New York University **Spring 2020**
Department of Economics **ECON-GA 3002-016**

Topics in Economics: Recent Advances in Time Series

Syllabus: Version 2 (February 4, 2020)

Instructor:	Mikkel Plagborg-Møller, mikkelpm@princeton.edu
Lectures:	Wed 10.00am–12.00pm, room 624, 19 W 4th St
Office hours:	Wed 2.00pm–3.00pm, office 826, 19 W 4th St

Description. Modern time series methods for applied macroeconomics. The first half of the course covers causal time series identification approaches, including Local Projections, SVARs, instruments/proxies, sign restrictions, and issues related to invertibility. The second half of the course covers a diverse set of topics: estimation of heterogeneous agent models, dynamic factor models, long-run variance estimation, and macroeconomic tail risk. The target audience includes both applied students and econometric theory students.

Prerequisites. ECON-GA 2100 and ECON-GA 2101 required. ECON-GA 3002-008 ("Empirical Methods for Dynamic Macroeconomics") recommended.

Material. There is no required textbook for the course. Handouts will be made available on the website. Attached to this syllabus is a list of optional readings that are useful for a deeper understanding of the material.

Some students might find it useful to have a textbook as an additional reference. Good reference books include:

Brockwell, P. J., and Davis, R. A. (1991). *Time Series: Theory and Methods*. 2nd edition, Springer. (Beautiful mathematical treatment of the classic theory of covariance stationary time series, but not aimed at economists.)

Davidson, J. (1994). *Stochastic Limit Theory*. Oxford University Press. (Thorough, technical treatment of stochastic limit theory for dependent data.)

Hamilton, J. D. (1994). *Time Series Analysis*. Princeton University Press. (Comprehensive reference for time series econometrics methods developed before the mid-1990s.)

Hayashi, F. (2000). *Econometrics*. Princeton University Press. (Accessible treatment of GMM and stochastic limit theory for time series data.)

Herbst, E. P., and Schorfheide, F., (2015). *Bayesian Estimation of DSGE Models*. Princeton University Press. (Recent reference on computational methods for Bayesian inference in structural time series models.)

Kilian, L., and Lütkepohl, H. (2017). *Structural Vector Autoregressive Analysis*. Cambridge University Press. (Recent reference on SVAR methods.)

Homework. I will post problem sets on the course website approximately every two-three weeks. The due date will typically be two weeks after the assignment is posted. Problem sets should be printed out and handed in at the beginning of class on the due dates. Students are encouraged to collaborate on the problem sets, but answers and computer code must be typed up independently. The problem sets will be graded coarsely, i.e., a full score will be given as long as the work demonstrates dedication and thoughtfulness. I reserve the right to subtract points for sloppy exposition, including unreadable code. If you find a grading error, please resubmit your problem set along with a one-paragraph explanation; I reserve the right to re-grade the entire problem set.

Class project. Each student will give a short presentation in class on a recent published paper or working paper that uses advanced time series methods. The paper must be pre-approved by me. The presentation should include a replication exercise and a critical discussion of the paper's methods. It is also acceptable to present applications or extensions of a purely theoretical paper. Original work is encouraged, as long as it relates to the pre-approved paper. Presentations will be graded based on clarity and effort.

Grading. The final course grade will be a monotonic function of the weighted average of (i) the average problem set score (50% weight) and (ii) the presentation score (50% weight).

Important dates. These dates are preliminary. Changes will be announced via course email.

Jan 29 (Wed): First class

Mar 18 (Wed): No class due to spring break

Mar 25 (Wed): Deadline for pre-approval of presentation topic

Apr 29 (Wed): Student project presentations

May 6 (Wed): Last class

Course outline. The following outline is preliminary and may change without warning.

1. Causal identification in macroeconomics.
    i) SVMA model, SVAR model, invertibility.
    ii) Identification through exclusion restrictions.
    iii) Local Projection versus VAR estimation of impulse responses.
    iv) Identification under potential non-invertibility.
    v) Identification using instruments/proxies.
    vi) Recoverability.
    vii) Partial identification through sign/magnitude restrictions.
    viii) Identification through non-Gaussianity/heteroskedasticity.
2. Challenges for statistical inference on impulse responses.
    i) Shrinkage estimation.
    ii) Simultaneous confidence bands.
    iii) Bootstrap.
    iv) Frequentist inference with persistent data and at long horizons.
3. Estimation of heterogeneous agent models.
    i) Challenges when combining micro and macro data.
    ii) Moment matching.
    iii) Likelihood inference.
4. Dynamic factor models.
    i) State space approach.
    ii) Principal components.

iii) Inference on number of factors.

5. Long-run variance estimation.

   i) Spectral estimators.

   ii) VAR-HAC.

   iii) Kernel estimators.

   iv) Fixed-b asymptotics.

6. Macroeconomic tail risk.

   i) Growth at Risk.

   ii) Forecast evaluation.

Optional reading list

Introductory readings are listed first and marked with a star (*). Other readings are included for your reference. Original contributions are not always cited when good handbook/textbook references are available. The reading list is preliminary and may change without warning.

1 Causal identification in macroeconomics

Exclusion restrictions, instruments/proxies

* Stock, J. H., and Watson, M. W. (2018). "Identification and Estimation of Dynamic Causal Effects in Macroeconomics Using External Instruments." *Economic Journal* 128(610), 917–948.

Kilian and Lütkepohl: chapters 4, 7–12, 15.

Blanchard, O., and Quah, D. (1989). "The Dynamic Effects of Aggregate Demand and Supply Disturbances." *American Economic Review* 79(4), 655–673.

Jordà, O. (2005). "Estimation and Inference of Impulse Responses by Local Projections."

Montiel Olea, J. L., Stock, J. H., and Watson, M. W. (2018). "Inference in SVARs Identified with External Instruments." Manuscript, Columbia University.

Plagborg-Møller, M. (2019). "Bayesian Inference on Structural Impulse Response Functions." *Quantitative Economics* 10(1), 145–184.

Plagborg-Møller, M., and Wolf, C. K. (2019). "Local Projections and VARs Estimate the Same Impulse Responses." Manuscript, Princeton University.

Rubio-Ramírez, J. F., Waggoner, D. F., and Zha, T. (2010). "Structural vector autoregressions: Theory of identification and algorithms for inference." *Review of Economic Studies* 77(2), 665–696.

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

Uhlig, H. (2005). "What are the effects of monetary policy on output? Results from an agnostic identification procedure." *Journal of Monetary Economics* 52(2), 381–419.

Invertibility, recoverability

Chahrour, R., and Jurado, K. (2018). "Recoverability." Manuscript, Duke University.

Fernández-Villaverde, J., Rubio-Ramírez, J. F., Sargent T. J., and Watson, M. W. (2007). "ABCs (and Ds) of Understanding VARs." *American Economic Review* 97(3), 1021–1026.

Forni, M., Gambetti, L., and Sala, L. (2019). "Structural VARs and noninvertible macroeconomic models." *Journal of Applied Econometrics* 34(2), 221–246.

Lippi, M., and Reichlin, L. (1994). "VAR analysis, nonfundamental representations, Blaschke matrices." *Journal of Econometrics* 63(1), 307–325.

Plagborg-Møller, M., and Wolf, C. K. (2019). "Instrumental Variable Identification of Dynamic Variance Decompositions." Manuscript, Princeton University.

Sign/magnitude restrictions

* Baumeister, C., and Hamilton, J. D. (2015). "Sign Restrictions, Structural Vector Autoregressions, and Useful Prior Information." *Econometrica* 83(5), 1963–1999.

Gafarov, B., Meier, M., and Montiel Olea, J. L. (2018). "Delta-Method Inference for a Class of Set-Identified SVARs." *Journal of Econometrics* 203(2), 316–327.

Giacomini, R., and Kitagawa, T. (2018). "Robust Bayesian inference for set-identified models." Manuscript, University College London.

Wolf, C. K. (2019). "SVAR (Mis)Identification and the Real Effects of Monetary Policy." *American Economic Journal: Macroeconomics*, forthcoming.

Identification through non-Gaussianity/heteroskedasticity

* Kilian and Lütkepohl: chapter 14.

Gouriéroux, C., Monfort, A., and Renne, J.-P. (2017). "Statistical inference for independent component analysis: Application to structural VAR models." *Journal of Econometrics* 196(1), 111–126.

Gouriéroux, C., Monfort, A., and Renne, J.-P. (2019). "Identification and Estimation in Non-Fundamental Structural VARMA Models." *Review of Economic Studies*, forthcoming.

Rigobon, R. (2003). "Identification Through Heteroskedasticity." *Review of Economics and Statistics* 85(4), 777–792.

Applications

* Ramey, V. A. (2016). "Macroeconomic Shocks and Their Propagation." In *Handbook of Macroeconomics, Volume 2A*, edited by Taylor, J. B., and Uhlig, H., Elsevier, chapter 2, 71–162.

Forni, M., Gambetti, L., Lippi, M., and Sala, L. (2017). "Noisy News in Business Cycles." *American Economic Journal: Macroeconomics* 9(4), 122–152.

Gertler, M., and Karadi, P. (2015). "Monetary Policy Surprises, Credit Costs, and Economic Activity." *American Economic Journal: Macroeconomics* 7(1), 44–76.

Mertens, K., and Ravn, M. O. (2010). "Measuring the Impact of Fiscal Policy in the Face of Anticipation: A Structural VAR Approach." *Economic Journal* 120(544), 393–413.

Mertens, K., and Ravn, M. O. (2013). "The Dynamic Effects of Personal and Corporate Income Tax Changes in the United States." *American Economic Review* 103(4), 1212–1247.

2 Challenges for statistical inference on impulse responses

Shrinkage

Barnichon, R., and Brownlees, C. (2019). "Impulse Response Estimation By Smooth Local Projections." *Review of Economics and Statistics* 101(3), 522–530.

Giannone, D., Lenza, M., and Primiceri, G. E. (2015). "Prior Selection for Vector Autoregressions." *Review of Economics and Statistics* 97(2), 436–451.

Hansen, B. E. (2016). "Stein Combination Shrinkage for Vector Autoregressions." Manuscript, University of Wisconsin-Madison.

Miranda-Agrippino, S., and Ricco, G. (2018). "The Transmission of Monetary Policy Shocks." Manuscript, Bank of England.

Plagborg-Møller, M. (2016). "Estimation of Smooth Impulse Response Functions." Chapter 3 of "Essays in Macroeconometrics", PhD thesis, Department of Economics, Harvard University.

Simultaneous confidence bands

* Montiel Olea, J. L., and Plagborg-Møller, M. (2019). "Simultaneous Confidence Bands: Theory, Implementation, and an Application to SVARs." *Journal of Applied Econometrics* 34(1), 1–17.

Bootstrap

* Kilian and Lütkepohl: chapters 12.1–12.5.

Brüggemann, R., Jentsch, C., and Trenkler, C. (2016). "Inference in VARs with conditional heteroskedasticity of unknown form." *Journal of Econometrics* 191(1), 69–85.

Gonçalves, S., and Kilian, L. (2004). "Bootstrapping autoregressions with conditional heteroskedasticity of unknown form." *Journal of Econometrics* 123(1), 89–120.

Horowitz, J. L. (2001). "The Bootstrap." In *Handbook of Econometrics, Volume 5*, edited by Heckman, J. J., and Leamer, E., Elsevier, chapter 52, 3159–3228.

Jentsch, C., and Lunsford, K. G. (2019). "Asymptotically Valid Bootstrap Inference for Proxy SVARs." Federal Reserve Bank of Cleveland Working Paper no. 19-08.

Kilian, L. (1998). "Small-sample Confidence Intervals for Impulse Response Functions." *Review of Economics and Statistics* 80(2), 218–230.

Persistent data, long horizons

* Montiel Olea, J. L., and Plagborg-Møller, M. (2019). "Local Projection Inference is Simpler and More Robust Than You Think." Manuscript, Princeton University.

Hansen, B. E. (1999). "The Grid Bootstrap and the Autoregressive Model." *Review of Economics and Statistics* 81(4), 594–607.

Inoue, A., and Kilian, L. (2019): "The Uniform Validity of Impulse Response Inference in Autoregressions." *Journal of Econometrics*, forthcoming.

Mikusheva, A. (2007). "Uniform Inference in Autoregressive Models." *Econometrica* 75(5), 1411–1452.

Mikusheva, A. (2012). "One-Dimensional Inference in Autoregressive Models With the Potential Presence of a Unit Root." *Econometrica* 80(1), 173–212.

Müller, U. K., and Watson, M. W. (2017). "Low-Frequency Econometrics." In *Advances in Economics and Econometrics, Volume II*, edited by Honoré, B., Pakes, A., Piazzesi, M., and Samuelson, L., Cambridge University Press, chapter 3, 53–94.

Sims, C. A., Stock, J. H., and Watson, M. W. (1990): "Inference in Linear Time Series Models with Some Unit Roots." *Econometrica* 58(1), 113–144.

Sims, C. A., and Uhlig, H. (1991). "Understanding Unit Rooters: A Helicopter Tour." *Econometrica* 59(6), 1591–1599.

Stock, J. H. (1994). "Unit roots, structural breaks and trends." In *Handbook of Econometrics, Volume 4*, edited by Engle, R. F., and McFadden, D. L., Elsevier, chapter 46, 2739–2841. Sections 1–3, 6.

3 Estimating heterogeneous agent models

* Winberry, T. (2018). "A method for solving and estimating heterogeneous agent macro models." *Quantitative Economics* 9(3), 1123–1151.

Herbst and Schorfheide: chapters 1–3, 5.

Ahn, S., Kaplan, G., Moll, B., Winberry, T., and Wolf, C. K. (2017). "When Inequality Matters for Macro and Macro Matters for Inequality." *NBER Macroeconomics Annual 2017*, edited by Eichenbaum, M., and Parker, J. A., chapter 1, 1–75.

Auclert, A., Bardóczy, B., Rognline, M., and Straub, L. (2019). "Using the Sequence-Space Jacobian to Solve and Estimate Heterogeneous-Agent Models." Manuscript, Northwestern University.

Chang, M., Chen, X., and Schorfheide, F. (2018). "Heterogeneity and Aggregate Fluctuations." Manuscript, University of Pennsylvania.

Cocci, M. D., and Plagborg-Møller, M. (2019). "Standard Errors for Calibrated Parameters." Manuscript, Princeton University.

Hahn, J., Kuersteiner, G., and Mazzocco, M. (2018). "Estimation with Aggregate Shocks." *Review of Economic Studies*, forthcoming.

Liu, L., and Plagborg-Møller, M. (2019). "Full-Information Estimation of Heterogeneous Agent Models Using Macro and Micro Data." Manuscript, Princeton University.

Mongey, S., and Williams, J. (2017): "Firm dispersion and business cycles: Estimating aggregate shocks using panel data." Manuscript, New York University.

4 Dynamic factor models

Estimation and inference

* Stock, J. H., and Watson, M. W. (2016). "Dynamic Factor Models, Factor-Augmented Vector Autoregressions, and Structural Vector Autoregressions in Macroeconomics." In *Handbook of Macroeconomics, Volume 2A*, edited by Taylor, J. B., and Uhlig, H., Elsevier, chapter 8, 415–525. Sections 1–3, 5–6.

Bai, J. (2003). "Inferential Theory for Factor Models of Large Dimensions." *Econometrica* 71(1), 135–171.

Bai, J., and Ng, S. (2008), "Large Dimensional Factor Analysis." *Foundations and Trends in Econometrics* 3(2), 89–163.

Doz, C., Giannone, D., and Reichlin, L. (2012). "A Quasi-Maximum Likelihood Approach for Large, Approximate Dynamic Factor Models." *Review of Economics and Statistics*, 94(4), 1014–1024.

Forni, M., Giannone, D., Lippi, M. and Reichlin, L. (2009). "Opening the Black Box: Structural Factor Models with Large Cross Sections." *Econometric Theory* 25(5), 1319–1347.

Forni, M., Hallin, M., Lippi, M., and Reichlin, L. (2000). "The Generalized Dynamic-Factor Model: Identification and Estimation." *Review of Economics and Statistics* 82(4), 540–554.

Stock, J. H., and Watson, M. W. (2002). "Forecasting Using Principal Components From a Large Number of Predictors." *Journal of the American Statistical Association* 97(460), 1167–1179.

Determining the number of factors

Bai, J., and Ng, S. (2002). "Determining the Number of Factors in Approximate Factor Models." *Econometrica* 70(1), 191–221.

Onatski, A. (2009). "Testing Hypotheses About The Number of Factors in Large Factor Models." *Econometrica* 77(5), 1447–1479.

Applications

Bernanke, B. S., Boivin, J., and Eliasz, P. (2005). "Measuring the effects of monetary policy: a factor-augmented vector autoregressive (FAVAR) approach." *Quarterly Journal of Economics* 120(1), 387–422.

Bok, B., Caratelli, D., Giannone, D., Sbordone, A. M., and Tambalotti, A. (2017). "Macroeconomic Nowcasting and Forecasting with Big Data." *Annual Review of Economics* 10, 615–643.

5 Long-run variance estimation

Theory

* Hayashi: 6.5–6.6.

* Lazarus, E., Lewis, D. J., Stock, J. H., and Watson, M. W. (2018). "HAR Inference: Recommendations for Practice." *Journal of Business and Economic Statistics* 36(4), 541–559. See also comments and rejoinder in the same journal issue.

Brockwell and Davis: chapters 10.1–10.5, 11.6.

Davidson: chapters 13–14, 24.

Andrews, D. W. K. (1991). "Heteroskedasticity and autocorrelation consistent covariance matrix estimation." *Econometrica* 59(3), 817–858.

Andrews, D. W. K., and Monahan, J. C. (1992). "An Improved Heteroskedasticity and Autocorrelation Consistent Covariance Matrix Estimator." *Econometrica* 60(4), 953–966.

Berk, N. (1974). "Consistent Autoregressive Spectral Estimates." *Annals of Statistics* 2(3), 489–502.

Den Haan, W. J., and Levin, A. (1997). "A practitioner's guide to robust covariance matrix estimation." In *Handbook of Statistics, Volume 15*, edited by Maddala, G. S., and Rao, C. R., North-Holland, 299–342.

Dou, L. (2019). "Optimal HAR Inference." Manuscript, Princeton University.

Ibragimov, R., and Müller, U. K. (2010). "t-Statistic Based Correlation and Heterogeneity Robust Inference." *Journal of Business and Economic Statistics* 28(4), 453–468.

Jansson, M. (2004). "The Error in Rejection Probability of Simple Autocorrelation Robust Tests." *Econometrica* 72(3), 937–946.

Kiefer, N. M., and Vogelsang, T. J. (2005). "A New Asymptotic Theory for Heteroskedasticity–Autocorrelation Robust Tests." *Econometric Theory* 21(6), 1130–1164.

Lazarus, E., Lewis, D. J., and Stock, J. H. (2019). "The Size-Power Tradeoff in HAR Inference." Manuscript, Harvard University.

Müller, U. K. (2007). "A theory of robust long-run variance estimation." *Journal of Econometrics* 141(2), 1331–1352.

Müller, U. K. (2014). "HAC Corrections for Strongly Autocorrelated Time Series." *Journal of Business & Economic Statistics* 32(3), 311–322.

Newey, W. K., and West, K. D. (1987). "A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix." *Econometrica* 55(3), 703–708. *Review of Economic Studies* 61(4), 631–653.

Pötscher, B. M. (2002), "Lower Risk Bounds and Properties of Confidence Sets for Ill-Posed Estimation Problems with Applications to Spectral Density and Persistence Estimation, Unit Roots, and Estimation of Long Memory Parameters." *Econometrica* 70(3), 1035–1065.

Sun, Y. (2014). "Let's Fix It: Fixed-b Asymptotics versus Small-b Asymptotics in Heteroscedasticity and Autocorrelation Robust Inference." *Journal of Econometrics* 178(3), 659–677.

Sun, Y., Phillips, P. C. B., and Jin, S. (2008). "Optimal Bandwidth Selection in Heteroskedasticity–Autocorrelation Robust Testing." *Econometrica* 76(1), 175–194.

Applications

Dew-Becker, I. (2017). "How Risky Is Consumption in the Long-Run? Benchmark Estimates from a Robust Estimator." *Review of Financial Studies* 30(2), 631–666.

Mavroeidis, S., Plagborg-Møller, M., and Stock, J. H. (2014). "Empirical Evidence on Inflation Expectations in the New Keynesian Phillips Curve." *Journal of Economic Literature* 52(1), 124–188.

6 Macroeconomic tail risk

* Adrian, T., Boyarchenko, N., and Giannone, D. (2019). "Vulnerable Growth." *American Economic Review* 109(4), 1263–1289.

Brownlees, C., and Souza, A. B. M. (2019). "Backtesting Global Growth-at-Risk." Manuscript, Universitat Pompeo Fabra.