Econ 312a

Advanced Econometrics II (Spring 2014)

Instructor: Prof. Davide Pettenuzzo (dpettenu@brandeis.edu)

Teaching fellow: Lara Loewenstein (lloewens@brandeis.edu)

Office: Sachar 216

Office hours: My regular office hours for the Spring semester are Wednesday 10:00-11:00 AM. If you need to see me outside the regular office hours, please make an appointment

Time and location

> **Lectures**: Sachar Chancellor's Suite; Tue & Thu, 09:30 - 11:00 AM

> **Recitations**: Tue 2:00 – 3:00 PM; Room TBD

Course description

This course examines the models and statistical techniques used to study time series data. Topics will include linear and non-linear univariate as well as multivariate econometric models.

Course goals: The first goal of the course is to provide you with a good understanding of econometric models for time series data. These models are widely used in the empirical literature, and a good understanding of these models is crucial for the second goal of the course: provide the students with the tools to understand and evaluate empirical studies. The third goal of the course is to develop practical skills, which are necessary to perform independent research using real world data.

A theme throughout the course is the use of computational methods for analyzing the material covered in class, and throughout the course we will rely heavily on examples and applications with Matlab.

Prerequisites: This is an advanced econometric course, and students are required to have a good knowledge of matrix algebra, probability and distribution theory, statistical inference, the classical multiple linear regression model (OLS) and the problems related to the assumptions of this model (multicollinearity, measurement error, heteroskedasticity), and the maximum likelihood method. Econ 311a is a prerequisite.

Textbooks and reading material
Required textbook

- Hamilton, J. D. (1994) *Time Series Analysis*, Princeton University Press, New Jersey.

   I will follow Hamilton's book rather closely: On the syllabus the notation H* indicates which chapter corresponds to each topic.

Additional textbooks and online material

- Enders, W.; Applied Econometric Time Series, 3rd Edition
- Kim, C.J., and Nelson, C.R.; State-space models with regime switching

- Cochrane, J.H.; Time series for macroeconomics and finance, unpublished lecture notes available at http://faculty.chicagobooth.edu/john.cochrane/research/papers/time_series_book.pdf
- A helpful reference on facts about matrices (i.e. identities, approximations, decompositions, proofs, etc.) can be found at http://orion.uwaterloo.ca/~hwolkowi/matrixcookbook.pdf

Additional reading material

- The assignments will consist of empirical applications of the material covered during classes, and will require familiarity with the software package MatLab. Early classes will go over some of the basics of the programming language, focusing on the tools that are required to work with time series
  - There are many Matlab "primers" available over the internet that will help you build the skills needed to complete the assignments. A few examples include:
    - http://faculty.olin.edu/bstorey/Notes/matlab.pdf
    - http://web.ift.uib.no/Teori/KURS/WRK/mat/singlemat.html
    - http://www.math.toronto.edu/mpugh/primer.pdf
  - In addition, while a little dated, the following book and companion toolbox are very helpful:
    - Manual: Duane Hanselman and Bruce Littlefield, 2005, "Mastering MATLAB 7", Pearson/Prentice Hall
    - Online toolbox: http://www.ece.umaine.edu/mm/mm7.html

Evaluation

There will be problem sets, a "replication" exercise, a mid-term and a final exam. Problem sets will involve a combination of theory and applied work (applied work will require the use of Matlab). The approximate week of distribution of the problem sets is indicated in the syllabus with the notation PS*. The replication exercise will involve the drafting of a medium length paper summarizing the replication of the results contained in a published or working paper (to be approved by the Professor), as well as an interesting and meaningful extension to it. You can work on the problem sets and the replication paper alone or in small groups (2 max), but you are required to turn in your answers individually. The final grading will weight problem sets, replication exercise, mid-term and final exams as follows:

- Problem sets: 25%
- Replication paper: 25%
- Mid-term & final exams: 50%

Course outline

As you can see below, the syllabus contains a rather long list of topics. This is what I plan to cover during the 14 weeks of classes. Due to time constrains I might skip over some of points listed to be able to cover some of the more interesting and cutting edge topics that I think may help you in developing your thesis proposal.

Week 1. Introduction to probabilistic structure of time series data (H1, H2)
- Difference equations
- Lag operators

Week 2. Stationary ARMA processes (H3, H4) – PS1
- ARMA processes, stationarity, ergodicity, invertibility
- The Box and Jenkins (1976) methodology
- Autocorrelations and partial autocorrelations

Week 3. The linear regression model – MLE and small sample properties (H5)
- Maximum likelihood estimation of stationary ARMA processes

Week 4. The linear regression model – Large sample properties (H7, H8) – PS2
- OLS and GLS estimators for stationary ARMA processes – small sample properties
- Review of asymptotic theory for i.i.d. random variables and serially dependent variables

Week 5. The linear regression model (cont'd) (H8)
- OLS and GLS estimators for stationary ARMA processes – large sample results

Week 6. Forecasting and forecasting evaluation (H4) – PS3

Week 7. Stationary vector autoregressions (H10, H11)
- VAR model specification, stationarity, mean and autocovariance function
- Estimation and testing of unrestricted VARs
- Asymptotic properties of stationary VARs
- Granger causality

Week 8. Midterm week
- Review of material covered during first half
- <u>Midterm exam (March 13, 2014)</u>

Week 9. Stationary vector autoregressions, continued (H11)
- Estimation and testing of restricted VARs
- Impulse response functions and variance decomposition
- Structural VAR models and identification

Week 10. State space models and the Kalman filter (H13) – PS4
- State-space representation of dynamic processes
- Derivation of the filter: filtered and smoothed state variables
- Some applications of the Kalman filter:
    i.   Forecasting
    ii. Evaluating the likelihood function of general ARMA(p,q) processes
    iii. Estimating time varying parameter (TVP) models

Week 11. Other non-linear time series models (H22)
- Threshold autoregressive models and smooth transition models
- Regime switching models
- Structural break models

Week 12. Models of non-stationary time series – part I (H15, H16, H17)
- Processes with deterministic time trends
- Brownian motions and the functional central limit theorem
- Unit root processes and tests

Week 13. Bayesian methods for empirical macroeconomic and finance
- Bayesian VARs
- Bayesian State Space modeling and stochastic volatility
    i.   Homoskedastic TVP-VAR
    ii. Heteroskedastic TVP-VAR

Week 14. Bayesian methods for empirical macroeconomic and finance (continued) – half week

Week 15. <u>Final exam (Thursday May 6, 2014)</u>

Disabilities

If you are a student with a documented disability on record at Brandeis University and wish to have a reasonable accommodation made for you in this class, please see me immediately.

Academic Integrity

You are expected to be familiar with and to follow the University's policies on academic integrity (see http://www.brandeis.edu/studentlife/sdc/ai/). Instances of alleged dishonesty will be forwarded to the Office of Campus Life for possible referral to the Student Judicial System. Potential sanctions include failure in the course and suspension from the University.

Additional Reading

Almost all the material for the class comes from Hamilton's book. 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.

Introduction to time series data

• Amemiya, T. (1985), Advanced Econometrics. Cambridge: Harvard University Press. (Chapter 3). [Amemiya]

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

• Hayashi, Fumio (2000) Econometrics. Princeton: Princeton University Press. (Chapter 2) [Hayashi]

Stationary ARMA processes

• Box, G.E.P. and G.M. Jenkins (1976), *Time Series Analysis: Forecasting and Control*, 2nd ed. San Francisco: Holden Day.

• Gourieroux C. and A. Monfort (1997), *Time Series and Dynamic Models*. Cambridge: Cambridge University Press.

• Sargent, T. J. (1987), *Macroeconomic Theory*. Boston: Academic Press. (Chapters 9-11).

Estimation and forecasting

• Amemiya, Chapter 4.

• Clements, Michael P. and David F. Hendry (1998) Forecasting Economic Time Series, Cambridge: Cambridge University Press.

• Davidson, R. and J. G. MacKinnon, Chapter 8.

• Engle, R. F. (1984), "Wald, Likelihood Ratio, and Lagrange Multiplier Tests in Econometrics," Ch. 13 in Handbook of Econometrics, Vol. II, eds. Z. Griliches and M.D. Intrilligator, Amsterdam: North-Holland.

• Granger, C. W. J. and P. Newbold, (1986) Forecasting Economic Time Series. Academic Press.

• Granger, C. W. J. and Timo Terasvirta (1993) Modelling Nonlinear Economic Relationships, Oxford: Oxford University Press, Chapter 8.

• Greene, W. H. (1997) *Econometric Analysis, 4th Edition*. New Jersey: Prentice Hall. (Chapter 5).

• Diebold, F.X. (1998)**,** "The Past and Present of Macroeconomic Forecasting," *Journal of Economic Perspectives*, 12, 175-192.

• Diebold, F.X. and R.S. Mariano (1995)**,** "Comparing Predictive Accuracy," *Journal of Business and Economic Statistics*, 13, 253-265. Re-printed in *Journal of Business and Economic Statistics*, 20(1), 134-145, January 2002.

• Mark, N. (1995), "Exchange Rates and Fundamentals: Evidence on Long-Horizon Predictability," *American Economic Review.*

Asymptotic theory

• Davidson, James (1994) Stochastic Limit Theory, Oxford: Oxford University Press.

• White, Halbert (1999) Asymptotic Theory for Econometricians, Revised Edition. San Diego: Academic Press. Chapters 2-5

Unit roots

• Brockwell, P.J. and R. A. Davis. Time Series: Theory and Methods. Springer-Verlag.

• Davidson, J. (1994) Stochastic Limit Theory. Oxford; Oxford University Press.

• Dickey, D. A. and W. A. Fuller (1979), " Distribution Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association*, 74, 437-431.

• Fuller, W. A. Introduction to Statistical Time Series. Wiley series in Probability and Statistics. John Wiley.

• Phillips, P.C.B. (1986), "Time Series Regression with Unit Roots," *Econometrica*, 55, 227-302.

• Phillips, P.C.B. (1998), "New Tools for Understanding Spurious Regressions," *Econometrica*, 66, 1299-1236.

• Stock, J. H. (1994)**,** "Unit Roots, Structural Breaks, and Trends," *in Handbook of Econometrics*, Vol. IV, eds. D. McFadden and R. F. Engle. Amsterdam: North-Holland.

• Tanaka, Katsuto, (1996) Time Series Analysis. New York: John Wiley (Chapter 3 and Chapter 9).

• Campbell, J. and G. Mankiw (1987), "Are Output Fluctuations Transitory," *Quarterly Journal of Economics.*

• Clark. P.K. (1987), "The Cyclical Component of U.S. Economic Activity," *Quarterly Journal of Economics.*

• Cochrane, J. (1988), "How Big is the Random Walk Component in GNP," *Journal of Political Economy*, No. 5.

• Nelson, C.R. and C.I. Plosser (1982), "Trends and Random Walks in Macroeconomic Time Series: Some Evidence and Implications," *Journal of Monetary Economics*, 10, 139-162.

• Stock, J.S. and M.Watson (1988), "Variable Trends in Economic Time Series," *Journal of Economic Perspectives*, Vol 2, No. 3..

• Morley, J., C.R. Nelson and E. Zivot (2002), "Why are Beveridge Nelson and Unobserved Components Decompositions of GDP so Different?". Working paper, Department of Economics, University of Washington.

• Campbell, J.Y. and P. Perron (1991), "Pitfalls and Opportunities: What Macroeconomists Should Know About Unit Roots," *NBER Macroeconomics Annual*, Cambridge, MA: MIT Press.

• Phillips, P.C.B. and Z. Xiao (1997), "A Primer on Unit Root Testing," Cowles Foundation Discussion Paper.

• Stock, J.S. (1995), "Unit Roots and Trend Breaks", in *Handbook of Econometrics*, Vol 4.

• Zivot, E. and D.W.K. Andrews (1992), "Further Evidence on the Great Crash, the Oil Price Shock and the Unit Root Hypothesis," *Journal of Business and Economic Statistics* 10, 251-70. Re-printed in *Journal of Business and Economic Statistics*, 20(1), January 2002.

Covariance stationary vector autoregressions

• Demiralp S. and K. D. Hoover, (2000), "Structural VARs," U.C. Davis, manuscript.

• Den Haan, W. J. and A. Levin, (1997), " A Practioner's Guide to Robust Covariance Matrix Estimation," *Handbook of Statistics* 15 (Chapter 12, 291-341)

• *Den Haan, W. J. and A. Levin, (1996), " Inferences from Parametric and Non-Parametric Covariance Matrix Estimation Procedures," NBER Technical Working Paper 195. Both papers can be downloaded from: http://weber.ucsd.edu/~wdenhaan/papers.html

• *Engle, R. F., D. F. Hendry, and J.-F. Richard, (1983), "Exogeneity," *Econometrica*, 51, 277-305.

• Granger, C. W. J. (1980), "Testing for Causality: A Personal Viewpoint," *Journal of Economic Dynamics and Control*, 2, 329-352

• Granger, C. W. J. (1989), *Modelling Economic Series*, Oxford: Oxford University Press.

• Hendry, D. F. (1995), *Dynamic Econometrics*, Oxford: Oxford University Press.

• Hoover, K. D. and S. M. Sheffrin, (1992), " Causation, Spending, and Taxes: Sand in the Sandbox or Tax Collector for the Welfare State?" *American Economic-Review*, 82(1), 225-48.

• Newey W. N. and K. D. West (1987), "A Simple Positive Semi-Definite Heteroskedasticity and Autocorrelation Consistent Covariance Matrix," *Econometrica*, 55, 703-708.

• Reinsel, G. C. (1993), *Elements of Multivariate Time Series Analysis*, New York: Springer-Verlag.

• Swanson, N. R. and C. W. J. Granger, (1997), "Impulse Response Functions Based on a Causal Approach to Residual Orthogonalization in Vector Autoregressions," Journal of the American Statistical Association, 92(437), 357-367.

• Sims, C.A. (1980), "Macroeconomics and Reality," *Econometrica*, 48, 1-48.

• Sims, C.A. (1992), "Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy," *European Economic Review*.

• Blanchard, O.J. and D. Quah (1989)**,** "The Dynamic Effects of Aggregate Demand and Supply Disturbances," *American Economic Review*, 79, 655-673.

• Bernanke, B. (1986), "Alternative Explanations of the Money-Income Correlation," *Carnegie Rochester Conference Series on Public Policy*, 25, 49-99.

• Gali, J. (1992)**,** "How Well Does the ISLM Model Fit Postwar Data?" *Quarterly Journal of Economics* 107, 709-735.

• King, R.G. and M. Watson (1997), "Testing Long-Run Neutrality," Federal Reserve Bank of Richmond *Economic Quarterly*, Vol. 83/3.

• Stock and Watson (2001)**,** "Vector Autoregressions", Journal of Economic Perspectives, 15(4).

• Watson, M. (1995), "VARs and Cointegration" chapter 47 (section 4) in *Handbook of Econometrics,* Vol 4.

Cointegration

• Engle, R. F. and C. W. J. Granger, (1991)**,** *Long-Run Economic Relationships*, Oxford: Oxford University Press.

• Johansen, S. (1995), *Likelihood-Based Inference in Cointegrated Vector-Autoregressive Models*, Oxford: Oxford University Press.

• Sims, C. A., J. H. Stock and M. W. Watson, (1990)**,** "Inference in Time Series Models with some Unit Roots," Econometrica, 58, 113-44.

• Watson, M. W. (1994), "Vector Autoregressions and Cointegration," *in Handboof of Econometrics*, Vol. IV, eds. D. McFadden and R. F. Engle. Amsterdam: North-Holland.

• Campbell, J.Y. and P. Perron (1991)**,** "Pitfalls and Opportunities: What Macroeconomists Should Know About Unit Roots," *NBER Macroeconomics Annual*, Cambridge, MA: MIT Press.

• Stock, J.S. and M.Watson (1988), "Variable Trends in Economic Time Series," *Journal of Economic Perspectives*, Vol 2, No. 3.

State space modeling and the Kalman filter

• *Hamilton, J. D. (1994), "State-Space Models," in Handbook of Econometrics, Vol. IV, R. F. Engle and D. L. McFadden, eds. Amsterdam: North-Holland.

• Harvey, Andrew C. (1989), *Forecasting Structural Time Series Models and the Kalman Filter*. Cambridge: Cambridge University Press.