### Course Goals:
The course is intended to fulfill two needs: (1) to provide students with applied interests with the most sophisticated and up to date techniques used in empirical time series analysis, and (2) to introduce students with more theoretical inclinations to the tools that are used to derive some of the more interesting results.

### Textbook:
Hamilton, J. D. (1994) *Time Series Analysis*, Princeton University Press, New Jersey. I will follow Hamilton's book rather closely. Regardless, this is a great book, worth having in your library. I will provide additional references for specific topics but these are easily available through the library or on the web.

### Assignments:
I am hoping to have 5 computer assignments that will involve the packages EViews and GAUSS. The home page for the course has a number of links to brief introductions to these programs. There will also be regular assignments of a more theoretical nature that do not require the use of a computer.

### Resources:
Mostly, you should check the home page for the course. Additional readings for each topic can be found at the end of this document.

### Grading:
There will be three components to your grade, assignments (30%), midterm/s (30%) and final (40%).
Course Outline:

TOPIC 0: REVIEW OF PROBABILITY THEORY

- **Basic Definitions**: sample space, σ-algebra, probability measure, probability space, random variable, distribution function, Borel-measurable functions, expected value.
- **Modes of Convergence**: convergence in probability, mean square, almost sure and convergence in law.
  - Mann-Wald Theorem
  - Cramer-Wold Theorem
  - Slutzky’s Theorem
- **Laws of Large Numbers**:
  - Kolmogorov: I and II
  - Khinchine
- **Central Limit Theorems**:
  - Lindeberg-Levy
  - Lindeberg-Fuller
- **The Delta Method**

TOPIC 1: INTRODUCTION TO UNIVARIATE, STATIONARY TIME SERIES

- **Introduction**: cross-section vs. time-series
- **Preliminary Concepts**:
  - Lag Operators
  - White noise, martingales and martingale difference sequences
  - Autocovariances and autocorrelations
  - Stationarity:
    - Weak stationarity
    - Strong stationarity
    - Random walks
  - Ergodicity and the Ergodic Theorem
  - Uniform-mixing and strong-mixing
- **Central Limit Theorem for Martingale Difference Sequences**
- **Central Limit Theorem for Dependent Processes**
  - The Beveridge-Nelson Decomposition
- **Basic ARMA models**:
  - MA, AR, and ARMA models
  - Common transformations and identification
  - Wold representation theorem
  - State-space representation

TOPIC 2: ESTIMATION, INFERENCE AND FORECASTING

- **The Method of Maximum Likelihood**
  - Consistency
  - Asymptotic Normality
- **MLE for ARMA models**
  - AR ML: exact versus conditional likelihood
  - MA ML: exact versus conditional likelihood
  - ARMA ML
- **Review of Numerical Optimization Routines**
  - Newton’s Method
  - Common algorithms: Newton-Raphson; Quadratic-Hill; Gauss-Newton/BHHH; Marquardt; DFP.
  - Elements of numerical optimization algorithms
• Statistical Inference
  o Wald, Likelihood Ratio and Lagrange Multiplier principles
  o Non-standard tests:
    ▪ QMLE
    ▪ Unidentified parameters under the null
    ▪ Ljung-Box statistic

• The Bootstrap
  o Definition and Edgeworth Expansion
  o The Classical Bootstrap
  o Applications:
    ▪ Bias reduction
    ▪ Standard error estimation
    ▪ Hypothesis testing
    ▪ Confidence intervals
  o Bootstrap variations
  o Bootstrap for time series data
    ▪ Parametric bootstrap
    ▪ Block bootstrap

• Forecasting
  o ARMA models
  o Nonlinear models: Methods
    ▪ Naïve
    ▪ Exact
    ▪ Monte Carlo
    ▪ Bootstrap
  o Direct Forecasting
  o Tests of predictive ability

TOPIC 3: UNIT ROOTS

• Detrending Methods: deterministic vs. stochastic trends
• Asymptotic distribution of the simple trend model
• Unit Roots
  o Preliminaries: Brownian motion
  o Functional central limit theorem:
    ▪ Convergence in law of random functions
    ▪ Convergence in probability of random functions
    ▪ Continuous mapping theorem
  o The Dickey-Fuller distribution
  o Functional central limit theorem for dependent processes
    ▪ The augmented Dickey-Fuller test: derivation
    ▪ The Phillips-Perron test: derivation
  o Local-to-unity asymptotics

TOPIC 4: COVARIANCE STATIONARY VECTOR TIME SERIES

• The VAR(p)
  o Presentation
  o Stationarity
  o Wold’s theorem and the VMA representation
• Heteroskedasticity and Autocorrelation Variance Estimation
  o Newey-West estimator
• Granger causality and exogeneity
• MLE of vector processes
• Structural interpretation of VARs
  o The impulse response function
  o The variance decomposition
  o Identification and Interpretation
• Inference in VARs
• Estimation and Inference of Impulse Responses by Local Projections

TOPIC 5: GENERALIZED METHOD OF MOMENTS

• Introduction: classical method of moments
• GMM
  o Formulation
  o Optimal weighting matrix
  o Asymptotic distribution
  o Inference:
    • The J-statistic
    • Tests of subsets of orthogonality conditions
    • LR tests
  o MLE and GMM
    • Wald tests
    • LM tests
  o Extensions

TOPIC 6: COINTRODUCTION

• Motivation: spurious regressions
• Definition:
  o Properties
  o Error correction representation
  o Granger representation theorem
  o Phillips triangular representation
  o Stock-Watson common trends representation
• Testing
  o Engle-Granger 2-step cointegration test
    • Corrections for serial correlation
• Full Information Maximum Likelihood analysis of cointegrated systems
  o Preliminaries: canonical correlations
  o Johansen’s test
  o Concentrating the likelihood
  o Hypothesis testing

TOPIC 7: TIME SERIES MODELS FOR HIGHER MOMENTS AND TRANSITION DATA

• ARCH models
  o Relation to ARMA
  o MLE – GARCH
  o Testing for ARCH
  o Extensions
• ACD models
  o Specification
TOPIC 8: STATE SPACE MODELING AND THE KALMAN FILTER

• State Space Representation
• Kalman Filter
  o Overview
  o Algorithm
  o Forecasting
• MLE with the Kalman filter
• Asymptotic properties of MLE/QMLE

Additional Reading

Almost all the material for the class comes from Hamilton's book so you need not worry about the reading list except when indicated in class. The references contained in Hamilton's book are quite comprehensive if you ever need to go deeper into a topic. The references below might be helpful if you have difficulty understanding the material. A * indicates references I find particularly useful.

TOPIC 0: REVIEW OF PROBABILITY THEORY

• Davidson, Russell and James G. MacKinnon (1993), Estimation and Inference in Econometrics. New York: Oxford University Press. (Chapter 4) [Davidson and MacKinnon]
• *Hamilton, Chapter 7.

TOPIC 1: INTRODUCTION TO UNIVARIATE, STATIONARY TIME SERIES

• *Hamilton, Chapters 1-3.

**TOPIC 2: ESTIMATION, INFERENCE AND FORECASTING**

• *Amemiya, Chapter 4.*
• *Davidson, R. and J. G. MacKinnon, Chapter 8.*
• *Hamilton, Chapters 4-5.*

**TOPIC 3: UNIT ROOTS**

• *Hamilton, Chapters 15-17.*

**TOPIC 4: COVARIANCE STATIONARY VECTOR TIME SERIES**

• *Hamilton, Chapters 10-11.

**TOPIC 5: GENERALIZED METHOD OF MOMENTS**

• *Hamilton, Chapter 14.
• *Hayashi, Chapters 3-4.

**TOPIC 6: COINTEGRATION**

• Hamilton, Chapters 19-20.
TOPIC 7: TIME SERIES MODELS FOR HIGHER MOMENTS AND TRANSITION DATA


TOPIC 8: STATE SPACE MODELING AND THE KALMAN FILTER

**TIME SERIES ECONOMETRICIANS IN DAVIS**

- **Arthur M. Havenner**, Professor, Department of Agricultural and Resource Economics.
  - Web-site: [http://www.agecon.ucdavis.edu/Faculty/Art.H/Havenner.html](http://www.agecon.ucdavis.edu/Faculty/Art.H/Havenner.html)
  - Research Interests: Econometrics, both classical and time series analysis, involving any aspects of hypothesis testing, policy simulation / optimal control, and forecasting. If you have any questions about State Space modeling and the Kalman filter, he is your man.

- **Prasad Naik**, Assistant Professor, Graduate School of Management. Although professor Naik is formally professor in Marketing, he has a lot of experience in time series modeling, forecasting and control.
  - Web-site: [http://www.gsm.ucdavis.edu/Faculty/Profiles/Naik/](http://www.gsm.ucdavis.edu/Faculty/Profiles/Naik/)
  - Research Interests: advertising strategy, consumer choice behavior, sales forecasting, dynamic market response models.

- **Aaron Smith**, Assistant Professor, Department of Agricultural and Resource Economics.
  - Web-site: [http://asmith.ucdavis.edu](http://asmith.ucdavis.edu)
  - Research Interests: In econometrics, forecasting time series processes using nonlinear models and measuring the distance between unknown distributions. In finance, studying excess volatility and bubbles in equity markets.

- **Robert Shumway**, Professor, Department of Statistics.
  - Web-site: [http://anson.ucdavis.edu/faculty/shumway.html](http://anson.ucdavis.edu/faculty/shumway.html)
  - Research Interests: applications of multivariate spectral analysis to high dimensional problems in discrimination and clustering for multivariate time series and to linear filter contrasts arising in a multivariate analysis of variance. Analysis of incomplete data that can be modeled in terms of linear and nonlinear state-space models.

- **Chih-Ling Tsai**, Professor, Graduate School of Business.
  - Web-site: [http://www.gsm.ucdavis.edu/Faculty/Profiles/tsai/](http://www.gsm.ucdavis.edu/Faculty/Profiles/tsai/)
  - Research Interests: application of statistics in business, regression diagnostics, model selection, optimal design.
TIME SERIES TOPICS

Here is a potpourri of other topics that we will not discuss in class. There is no particular order and were possible, I enclose relevant references.

Time Series Topics in Finance


ARCH Models and Stochastic Volatility Models


Continuous Time Models


Neural Networks


Time Series Duration Models


Long Memory Models

- *Journal of Econometrics*, (1996), Volume 73, Issue 1, July. This issue is a monograph on Long Memory Models and is edited by Richard T. Baillie and Maxwell L. King.

Time Series Topics in Macroeconomics

Nonlinear Time Series Models

Markov Switching Regimes Models


Threshold Autoregressive and Smooth Transition Models


Structural Break Testing


Causality in Macroeconomics


Other Topics

**Time Aggregation**

**Simulation Methods for Time Series Models**

**Bootstrap in Time Series**

**Spectral Analysis and Wavelets**

**Dynamic Panel Data Models**

### Additional Resources

I recommend that you visit Eric Zivot’s home page. He has collected numerous interesting links if you are interested in time series. This is his web-site:  
[http://faculty.washington.edu/ezivot/econ584/econ584.htm](http://faculty.washington.edu/ezivot/econ584/econ584.htm)