Instructor: Professor Óscar Jordà

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CLASS URL:

Class Meets: T – R, 2:10 – 3:30pm. Room: WICKSN 1038

Office Hours: Mondays, 1 – 3pm; Wednesdays 10-11am, or by appointment

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 plan to have 5 assignments, hopefully involving some computer work as well. The software programs that I plan to use are STATA, EViews and GAUSS. You should not be too stressed about this since most of the exercises will involve relatively simple manipulations of programs that I will have prepared for you.

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 (30%) and final (40%).

Planned Schedule:

| January 14 | Problem Set 1 Due |
| January 28 | Problem Set 2 Due |
| February 4 | Midterm |
| February 11 | Problem Set 3 Due |
| February 25 | Problem Set 4 Due |
| March 11 | Problem Set 5 Due |
| March 18 | FINAL |
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
  - Slutsky’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: LARGE SAMPLE ESTIMATION, HYPOTHESIS TESTING AND FORECASTING

- **Maximum Likelihood, Extremum Estimation, Minimum Distance and GMM**
  - 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
  - The impulse response function
  - The variance decomposition
  - 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
  - Formulation
  - Optimal weighting matrix
  - Asymptotic distribution
  - Inference:
    - The J-statistic
    - Tests of subsets of orthogonality conditions
    - LR tests
  - MLE and GMM
    - Wald tests
    - LM tests
  - Extensions

**TOPIC 6: COINTEGRATION**

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

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

- **ARCH models**
  - Relation to ARMA
  - MLE – GARCH
  - Testing for ARCH
  - Extensions
- **ACD models**
  - Specification
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• Estimation
  • ACH models
    o Presentation
    o Relation to ACD
    o Estimation
  • ACI models
    o Presentation
    o Relation to ACD
    o Estimation

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.
- *Hamilton, Chapters 4-5.

**TOPIC 3: UNIT ROOTS**

- *Hamilton, Chapters 15-17.
**TOPIC 4: COVARIANCE STATIONARY VECTOR TIME SERIES**


**TOPIC 6: COINTEGRATION**

• Hamilton, Chapters 19-20.

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

• *Hamilton, Chapter 21.

**TOPIC 8: STATE SPACE MODELING AND THE KALMAN FILTER**

• *Hamilton, Chapter 13.