14.384. Time Series Analysis
Fall, 2007
Anna Mikusheva

Meeting time and location: Tue., Thu., 2.30-4p.m., E25-117
Recitations: Fri 4-5.30pm, E51-390
Instructor: Anna Mikusheva
E52-262b, (617) 324-5459, amikushe@mit.edu
Office Hours: Tuesdays, noon-2 p.m. and by appointment
Feel free to stop by my office whenever I am in (6am-4pm, except Thurs).
TA: Paul Schrimpf, paul_s@mit.edu
Office Hours:TBA

Course Description
The course provides a survey of the theory and application of time series methods in econometrics. Topics covered will include univariate stationary and non-stationary models, vector autoregressions, frequency domain methods, models for estimation and inference in persistent time series, structural breaks. We will cover different methods of estimation and inferences of modern dynamic stochastic general equilibrium models (DSGE): simulated method of moments, Maximum likelihood and Bayesian approach. The empirical applications in the course will be drawn primarily from macroeconomics.

Goals:
The main objective of this course is to develop the skills needed to do empirical research in fields operating with time series data sets. The course aims to provide students with techniques and receipts for estimation and assessment of quality of economic models with time series data. Special attention will be placed on limitations and pitfalls of different methods and their potential fixes. The course will also emphasize recent developments in Time Series Analysis and will present some open questions and areas of ongoing research.

Grading
Final grades will be based on several (probably around 6) problem sets (60% weight), and a final exam (40% weight). The problem sets will emphasize different aspects of the course, including theory and estimation procedures we discuss in class. I strongly believe that the best way to learn the techniques is by doing. Every problem set will include an applied task that may include computer programming. I do not restrict you in your choice of computer language. I also do not require you to write all programs by yourself from scratch. You may use user-written parts of codes you find on the Internet, but I do require that you understand the program you use and properly document it with all needed citations of original sources. Collaboration with other students on problem sets is encouraged, however, the problem sets should be written independently.

If you are Economics PhD student, your econometrics paper requirement could be fulfilled by turning in a research paper on a topic related to material covered in the class. The paper is due at the end of IAP. The paper should be empirical.

Textbooks and Readings

The primary text is Hamilton (1994). Most of the readings for the later parts of the course are journal articles. The course overviews a large literature, so not all topics are treated in the same depth, and only a few references listed under a topic will be covered. The other papers are additional references for those who wish to study specific topics in greater detail. The lectures will be self-contained.

Books:

Required:

Hamilton, James D., *Time Series Analysis*, Princeton University Press, 1994, ISBN 0691042896, MIT library call number QA280.H264.

Recommended:

Brockwell Peter, J. and Davis Richard A. (1991), *Time Series: Theory and Methods*, New York: Springer-Verlag, ISBN 0387974296, Call number QA280.B76.

Canova, Fabio, *Methods for Applied Macroeconomic Research*, Princeton University Press, 2007.

DeJong, David N. and Chetan Dave (2007), *Structural Macroeconometrics*, Princeton University Press.

Hall P. and Heyde C.C. (1980), *Martingale Limit Theory and Its Application*, New York: Academic Press, ISBN 0123193508, MIT call number QA274.5.H34.

Zvi Griliches and Michael D. Intriligator (eds.) (1983-2001), *Handbook of Econometrics, Vol. IV*, Elsevier Science Publishing Company, ISBN 0444861882, MIT call number HB139.H36.

Lütkepohl, H. (1993), *Introduction to Multiple Time Series Analysis*, New York: Springer-Verlag, ISBN 0387569405, MIT call number QA280.L87.

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I am extremely grateful to Jim Stock (Harvard), Rustam Ibragimov (Harvard), Frank Schorfheide (UPenn) and Barbara Rossi (Duke) for their advice and permission to use their course materials.

The last but not the least:

Your feedback is highly valuable. Please, speak up if you have suggestions on how the course can be improved.

Course Outline

Asterisked references are more important to the course. The following is a tentative list of topics that will be covered in this course. I reserve the right to add (hardly possible) or delete (very likely) topics as the course progresses.

I. Introduction. Stationary time series.

- **Introduction to stationary time series:** *ARMA, limit theory for stationary time series, causal relationships, HAC*

*Hamilton, Chs. 1-5, 7, 8.

*Hall and Heyde, Ch 3.

Brockwell and Davis, Chs. 1, 3, Sect. 5.7.

*Newey, W.K. and West, K.D. (1987). "A simple positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix," *Econometrica* **55**, 703-708.

*Andrews, D.W.K. (1991). "Heteroskedasticity and autocorrelation consistent covariance matrix estimation," *Econometrica* **59**, 817-858.

Beveridge, S. and Nelson, C.R. (1981). "A new approach to decomposition of economic time series into permanent and transitory components with particular attention to measurement of the 'business cycle'," *Journal of Monetary Economics* **7**, 151-174.

Andrews, D.W.K. and Monahan, J.C. (1992). "An improved heteroskedasticity and autocorrelation consistent covariance matrix estimator," *Econometrica* **60**, 953-966.

den Haan, W.J. and Levin, A. (1997). "A practitioner's guide to robust covariance matrix estimation," in Maddala, G.S. and Rao, C.R. (Eds), *Handbook of Statistics* **15**, Ch. 12, 291-341.

Kiefer, N. and Vogelsang, T. (2002). "Heteroskedasticity-autocorrelation robust testing using bandwidth equal to sample size," *Econometric Theory* **18**, 1350-1366.

- **Frequency Domain Analysis**: *spectra; filters; transforms; nonparametric estimation*

*Hamilton, Ch. 6.

Brockwell and Davis, Chaps. 4 and 10.

*Baxter, M. and King, R. (1999). "Measuring business cycles: approximate band-pass filters for economic time series," *Review of Economics and Statistics*, **81**, 575-593.

Berk, K.N. (1974). "Consistent autoregressive spectral estimates," *Annals of Statistics* **2**, 489-502.

Hodrick, R. and Prescott, E. (1997). "Post-war US business cycles: an empirical investigation," *Journal of Money Banking and Credit* **29**, 1-16.

Christiano, L.J., and Fitzgerald, T.J. (1999). "The band pass filter," NBER Working Paper 7257, httpf/www.nber.orglpapers/w7257.

- **Model selection and information criteria:** *consistent estimation of number of lags, discussion of non-uniformity and post-selection inferences*

*Geweke, J. and Meese, R. (1981). "Estimating regression models of finite but unknown order," *International Economic Review* **22**, 55-70.

Ng, S. and Perron, P. (2005). "A note on the selection of time series models," *Oxford Bulletin of Economics and Statistics* **67:1**, 115-134.

Leeb, H. and Potscher, B.M. (2005). "Model selection and inference: facts and fiction," *Econometric Theory* **21**, 21–59.

Leeb, H. and Potscher, B.M. (2003). "The finite-sample distribution of post-model-selection estimators and uniform versus nonuniform approximations," *Econometric Theory* **19**, 100–142.

Hansen, B. (2005). "Challenges for econometric model selection," *Econometric Theory* **21**, 60-68.

Kuersteiner, G.M. (2005). "Automatic inference for infinite order vector autoregressions," *Econometric Theory* **21**, 85-115.

II. Mutivariate stationary analysis

- **VAR**: *definition, estimation: OLS, ML, Granger causality, Impulse response functions and variance decompositions*

  *Hamilton, Chaps. 10, 11

  *Lütkepohl, H. (2005), Chaps. 2, 3

  Canova, F. (2006), Ch. 4

  Lütkepohl, H. and M. Kratzig (2004), Ch. 4

Watson, M. (1994). "Vector autoregressions and cointegration," *Handbook of Econometrics*, vol IV, chapter 47.

Stock, J.H. and Watson, M.W. (2001). "Vector autoregressions," *Journal of Economic Perspectives* **15:**4, 101-116.

Wright, J.H. (2000). "Confidence intervals for univariate impulse responses with a near unit root," *Journal of Business and Economic Statistics* **18**, 368-373.

Killian, L. (1998). "Small sample confidence intervals for impulse response functions," *Review of Economics and Statistics*, 218-230.

- **Structural VARs:** *Identification, short term restrictions, long-term restrictions*

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

*Blanchard, O.J. and Quah, D. (1989). "Dynamic effects of aggregate demand and supply disturbances," *American Economic Review* 7**9**, 655-673.

Blanchard, O.J. (1989). "A traditional interpretation of economic fluctuations," *American Economic Review* **79**, 1146-1164.

King, R.G., Plosser, C. I., Stock, J.H. and Watson, M.W. (1991). "Stochastic trends and economic fluctuations," *American Economic Review* **81**, 819-840.

Cooley, T. and LeRoy, S. (1985). "A theoretical macroeconomics: A critique," *Journal of Monetary Economics* **16**, 283-308.

Braun, P. and Mittnik, S. (1993). "Misspecification in VAR and their effects on impulse responses and variance decompositions," *Journal of Econometrics*, 59, 319-341.

Cooley, T. and Dwyer, M. (1998). "Business cycle analysis without much theory: A look at structural VARs," *Journal of Econometrics* **83**, 57-88.

- **VAR and DSGE models:** *World decomposition, fundamentality of shocks, do long-run restrictions identify anything?*

Chari, V., Kehoe, P. and McGrattan, E. (2005). "A critique of structural VARs using business cycle theory," Federal Reserve Bank of Minneapolis, Research Department Staff Report 364.

*Christiano, L., Eichenbaum, M. and Vigfusson, R. (2005). "Assessing structural VARs," Northwestern University, manuscript.

*Fernandez Villaverde, J., Rubio Ramirez, J. and Sargent, T. (2005). "The ABC and (D's) to understand VARs," NYU manuscript.

Erceg, C, Guerrieri, L. and Gust, C. (2005). "Can long run restrictions identify technology shocks?" Board of Governors of the Federal Reserve, International Finance discussion paper, 792.

Lippi, M. and Reichlin, L., (1994). "VAR analysis, non-fundamental representation, Blaschke matrices", *Journal of Econometrics* **63**, 307- 325.

Faust, J. and Leeper, E. (1997). "Do long run restrictions really identify anything?" *Journal of Business and Economic Statistics* **15**, 345-353.

- **Factor model and FAVAR:** *Motivation, Principal components, choosing number of static and dynamic factors, structural FAVAR, IV regression with factors.*

*Stock, J.H. and Watson, M.W. (2005). "Implications of dynamic factor models for VAR analysis," NBER Working Paper 11467.

Bernanke, B.S. and Boivin, J. (2003). "Monetary policy in a data-rich environment," *Journal of Monetary Economics* **50**: 525-546.

*Bernanke, B.S., Bovian, J. and Eliasz, P. (2005). "Measuring the effects of monetary policy: a factor-augmented vector autoregressive (FAVAR) approach," *Quarterly Journal of Economics* **120**: 387-422**.**

*Forni, M., Giannoni, D., Lippi, M. and Reichlin, L. (2007), "Opening the black box: structural factor models with large cross-sections," European Central Bank, working paper #712.

Chamberlain, G. and Rothschild, M. (1983). "Arbitrage, factor structure and mean-variance analysis of large asset markets," *Econometrica* **51**, 1281-1304.

Favero, C.A., Marcellino, M. and Neglia, F. (2005). "Principal components at work: the empirical analysis of monetary policy with large datasets," *Journal of Applied Econometrics* **20**: 603–620.

Forni, M., Hallin, M., Lippi, M. and Reichlin, L. (2000), "The generalized factor model: identification and estimation," *Review of Economics and Statistics* 82: 540–554.

Bai, J., and Ng, S. (2002). "Determining the number of factors in approximate factor models," *Econometrica* **70**: 191-221.

Bai, J. and Ng, S. (2005b). "Determining the number of primitive shocks in factor models," *forthcoming, Journal of Business Economics and Statistics.*

*Bai, J. and Ng, S. (2006). "Instrumental variable estimation in a data rich environment," manuscript.

III. Univariate non-stationary processes

- **Asymptotic theory of empirical processes**:

*Hamilton, Sections 17.1-17.3

Hall and Heyde, Chaps. 3, 4, and 5 and the Appendix.

- **Univariate unit roots and near unit root problem:** *unit root testing, confidence sets for persistence, tests for stationarity*

*Hamilton, Ch. 17

*Stock, J.H. (1994). "Unit roots and trend breaks in econometrics," *Handbook of Econometrics*, Vol. IV, 2740-2841 (sections 1-4).

Dickey, D.A. and Fuller, W.A. (1979). "Distribution of the estimators for autoregressive time series with a unit root," *Journal of the American Statistical Association* 7**4**, 427-431.

Campbell, J.Y. and Perron, P. (1991). "Pitfalls and opportunities: what macroeconomists should know about unit roots," *NBER Macroeconomics Annual*, Vol. 6., pp. 141-201.

Andrews, D.W.K. (1993). "Exactly median-unbiased estimation of first order autoregressive/unit root models," *Econometrica* **61(1)**, 139-165.

Hansen, B.E. (1999). "The grid bootstrap and the autoregressive model," *Review of Economics and Statistics* **81(4)**, 594-607.

*Phillips, P.C.B. (1987). "Toward a unified asymptotic theory for autoregression," *Biometrika* **74(3)**, 535-547.

Stock, J. (1991). "Confidence intervals for the largest autoregressive root in US macroeconomic time series," *Journal of Monetary Economics* **28**, 435-459.

Mikusheva, A. (2007). "Uniform inference in autoregressive models," *Econometrica,* **75(5).**

- **Structural breaks and non-linearity:** *testing for breaks with known and unknown dates, multiple breaks, estimating number of breaks*

*Hamilton (1994), Ch. 22.

*Andrews, D.W.K. (1993). "Tests for parameter instability and structural change with unknown change-point," *Econometrica* **61**, 821-856.

*Hansen, B.E. (2001). "The new econometrics of structural change: dating breaks in U.S. labor productivity," *Journal of Economic Perspectives* **15**, 117-128.

*Perron, P. (1989). "The great crash, the oil price shock, and the unit root hypothesis," *Econometrica* **57**, 1361-1401.

Andrews, D.W.K. and Ploberger, W. (1994). "Optimal tests when a nuisance parameter is present only under the alternative," *Econometrica* **62**, 1383-1414.

Bai, J. S. (1997). "Estimating multiple breaks one at a time," *Econometric Theory* **13**, 315-352.

Bai, J. and Perron, P. (1998). "Estimating and testing linear models with multiple structural changes," *Econometrica* **66**, 47-78.

Bai, J., Lumsdaine, R.L. and Stock, J.H. (1998). "Testing for and dating common breaks in multivariate time series," *Review of Economic Studies* **65**, 395-432.

Zivot, E. and Andrews, D.W.K. (1992). "Further evidence on the great crash, the oil price shock, and the unit root hypothesis," *Journal of Business and Economic Statistics* **10**, 251-270.

IV. Multivariate non-stationary

- **Multivariate unit roots and co-integration:** *estimating cointegration relations, canonical form*

Stock, J.H. (1987). "Asymptotic properties of least squares estimators of cointegrating vectors," *Econometrica* **55**, 1035-1056.

Stock, J.H. and Watson, M.W. (1993). "A simple estimator of cointegrating vectors in higher order integrated systems," *Econometrica* **61**, 783- 820.

*Watson, M.W. (1994). "Vector autoregressions and cointegration," *Handbook of Econometrics*, v. IV, 2844-2915 (sections 1 and 2).

- **Persistent regressors (prediction regression)** *limit theory, Stambaugh correction, nuisance parameter problem, conservative procedures, conditional procedures*

Bekaert, G. and Hodrick, R.J. (2001). "Expectations hypotheses test," *Journal of Finance* **56**, 1357-94.

Campbell, J.Y. and Yogo, M. (2006). "Efficient tests of stock return predictability," *Journal of Financial Economics* **81**, 27-60.

*Cavanagh C.L., Elliott, G. and Stock, J.H. (1995). "Inference in models with nearly integrated regressors," *Econometric Theory* **11**, 1131-1147.

Lewellen, J. (2004). "Predicting returns with financial ratios," *Journal of Financial Economics* **74,** 209-235.

*****Stambaugh, R.F. (1999). "Predictive regressions," *Journal of Financial Economics* **54**, 375-421.

Torous, W., Valkanov, R. and Yan, S. (2004). "On predicting stock returns with nearly integrated explanatory variables," *Journal of Business* **77,** 937-966.

Jansson M. and Moreira, M.J. (2006) "Optimal inference in regression models with nearly integrated regressors," *Econometrica* **74(3)**, 681-715.

V. Simulated GMM

- **GMM and Simulated GMM:** *GMM estimation and asymptotic theory, testing in GMM setting, simulated method of moments and time series specifics: estimation of covariance structure, initial condition problem, indirect inference*

*Hamilton, Chap. 14

*DeJong and Dave, Ch. 7

Canova, Ch. 5

*Hansen, L.P. (1982). "Large sample properties of GMM estimators," *Econometrica* 50, 1029-1054.

*Hansen, L.P. and Singleton, K. (1982). "Generalized instrumental variables estimation of nonlinear rational expectations models," *Econometrica* **50**, 1269-1286. (*corrigenda*, 1984).

Mc Fadden, D. (1989). "A method of simulated moments of estimation for discrete response models without numerical integration," *Econometrica*, 57, 995-1026.

Pakes, A. and Pollard, D. (1989). "Simulation and the asymptotics of optimization estimators," *Econometrica*, 57, 1027-1057.

*Lee, B. and Ingram, B. (1991), "Simulation estimation of time series models," *Journal of Econometrics* **47**, 197-205.

Duffie, D. and Singleton, K. (1993). "Simulated moments estimation of Markov models of asset prices", *Econometrica* **61**, 929-952.

*Smith, A. (1993). "Estimation of nonlinear time series models using simulated VARs," *Journal of Applied Econometrics* **8**, s63-s84.

- **Estimating DSGE with GMM**

Rotemberg, J. and Woodford, M. (1997). "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy", in Bernanke, B. and J. Rotemberg, eds., *NBER Macroeconomics Annual*, Cambridge, MA: MIT Press.

Christiano, L., Eichenbaum, M. and Evans, C. (2005). "Nominal rigidities and the dynamic effects of a shock to monetary policy," *Journal of Political Economy*.

Altig, D., Christiano, L., Eichenbaum, M., and Linde, J. (2004). "Firm-specific capital, nominal rigidities and the business cycle,", manuscript, Northwestern University.

Jordà, O. and Kozichi, S. (2005). "An efficient IRF matching estimator for rational expectations models," manuscript, University of California at Davis.

Hall, A., Inoue, A., Nason, J.M. and Rossi, B. (2007)."Information criteria for Impulse response function matching estimation of DSGE models," manuscript.

VI. Likelihood methods

- **Kalman filter and its applications:** *State-Space models, time varying coefficients*

*Hamilton (1994), Ch. 13

Canova (2007), Ch. 6

*Hamilton, J.D. (1989). "A new approach to the economic analysis of nonstationary time series and the business cycle," *Econometrica* **57**, 357-384.

- **ML estimation of DSGE:** *stochastic singularities problem, misspecification and quasi-ML, identification.*

DeJong and Dave, Ch. 8

Canova, Ch. 6

Sargent, T. (1989). "Two models of measurements and the investment accelerator" *Journal of Political Economy* **97(2)**, 251-287.

Ingram, Kocherlakota and Savin (1994). "Explaining business cycles: a multi-shock approach," *Journal of Monetary Economics* **34**, 415-428.

Hansen and Sargent (2005). *Recursive Linear Models of Dynamic Economies.*

Ireland, P. (2004). "A method for taking models to data," *Journal of Economic Dynamics and Control* **28**, 1205-26.

Ireland, P. (2000). Sticky price models and the business cycle: specification and stability," *Journal of Monetary Economics* **47**, 3-18.

Watson, M. (1989). "Recursive solution methods for dynamic linear rational expectations models," *Journal of Econometrics* **41**, 65-89.

White, H. (1982). "Maximum likelihood estimation of misspecified models," *Econometrica* **50**, 1-25.

VII. Bayesian methods

- **Bayesian concepts:**

*Hamilton, 1994, section 12.3

- **Markov Chain Monte Carlo (MCMC):** *Metropolis-Hastings, Gibbs sampler, data augmentation*

*****Chib, S. and Greenberg, E. (1995). "Understanding the Metropolist-Hastings algorithm," *American Statistician* **49(4)**, 327-335.

*****Chib, S. and Greenberg, E. (1996). "Markov chain Monte Carlo simulation methods in econometrics," *Econometric Theory* **12**, 409-431.

*Chib, S. (2001). "Markov chain Monte Carlo methods: computation and inference," in: Heckman, J.J., Leamer, E. (Eds.), *Handbook of Econometrics, Vol. 5*. Amsterdam: North-Holland, 3564–3634, Chapter 5.

Chib, S., Nardari, F. and Shephard (2002). "Markov chain Monte Carlo methods for stochastic volatility models," *Journal of Econometrics* **108**, 281-316.

- **Estimation of DSGE models using Bayesian methods.**

Del Negro, M. and Schorfheide, F. (2004). "Priors from general equilibrium models for VARs," *International Economic Review* **45**, 643-673.

Del Negro, M. Schorfheide, F., Smets, F. and Wouters, R. (2007). "On the fit and forecasting performance of new Keynesian models," *Journal of Business and Economic Statistics*.

Rabanal, P. and Rubio-Ramirez, J. (2005). "Comparing new Keynesian models of the business cycle: a Bayesian approach," *Journal of Monetary Economics* **52**, 1151-1166.

Fernandez-Villaverde, J. and Rubio-Ramirez, J. (2005). "Estimating dynamic equilibrium economies: linear versus nonlinear likelihood," *Journal of Applied Econometrics* **20**, 891-910.

Boivin, J. and Giannoni, M.P. (2005), "DSGE models in a data-rich environment," manuscript, Columbia University.