Department of Economics
University of Maryland

Fall 2025

Econ 721 - Econometrics III
(Section 0101)

Instructor:

John C. Chao	Office:	Tydings Hall, Room 3141
	Office Hours:	Tues/Thurs 2:30pm - 3:30pm (or by appointment)
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Lecture:

Tues/Thurs 3:30 - 4:45 pm, Tydings Hall, Room 2109

Course Overview:

This course covers selected topics in econometrics and statistics. Particular attention is paid to the following four topics: methods for analyzing non-stationary economic time series, Bayesian approaching for analyzing time series data, methods for factor analysis, and models of conditional heteroskedasticity. Throughout this course, there will be a focus on understanding the statistical properties of the methods being discussed.

Prerequisite:

Students are presumed to have had at least a one-semester course in mathematical statistics at the level of R.V.Hogg, A.Craig, and J.W.McKean, *Introduction to Mathematical Statistics (*7th Edition) as well as a strong background in linear algebra. Students are also assumed to have knowledge of the material covered in Econ 623 and Econ 624, including basic knowledge of asymptotic theory and of the linear regression model.

University Policies Regarding Graduate Courses

A guide to UMD policies towards graduate courses can be found at

https://gradschool.umd.edu/faculty-and-staff/course-related-policies

This link takes one to a graduate school website which lists official university policies with regard to such issues as academic integrity, grading disputes, sexual misconduct, non-discrimination policy, absences and accommodations, and so forth. In particular, the University of Maryland Code of Academic Integrity prohibits students from engaging in various forms of academic dishonesty including cheating, fabrication, plagiarism, self-plagiarism, and the facilitation of academic dishonesty. A complete statement of the University of Maryland Code of Academic Integrity can be downloaded at

https://policies.umd.edu/assets/section-iii/III-100A.pdf

Students with Disability

UMD guarantees appropriate accommodations for students with disabilities. If you require accommodations, please contact me as soon as possible. If you need further clarification, the link to Accessibility and Disability Service (ADS) is https://www.counseling.umd.edu/ads/

Lecture Slides

A copy of the lecture slides will be uploaded onto ELMS. They are made available for the sole purpose of helping students learn the course material. Students are not allowed to copy and/or distribute these slides without the instructor's permission.

Recommended Textbooks and References in Econometrics and Statistics:

Anderson, T. W. (1971). *The Statistical Analysis of Time Series*, New York: Wiley.

Anderson, T.W. (2003). *An Introduction to Multivariate Statistical Analysis*, (3rd Edition) New York: Wiley.

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

Brillinger, D. R. (1981). *Time Series: Data Analysis and Theory*, (2nd Edition), San Francisco: Holden Day.

Brockwell, P. J. and R. A. Davis (1993). *Time Series:Theory and Methods*, (2nd Edition) New York: Springer-Verlag.

Campbell, J., A. Lo, C. MacKinlay (1996). *The Econometrics of Financial Markets*, Princeton University Press.

Canova, F. (2007). *Methods for Applied Macroeconomic Research*, Princeton University Press.

Fuller, W. A. (1976). *Introduction to Statistical Time Series*, New York: Wiley.

Granger, C. W. T. and P. Newbold (1987). *Forecasting Economic Time Series*, (2nd Edition), New York: Academic Press.

Grenander, U. and M. Rosenblatt (1957). *Statistical Analysis of Stationary Time Series*, New York: Wiley.

Hamilton, J.D. (1994). *Time Series Analysis*, Princeton University Press.
(ISBN: 978-0-691-04289-3)

Hannan, E. J. (1970). *Multiple Time Series*, New York: Wiley.

Hannan, E. J. and M. Deistler (1988). *Statistical Theory of Linear Systems*, New York: Wiley.

Harvey, A. C. (1993). *Time Series Models*, (2nd Edition), Cambridge: MIT Press.

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

Hayashi, F. (2000). *Econometrics*, Princeton: Princeton University Press.

Johnston, J. and J. DiNardo (1997). *Econometric Methods*, 4th Edition, McGraw Hill.

G. G. Judge, et al. (1985). *The Theory and Practice of Econometrics*, 2nd Edition, John Wiley & Sons.

Lutkepohl, H. (1993). *Introduction to Multiple Time Series Analysis*, (2nd Edition), New York: Springer-Verlag.

Priestley, M. B. (1981). *Spectral Analysis and Time Series*, New York: Academic Press.

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

Robert, C.P. and G. Casella (2004). *Monte Carlo Statistical Methods*. Springer.

Tsay, R.S. (2010). *Analysis of Financial Time Series*, John Wiley & Sons.

Whittle, P. (1984). *Prediction and Regulation*, (2nd Edition) Oxford: Blackwell.

White, H. (2000). *Asymptotic Theory for Econometrician,* Revised Edition, Academic Press.

A. Zellner (1996). *An Introduction to Bayesian Inference in Econometrics.* Wiley-Interscience,.

Some Useful References in Probability:

The following books are good references for the asymptotic theory presented in this course.

Billingsley, P. (1968). *Convergence of Probability Measures*, New York: Wiley.

Hall, P. and C. C. Heyde (1980). *Martingale Limit Theory and Its Application*, New York: Academic Press.

Ibragimov, I. A. and Y. V. Linnik (1971). *Independent and Stationary Sequences of Random Variables*, Groningen: Wolters - Noordhoff.

Stout, W. F. (1974). *Almost Sure Convergence*, New York: Academic Press.

Pollard, D. (1984). *Convergence of Stochastic Processes*, New York: Springer-Verlag.

Course Outline and Reading List

1. Topics in Trending/Persistent Time Series (Univariate Case)

1a. Processes with Deterministic Time Trends

- Hamilton (1994): Chapter 16

1b Functional Limit Theory and Asymptotics for Integrated Processes

- Hamilton (1994): Chapter 17, Sec. 17.2-17.3; Chapter 18, Sec. 18.1.
- Billingsley (1958): Chapters 2 and 3.

1c. Unit Root Processes: Estimation and Hypothesis Testing

- Hamilton (1994): Chapter 17, Sec 17.1, 17.4-17.9.

- Andrews, D. W. K. (1993). "Exactly Median - Unbiased Estimation of First Order Autoregressive / Unit Root Models," *Econometrica*, 61, 139-165.
- Dickey, D. A. and W. A. Fuller (1979). "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association*, 74, 427-431.
- Dickey, D. A. and W. A. Fuller (1981). "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root," *Econometrica*, 49, 1057-1072.
- Elliot, G., T.J.Rothenberg, and J.H.Stock (1996). "Efficient Tests for an Autoregressive Unit Root," *Econometrica*, 64, 813-836.
- Mikusheva, A. (2007). "Uniform Inference in Autoregressive Models," *Econometrica*, 75, 1411-1452.
- Nelson, C.R. and C.I. Plosser (1982). "Trends and Random Walks in Macroeconomic Time Series," *Journal of Monetary Economics*, 129-162.
- Phillips, P. C. B. (1987). "Time Series Regression with a Unit Root," *Econometrica*, 55, 277-302.
- Phillips, P. C. B. and P. Perron (1987). "Testing for a Unit Root in Time Series Regression," *Biometrika*, 75, 335-346.
- Phillips, P.C.B. and V. Solo (1992). "Asymptotics for Linear Processes," *Annals of Statistics,* 20, 971-1001.
- Stock, J. H. (1991). "Confidence Intervals for the Largest Autoregressive Root in U. S. Macroeconomic Time Series," *Journal of Monetary Economics*, 28, 435-459.
- Stock, J.H. (1994). "Unit Roots and Trend Breaks," *Handbook of Econometrics Vol IV*, sections 1-4.

2. Topics in Trending/Persistent Time Series (Multivariate Case)

2a. Spurious Regression

- Hamilton (1994): Chapter 18, Sec. 18.
- Granger, C. W. J. and P. Newbold (1974). "Spurious Regression in Econometrics," *Journal of Econometrics*, 2, 111-120.
- Phillips, P. C. B. (1986). "Understanding Spurious Regressions in Econometrics," *Journal of Econometrics*, 33, 311-340.

2b Cointegration: Estimation, Testing, and Cointegrating Rank Determination

- Hamilton (1994): Chapter 18, Sec.18.1-18.2; Chapter 19, Sec. 19.1-19.3; Chapter 20.
- Tsay (2010): Chapter 8
- Chao, J.C. and P.C.B. Phillips (1999). "Bayesian Model Selection in Partially Nonstationary Vector Autoregressive Processes with Reduced Rank Structure," *Journal of Econometrics*, 91, pp. 227-271.
- Engle, R. F. and C. W. J. Granger (1987). "Cointegration and Error Correction: Representation, Estimation, and Testing," *Econometrica*, 55, 251-276.

- Johansen, S. (1988). "Statistical Analysis of Cointegrating Vectors," *Journal of Economic Dynamics and Contro*l, 12, 231-254.
- Johansen, S. (1991). "Estimation and Hypothesis Testing of Cointegrating Vectors in Gaussian Vector Autoregressive Models," *Econometrica*, 59, 1551-1580.
- Johansen, S. (1992). "Determination of Cointegrating Rank in the Presence of a Linear Trend," *Oxford Bulletin of Economics and Statistics*, 54, 383-397.
- Park, J. Y. and P. C. B. Phillips (1988). "Statistical Inference in Regressions with Integrated Processes: Part I," *Econometric Theory*, 4, 468-498.
- Park, J. Y. and P. C. B. Phillips (1989). "Statistical Inference in Regressions with Integrated Processes: Part II," *Econometric Theory*, 5, 95-132.
- Phillips, P. C. B. and S. Ouliaris(1990). "Asymptotic Properties of Residual Based Tests for Cointegration," *Econometrica*, 58, 165-193.
- Phillips, P. C. B. (1991). "Optimal Inference in Cointegrated Systems," *Econometrica*, 59, 238-306.
- Phillips, P. C. B. (1995). "Fully Modified Least Squares and Vector Autoregression," *Econometrica*, 53, 1023-1078.
- Stock, J.H. (1987). "Asymptotic Properties of Least Squares Estimators of Cointegrating Vectors," *Econometrica*, 55, 1035-1056.

3. Methods of Bayesian Inference and Bayesian Computation

a. Background on Bayesian Econometrics and Statistics
b. Background on Markov Chains
c. Basic Monte Carlo Integration
d. Importance Sampling
e. Markov Chain Monte Carlo
f. Empirical Bayes
g. Bayesian VAR
h. Bayesian Estimation of DSGE Models

- Zellner (1996): Chapters 2-4, 6 and 7
- Robert and Casella (2004): Chapters 2,3, 6, and 7
- Chib, S. and E. Greenberg (1995). "Understanding the Metropolis-Hastings Algorithm," *American Statistician*, 49, 327-335.
- Chib, S. and E. Greenberg (1996). "Markov Chain Monte Carlo Simulation Methods in Econometrics," *Econometric Theory*, 12, 409-431.
- Chib, S. "Markov Chain Monte Carlo Methods: Computation and Inference." In *Handbook of Econometrics*, Vol 5. Edited by J. J. Heckman and E. Leamer. Amsterdam: Elsevier Science.
- Doan, T., R. Litterman, and C.A.Sims (1984). "Forecasting and Conditional Projection Using Realistic Prior Distributions," *Econometric Reviews*, 3, 1-100.
- Litterman, R. (1986). "Forecasting with Bayesian Vector Autoregression: Five Years

of Experience," *Journal of Business and Economic Statistics*, 4, 25-38.

- Phillips, P.C.B. (1996). "Econometric Model Determination," *Econometrica*, 64, 763-812.
- Knox, T., J.H.Stock, and M.W.Watson (2000). "Empirical Bayes Forecasts of One Time Series Using Many Predictors," Working Paper, Kennedy School of Government, Harvard University.
- Del Negro, M., and F. Schorfheide. (2004). "Priors from General Equilibrium Models for VARs," *International Economic Review* 45, 643-673.
- Del Negro, M., F. Schorfheide, F. Smets, and R. Wouters (2007). "On the Fit and Forecasting Performance of New Keynesian Models," *Journal of Business and Economic Statistics*, 25, 123-143.
- Rabanal, P., and J. Rubio-Ramirez (2005). "Comparing New Keynesian Models of the Business Cycle: A Bayesian Approach," *Journal of Monetary Economics* 52, 1151-1166.
- Fernandez-Villaverde, J., and J. Rubio-Ramirez (2005). "Estimating Dynamic Equilibrium Economies: Linear Versus Nonlinear Likelihood." *Journal of Applied Econometrics* 20, 891-910.
- An, S. and F. Schorfheide (2007). "Bayesian Analysis of DSGE Models," *Econometric Reviews*, 26, 113-172.

4. ARCH/GARCH and Stochastic Volatility Models

a. AutoRegressive Conditional Heteroskedasticity (ARCH)
b. Generalized ARCH (GARCH)
c. Other Extensions of the ARCH Model
d. Stochastic Volatility Model

- Tsay (2010): Chapter 2
- Hamilton (1994): Chapter 21
- Bollerslev, T. (1986). "Generalized Autoregressive Conditional Heteroskedasticity," *Journal of Econometrics*, 31, 307-327.
- Bollerslev, T., R.Y. Chou, and K.F.Kroner (1992). "ARCH Modelling in Finance: A Review of the Theory and Empirical Evidence," *Journal of Econometrics*, 52, 5-59.
- Engle, R. F. and T. Bollerslev (1986). "Modelling the Persistence of Conditional Variances," *Econometric Reviews*, 5, 1-50.
- Bollerslev, T., R.F.Engle, and D.B.Nelson (1994). "ARCH Model," in *Handbook of Econometrics 4*, Engle, R.F. and D.L.McFadden (Eds.) New York: Elsevier Science; 2961-3031.
- Engle, R.F. (1982). "Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of United Kingdom Inflation," *Econometrica*, 50, 987-1007.
- Engle, R.F. (2001). "GARCH 101: An Introduction to the Use of ARCH/GARCH Models in Applied Econometrics," *Journal of Economic Perspectives*, 15, 157-168.
- Engle, R.F. (2002). "New Frontiers for ARCH Models," *Journal of Applied*

Econometrics, 17, 425-446.
- Engle, R.F. (2004). "Risk and Volatility: Econometric Models and Financial Practice," *American Economic Review*, 94, 405-420.
- Poon, S.-H. and C.W.J. Granger (2003). "Forecasting Volatility in Financial Markets: A Review," *Journal of Economic Literature*, 41, 478-539.
- Ait-Sahalia, Y. and R. Kimmel (2007). "Maximum Likelihood Estimation of Stochastic Volatility Models," *Journal of Financial Economics*, 83, 413-452.
- Andersen, T.G., T. Bollerslev, and F.X.Diebold (2002). "Parametric and Nonparametric Volatility Measurement," in: *Handbook of Financial Econometrics*, Ait-Sahalia, Y. and L.P.Hansen (Eds.) Amsterdam: North-Holland.
- Andersen, T.G., T.Bollerslev, F.X.Diebold, and P. Labys (2003). "Modeling and Forecasting Realized Volatility," *Econometrica*, 71, 579-625.
- Barndorff-Nielsen, O.E. and N. Shephard (2004). "Econometric Analysis of Realized Covariation: High Frequency Based Covariance, Regression, and Correlation in Financial Economics," *Econometrica*, 72, 885-925.
- Broto, C. and E.Ruiz (2004). "Estimation Methods for Stochastic Volatility Models: A Survey," *Journal of Economic Surveys*, 18, 613-649.
- Jacquier, E., N. G. Polson and P. E. Rossi (1994). "Bayesian Analysis of Stochastic Volatility Models," *Journal of Business and Economic Statistics*, 12, pp. 371-89.
- Kim, S., N.Shephard, and S.Chib (1998). "Stochastic Volatility Likelihood Inference and Comparison with ARCH Models," *Review of Economic Studies*, 65, 361-393.

5. Factor Analysis and Related Techniques for Multivariate Data Analysis

a. Principal Components
b. Factor Models
c. EM Algorithm

- Tsay (2010): Chapter 9
- Anderson (2003): Chapters 11-14.
- Bai, J. and S. Ng (2002). "Determining the Number of Factors in Approximate Factor Models," *Econometrica*, 70, 191-221.
- Bai, J. (2003). "Inferential Theory for Factor Models of Large Dimensions," *Econometrica*, 71, 135-171.
- Bernanke, B.S. and J.Boivin (2003). "Monetary Policy in a Data-Rich Environoment," *Journal of Monetary Economics*, 50, 525-546.
- Bernanke, B. S., J. Boivin, and P. Eliasz (2005). "Measuring the Effects of Monetary Policy: A Factor-augmented Vector Autoregressive (FAVAR) Approach," *Quarterly Journal of Economics*, 120, 384-387.
- Forni, M., M. Hallin, M. Lippi, and L. Reichlin (2000). "The Generalized Factor Model: Identification and Estimation," *Review of Economics and Statitsics*, 82, 540-552.

- Alessi, L., M. Barigozzi, and M. Capasso (2010). "Improved Penalization for Determining the Number of Factors in Approximate Factors Models," *Statistics and Probability Letters*, 80, 1806-1813.
- Stock, J.H. and M.W.Watson (2010). "Dynamic Factor Models," Working Paper, Department of Economics, Harvard University.
- Stock, J. and M. Watson (2002). "Macroeconomic Forecasting Using Diffusion Indexes,@ *Journal of Business and Economic Statistics*, 20, 147-162.
- Dempster, A.P., N.M. Laird, and D.B.Rubin (1977). "Maximum Likelihood from Incomplete Data via the EM Algorithm," *Journal of the Royal Statistical Society, Series B*, 39, 1-38.

6. Methods of Forecasting

a. Principles of Forecasting
b. Forecast Evaluation
c. Bayesian and Frequentist Model Averaging
d. Bagging

- Hamilton (1994): Chapter 4
- Diebold, F.X. and R.S.Mariano (1995). "Comparing Predictive Accuracy," *Journal of Business and Economic Statistics*, 13, 253-263.
- West, K.D. (1996). "Asymptotic Inference about Predictive Ability," *Econometrica*, 64, 1067-1084.
- White, H. (2000). "A Reality Check for Data Snooping," *Econometrica*, 68, 1097-1126.
- Giacomini, R. and H.White (2006). "Tests of Conditional Predictive Ability," *Econometrica*, 74, 1545-1578.
- Hoeting, J., D. Madigan, A.R.Raftery, C.T.Volinsky (1999). "Bayesian Model Averaging: A Tutorial," *Statistical Science*, 14, 382-401.
- Hansen, B.E. (2007). "Least Squares Model Averaging," *Econometrica*, 75, 1175-1189.
- Hansen, B.E. (2008). "Least Squares Forecast Averaging," *Journal of Econometrics*, 146, 342-350.
- Sala-i-Martin, X., G. Doppelhofer, and R. Miller (2004). "Determinants of Long-Term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach," *American Economic Review*, 94, 813-835.
- Wright, J.H. (2008). "Bayesian Model Averaging and Exchange Rate Forecasting," *Journal of Econometrics*, 146, 329-341.
- Inoue, A. and L.Kilian (2008). "How Useful Is Bagging in Forecasting Economic Time Series: A Case Study of U.S. CPI Inflation," *Journal of the American Statistical Association*, 103, 511-522.

7. Time Series Models of Regime Switching

- Hamilton (1994): Chapter 22
- Hamilton, J.D. (1989). "A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle," *Econometrica*, 57, 357-384.
- Lam, P. (1990). "The Hamilton Model with a General Autoregressive Component Estimation and Comparison with Other Models of Economic Time Series," *Journal of Monetary Economics*, 26, 409-432.
- Diebold, F. X., J-H Lee, and G. C. Weinbach (1994). "Regime Switching with Time-Varying Transition Probabilities," in C. Hargreaves, ed., *Nonstationary Time Series Analysis and Cointegration*, Oxford: Oxford University Press.
- Kim, C. J. (1994). "Dynamic Linear Models with Markov Switching," *Journal of Econometrics*, 60, 1-22.
- Hamilton, J. D. (1996), "Specification Testing in Markov-Switching Time Series Models," *Journal of Econometrics*, 70, 127-157.
- Timmermann, A. (2000). "Moments of Markov Switching Models," *Journal of Econometrics*, 96, 75-111.
- Chauvet, M. and J. D. Hamilton (2005). "Dating Business Cycle Turning Points," in *Nonlinear Analysis of Business Cycle*, edited by Costas Milas, Philip Rothman, and Dick van Dijk, Elsevier.
- Pesaran, H., D. Pettenuzzo, and A. Timmermann (2006). "Forecasting Time Series Subject to Multiple Structural Breaks," *Review of Economic Studies*, 73, 1057-1084.
- Smith, A. (2012). "Markov Breaks in Regression Models," *Journal of Time Series Econometrics*, 4: Article 3.

Grading for Econ 721:

The course grade will be based on an empirically-oriented term paper. It is due by 5:00pm on Friday, December 19, 2025.