project individually or in a group (limited in size to 3). Students should submit a proposal for their project topic and list of fellow group members (if not an individual project) by session 4 of the seminar course.

Suggested project topics are to choose one real-world time series and conduct a thorough time series analysis (smoothing, model estimation and forecasting).

Possible time series include:

Macro-Economy: Unemployment, Gross Domestic Product, Consumer Prices Index Financial Markets: Yield on ten-year US Treasury Securities (interest rate), credit spread (difference in yields of corporate and government bonds), housing price index

Public health: global health nutrition and population time series (incidence of infectious disease, population dynamics, nutrition, reproductive health, food-price inflation).

5.1 Final Oral Presentation

- Final presentation should be in form of slides (e.g., Powerpoint, Google Slides)
- Deadline: session 7 of the online research seminar

5.2 Will you require a written final report as well?

Written report of project: each student is expected to provide 7-10 pages (with group projects, each student should take responsibility for separate sections).

6. Suggested Future Research Fields/Direction/Topics

- Multivariate time series analysis concerns the analysis of time series of multiple variables observed simultaneously over time, such as monthly or quarterly economic time series. Vector autoregressive (VAR) models are well-suited to analyzing and forecasting such multivariate time series.
- Process control techniques are useful for determining when systems are in control or out of control. Univariate and multivariate control charts use time series methods to specify control policies.
- In financial markets, state-of-the art models of asset return volatility/risk use advanced time series models. These models include ARCH, GARCH, EGARCH, and stochastic volatility models using alternate distributions (e.g., normal, Laplace). Important research directions include model selection, and the development of adaptive specification methods.
- With global databases (across countries) of time series of public health statistics, the understanding and interpretation of such information can benefit from clustering of countries based on geographic region and income level. Multivariate time series models can be implemented exploiting the cluster information.

7. Instructor Introduction

- **Instructor Title:** Peter, Lecturer in Financial Mathematics and Statistics, MIT
- **Instructor Bio**: visit https://math.mit.edu/directory/profile.php?pid=1521
- **Instructor Profile Photo**