Course Outline and Reading List

This outline lays out the topics that we should try to cover in this course. If viewed online with Acrobat Reader, there should be clickable links in the text.

Kallenberg (2002) is an advanced, thorough, account of probability and stochastic process theory. It assumes solid grounding in real analysis and measure theory. It is listed here only as a reference, for students whose mathematical background is strong and may want to pursue topics in this course at a more advanced or rigorous level. The Hamilton (1994) book covers many of the models used in time series econometrics and that we will deal with in this class. Hamilton proceeds more slowly through the material than we will in this class and he gives more emphasis to non-Bayesian asymptotic theory of inference than we will (and less to Bayesian inference). The Bauwens, Lubrano, and Richard (1999) book is closer in approach to this course than is Hamilton's but because of its variations in mathematical level and choice of topics only parts of it are assigned reading.

This course will primarily discuss inference from a Bayesian perspective. Books that lay out this perspective incude Schervish (1995), Robert (1994), Berger (1985), Geweke (2006), Lancaster (2004) and Gelman, Carlin, Stern, Dunson, Vehtari, and Rubin (2014). They have somewhat different choices of topics and assume varying levels of mathematical background, with Schervish the most demanding and Lancaster or Gelman et al the least, in this respect. Geweke and Lancaster are both oriented toward econometrics, while the others are oriented toward statistics. A reference for Monte Carlo computational methods for sampling from posterior densities is Robert and Casella (2004).

A book written by the computer scientist David Mackay (2003), provides an introduction to many of the ideas you will encounter in this course — the principles of Bayesian inference, its connection to decision theory, Monte Carlo methods for characterizing posterior distibutions, and contrasts of Bayesian and frequentist interpretations of evidence. It uses lots of examples, though none of these are from economics. It also contains material on machine learning and information theory that will not connect to this course but that has potential application in economic theory and econometrics. The book can be purchased (for about $50), but it also is available for online viewing and can be downloaded (but not printed out) at no charge, via the URL `http://www.inference.phy.cam.ac.uk/mackay/itprnn/book.html`.

There will be exercises that assume you are able to use a programming language like S, R, Matlab, Scilab, Octave, or possibly Mathematica, to carry out matrix algebra calculations and to run iterative algorithms. R and Octave are free, open-source software. R is almost identical, as a language, to S, but has a limited graphical interface (GUI). (Its ability to produce graphs is not limited. It just has limited ability to produce menus and let you initiate actions with mouse clicks.) Rstudio is a nice GUI for R, and if you already know emacs, ess (emacs for statistics) provides a good environment for using R. Octave is similarly very close as a language to Matlab, while having a more limited GUI. If you use, or want to try, R, good references are Venables and Ripley (2001) and Venables and Ripley (2002). My own research work is now entirely in R, and though I try to maintain matlab/octave versions of software I've developed, those versions sometimes lag the R versions.

None of the books are required for purchase, but any of those listed that fit your mathematical and statistical background would be good investments, both for this course and later reference.

1. Inference: Bayesian basics

    (a) Decision theory
    (b) Complete class theorems
    (c) Likelihood principle
    (d) Bayesian scientific reporting

    (MacKay, 2003, Sections 2.1-3, Chapter 3, Chapters 21-24, 36-37)
    Ferguson (1967)
    Class notes.

2. Second-order stochastic processes

    (a) Wold decomposition
    (b) MA processes: Non-uniqueness of MA representation
    (c) Fundamental MA and how to check for it
    (d) AR processes
    (e) ARMA processes and their pitfalls

    Class notes

3. Priors and posteriors for VAR's

    (a) Dummy observation priors.

        (Sims and Zha, 1998)
        Notes: Dummy observation priors
        (Giannone, Lenza, and Primiceri, 2016)

    (b) Impulse response functions

        Sims and Zha (1999)

    (c) Exogeneity, Granger causality, Wold and Granger causal orderings

4. Modeling initial conditions and "trend"

    (a) High-order AR + conditioning on initial conditions + flat prior $\Rightarrow$ belief in likely historical uniqueness of sample start date

(b) Unit roots
(c) Cointegration
(d) Realistic modeling of uncertainty about the long run vs. "removing trend".

(Sims, 2000)
(Sims, 1989)
(Sims, revised 1996)
(Hamilton, 1994, section 19.1)
(Sims and Uhlig, 1991)

5. Structural VAR's and identification

   (a) Delay restrictions
   (b) Long run restrictions
   (c) Restrictions on impulse responses
   (d) Identification through heteroskedasticity

6. The Kalman filter.

   (a) Priors and posteriors for the standard normal linear model
   (b) The Kalman filter
   (c) Initialization
   (d) AR models: AR coefficients as states
   (e) MA models: Lagged innovations as states
   (f) The Kalman filter as a component of likelihood-based inference
   (g) Smoothing vs. filtering

7. Particle Filtering

   Kantas, Doucet, Singh, Maciejowski, and Chopin (2915)
   Doucet and Johansen (2008)
   Shephard (2013)

8. Importance Sampling, Metropolis-Hastings MCMC

   (a) Importance sampling and its pitfalls
   (b) Metropolis Markov Chains and their pitfalls
   (c) Metropolis-Hastings
   (d) "Gibbs" Sampling
   (e) Assessing convergence
   (f) Computing marginal data density
   (g) Particle filtering
   (h) Application to dynamic factor models
   (i) Application to ARMA models nonlinear in parameters: Linearized DSGE models.

(MacKay, 2003, Chapters 27-30)
(Hamilton, 1994, section 12.3)
Gelman, Carlin, Stern, and Rubin (2004), Chapters 10-13
Notes: "Proof of Fixed Point Property for Metropolis Algorithm"
Bridge and path sampling. Gelman and Meng (1998)

9. ARMA models nonlinear in parameters: Linearized DSGE models.

   (a) The Smets and Wouters project

   Smets and Wouters (2003)

10. More models

    (a) Dynamic factor models
    (b) Stochastic volatility

References

BAUWENS, L., M. LUBRANO, AND J.-F. RICHARD (1999): *Bayesian Inference in Dynamic Econometric Models*. Oxford University Press.

BERGER, J. O. (1985): *Statistical Decision Theory and Bayesian Analysis*, Springer Series in Statistics. Springer, 2nd edn.

DOUCET, A., AND A. N. JOHANSEN (2008): "A Tutorial on Particle Filtering and Smoothing: Fifteen years later," Discussion paper, Oxford University, `http://www.stats.ox.ac.uk/~doucet/doucet_johansen_tutorialPF2011.pdf`.

FERGUSON, T. S. (1967): *Mathematical Statistics: A Decision Theoretic Approach*. Academic Press, New York and London.

GELMAN, A., J. B. CARLIN, H. S. STERN, D. B. DUNSON, A. VEHTARI, AND D. B. RUBIN (2014): *Bayesian Data Analysis*. CRC Press.

GELMAN, A., J. B. CARLIN, H. S. STERN, AND D. B. RUBIN (2004): *Bayesian Data Analysis*. Chapman and Hall, London, 2nd edn.

GELMAN, A., AND X.-L. MENG (1998): "Simulating Normalizing Constants: From Importance Sampling to Bridge Sampling to Path Sampling," *Statistical Science*, 13(2), 163–185.

GEWEKE, J. (2006): *Contemporary Bayesian Econometrics and Statistics*, Wiley Series in Probability and Statistics. Wiley.

GIANNONE, D., M. LENZA, AND G. E. PRIMICERI (2016): "Priors for the Long Run," Discussion paper, Northwestern University, `http://faculty.wcas.northwestern.edu/%7Egep575/plr3-2.pdf`.

HAMILTON, J. D. (1994): *Time Series Analysis*. Princeton University Press, Princeton, NJ.

KALLENBERG, O. (2002): *Foundations of Modern Probability*, Probability and its Applications. Springer, New York, Berlin, Heidelberg, second edn.

KANTAS, N., A. DOUCET, S. S. SINGH, J. MACIEJOWSKI, AND N. CHOPIN (2915): "On Particle Methods for Parameter Estimation in State-Space Models," *Statistical Science*, 30(3), 328–351.

LANCASTER, T. (2004): *An Introduction to Modern Bayesian Econometrics*. Blackwell.

MACKAY, D. J. C. (2003): *Information Theory, Inference, and Learning Algorithms*. Cambridge University Press.

ROBERT, C. (1994): *The Bayesian Choice*, Springer Texts in Statistics. Springer-Verlag, New York.

ROBERT, C. R., AND G. CASELLA (2004): *Monte Carlo Statistical Methods*, Springer Texts in Statistics. Springer, 2nd edn.

SCHERVISH, M. J. (1995): *Theory of Statistics*, Springer Series in Statistics. Springer, New York.

SHEPHARD, N. (2013): "Martingale unobserved component models," Discussion paper, Oxford University, `http://www.people.fas.harvard.edu/~shephard/ll20130210.pdf`.

SIMS, C. A. (1989): "Modeling Trends," in *Proceedings*, American Statistical Association Annual Meetings, `http://sims.princeton.edu/yftp/trends/asa889.pdf`.

——— (2000): "Using a Likelihood Perspective to Sharpen Econometric Discourse: Three Examples," *Journal of Econometrics*, 95(2), 443–462, `http://www.princeton.edu/~sims/`.

——— (revised 1996): "Inference for Multivariate Time Series with Trend," Discussion paper, presented at the 1992 American Statistical Association Meetings, `http://sims.princeton.edu/yftp/trends/ASAPAPER.pdf`, `http://sims.princeton.edu/yftp/trends/ASAPAPER.pdf`.

SIMS, C. A., AND H. D. UHLIG (1991): "Understanding Unit Rooters: A Helicopter Tour," *Econometrica*, 59(6), 1591–1599.

SIMS, C. A., AND T. ZHA (1998): "Bayesian Methods for Dynamic Multivariate Models," *International Economic Review*.

——— (1999): "Error Bands for Impulse Responses," *Econometrica*, 67(5), 1113–1156.

SMETS, F., AND R. WOUTERS (2003): "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area," *Journal of the European Economic Association*, 1, 1123–1175.

VENABLES, W. N., AND B. D. RIPLEY (2001): *S Programming*, Statistics and Computing. Springer.

——— (2002): *Modern Applied Statistics with S*, Statistics and Computing. Springer.