Economics 871
Time Series Analysis

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Office Hours
M,W 10am-11am

Prerequisites
1. Economics 770 (Introduction to Econometric Theory)
2. Economics 771 (Econometrics)
3. Graduate level probability theory and mathematical statistics (usually obtained through 1 and 2).

Objectives
This course is concerned with modeling information over time from statistical, mathematical and economic perspectives. Economic information over time exhibits stylized characteristics: 1. *persistence*: values today are weakly-to-highly dependent on values in the near-to-distant past (e.g. output, investment, equity returns); 2. *nonlinearity*: the relationship between economic variables over time is often nonlinear based on forecasting principles and/or economic rational (e.g. exchange rates); 3. *heterogeneity* and *non-stationarity*: attributes of economic events evolve or suddenly change over time (e.g. output; shock to investment trend); 4. *conditional heteroscedasticity*: volatility in macroeconomic and financial variates cluster (e.g. equity returns); 5. *leptokurtosis*: many economic time series have too many large values to be modeled by a Gaussian distribution, and many suggest extremely heavy distribution tails (infinite fourth or even second moment: asset returns).

All of these properties alone, or in combination, imply standard modeling and estimation techniques, and accompanying large sample theory, are either more difficult to verify, or simply do not apply. We begin by studying formal concepts of memory, from the very abstract (mixing, regularity, ergodocity, near-epoch-dependence) to more concrete notions (autocovariance). We will use the concrete concepts (autocovariance) to construct linear and nonlinear parametric time series models (Autoregressive Moving Averages:ARMA, Vector Autoregression: VAR, Generalized Autoregressive Conditional Heteroscedasticity: GARCH), and use the abstract concepts to analyze the small and large sample properties of parameter estimators (Ordinary Least Squares, Nonlinear Least Squares, Quasi-Maximum Likelihood).

Evaluation
There will be one midterm exam (30%), a final exam (40%), and an assortment of assignments based on econometric theory and computer applications (30%). While students may consult with each other, each must turn in his or her own work.

Reading and Textbooks

Required Reading
Time Series Analysis by J. D. Hamilton, 1994, Princeton University Press.

Suggested Textbook Reading

Time Series: Theory and Methods, by P. J. Brockwell and R. Davis (1991), Springer Verlag.
Introduction to Multiple Time Series Analysis by Helmut Lutkepohl (1991), Springer Verlag.
Forecasting by M.P. Clements and D.F. Hendry (2000), Cambridge Univ. Press.
Analysis of Financial Time Series by R. Tsay (2002), Wiley.
ARCH Models and Financial Applications by C. Gourieroux (1997), Springer.
The Econometric Modeling of Financial Time Series by T.C. Mills (1996), Cambridge.
Stochastic Limit Theory, by James Davidson (1994), Cambridge University Press.
Asymptotic Theory for Econometricians by Halbert White (1999), Academic Press.
Asymptotic Theory of Statistic Inference for Time Series by M. Taniguchi and Y. Kakizawa (2000).
Financial Modeling under Non-Gaussian Distributions by E. Jondeau, S-H.Poon, M. Rockinger (2006).

Topics (*these many change during the course of the semester***)**	**Readings**[1]
1. Stationarity, ergodicity, dependence concepts, limit theory for linear processes	L; D 1, 13; B 1; W 2; **P 1** [2]
2. Autocorrelation function: theory, estimation, asymptotics, inference.	**H 3, 7**; B 3, 7; **P 2**
3. Stationary ARMA: representation, spectrum, QML estimation, forecasting, asymptotic theory	**H 1-5, 7, 14**; **P 3** B 8; D 13-20, 23-24, CH all.
4. Spectral analysis (time and frequency domain decompositions)	**H 6**; B 4
5. Kalman Filter - State Space representations, ARMA	**H 13**
6. Regression Models with Dependent Regressors (ARX, NLARX)	**H 8**; W 3, 5; **P 4**
7. Model specification testing: martingale difference hypothesis, linearity.	B 9; **[P 5**]
8. Non-Stationarity: Trend, Unit Roots, Cointegration	**H 15-17, 19; P 6**
9. Random volatility models: GARCH, Stochastic Volatility	**H 21, G; P 7**
10. Vector Autoregressions: estimation, asymptotic theory, cointegration.	**H 11; P 8**

Journal Papers

1. Asymptotic Theory

Laws of Large Numbers for Dependent Non-Identically Distributed Random Variables, by D.W.K. Andrews, *Econometric Th.*, 4 (1988), 458-467.
Consistency in Nonlinear Econometric Models: A Generic Uniform Law of Large Numbers, by D.W.K. Andrews, *Econometrica*, 55 (`1992), 1465-1471.
The Lindeberg-Lévy Theorem for Martingales, P. Billingsley, *Proc. Amer. Math. Soc.*, 12 (1961), 788-792.
Some Limit Theorems for Stationary Processes, I. A. Ibragimov *Th. Prob. Appl.*, 7 (1962), 349-382.
A Maximal Inequality and Dependent Strong Laws, D. L. McLeish, *An. Prob.*, 3 (1975), 829-839.

2. Serial Correlation, Q-Test, White Noise Tests

Distribution of Residual Autocorrelations in Autoregressive-Integrated Moving Average Time Series Models, G.E.P. Box and D.A. Pierce *J. Am. Stat. Assoc.*, 65 (1970), 1509-1526.
The Asymptotic Distribution of Serial Covariances, by E.J. Hannan, *Ann. Stat.* 4 (1976), 396-399.

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[1] Readings from Hamilton (**H**) and journal papers groups (**P**) are mandatory. All other suggested readings are based on the bibliography above. Davidson and White provide theoretical underpinnings of ideas developed in the lecture notes, but keep in mind that the lecture notes are just a sketch of some ideas.
[2] H = Hamilton (required reading); P = paper groups (required reading); L = lecture notes (suggested); D = Davidson; W = White; B = Brockwell and Davis; CH = Clements and Hendry (forecasting); G = Gourieroux.

Bootstrapping the Box-Pierce Q Test: A Robust Test of Uncorrelatedness, by J.L. Horowitz, I.N. Lobato, J.C. Nankervis, and N.E. Savin, *J. Econometrics*, 133 (2006), 841-862.
A Bootstrap-Assisted Spectral Test of White Noise under Unknown Dependence, by X. Shao, *J. Econometrics*, 162 (2011), 213-224.

3. ARMA Models in Practice, Bootstrapping SE's
Macroeconomic Forecasting Using Pooled International Data, by S. Mittnik, *J. Bus. Econ. Stat.* 8 (1990), 205-208.
Premia in Forward Foreign Exchange as Unobserved Components: A Note, by E. Nijman, F. Palm and C.P. Wolff, *J. Bus. Econ. Stat.*, 11 (1993), 361-365.
Bootstrapping Autoregressions with Conditional Heteroskedasticity of Unknown Form, by Goncalves, S. and Killian, *J. Econometrics* (2004) 123, 89-120.
Bootstrao Standard Error Estimates for Linear Regression, by Goncalves, S. and White, H., *J. Amer. Stat. Assoc*. (2005) 100, 970-979.

4. Regression Models with Dependent Regressors
National Savings and Budgets, R. Eisner, *Rev. Econ. Stat.* 76 (1994), 181-186
Predictions From ARMAX Models, R. Baillie, *J. Econometrics* 12 (1980), 365--374.
ARMAX Model Specification Testing, with an Application to Unemployment in the Netherlands, by H.J. Bierens, *J. Econometrics* 35 (1987), 161-190.

5. Model Specification Testing
Nonlinear Time-Series Analysis of Stock Volatilities, by C.Q. Cao and R.S.Tsay, *J. Appl. Econometrics* 7 (1992), S165-S185.
A Consistent Conditional Moment Test of Functional Form, by H.J. Bierens, *Econometrica* 58 (1990), 1443-1458.
Inference When a Nuisance Parameter Is Not Identified Under the Null Hypothesis, by. B. Hansen, *Econometrica* 64 (1996), 413-430.

6. Non-Stationarity
Time Series Regression with a Unit Root, by P.C.B. Phillips, *Econometrica* 55 (1987), 277-301.
Towards a Unified Asymptotic Theory for Autoregression, by P.C.B. Phillips, *Biometrika* 74 (1987), 535-547.
Testing for a Unit Root in Time Series Regressions, by P.C.B. Phillips and P. Perron, *Biometrika* 75 (1988), 335-346.
Co-Integration and Error Correction: Representation, Estimation, and Testing, by R. Engle and C. Granger, *Econometrica* 55 (1987), 251-276.
Some Properties of Time Series Data and Their Use in Econometric Model Specification, by C. Granger, *J. Econometrics* 16 (1981), 121-130.

7. GARCH and Stochastic Volatility
Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation, by R. Engle, *Econometrica* 50 (1982), 987-1007.
Generalized Autoregressive Conditional Heteroskedasticity, by T. Bollerslev, *J. Econometrics* 31, (1986), 307-327
ARCH Models, by R. Engle, D. Nelson and T. Bollerslev, in *Handbook of Econometrics*, Volume IV, ed. R. Engle and D. McFadden (Amsterdam: North Holland, 1994), 2959-3038.
New Frontiers in ARCH Models, by R. Engle, *J. Appl. Econometrics*, (2002): 425-446.
Nonlinear Features of Realized FX Volatility, by J.M. Maheu; T.H. McCurdy, *Rev. Econ. Stat.*, 84 (2002), 668-681.
Fractionally Integrated GARCH, by R.T. Baillie, T. Bollerslev and H.O. Mikkelsen, *J. Econometrics* 74 (1996), 3-30.

8 VAR's
Short Run and Long Run Causality in Time Series: Theory, by J.M. Dufour and E. Renault, *Econometrica* 66 (1998), 1099-1125.
Long-Run Neutrality and Superneutrality in an ARIMA Framework, by M.E. Fisher and J.T. Seater, *Amer. Econ. Rev.* 83 (1993), 402-415.