Advanced Bayesian Models for the Social Sciences

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Date and Time: July 21 to August 15, 1-3 PM.
Office Hours: TBD.

Description and Schedule:

This course covers the theoretical and applied foundations of Bayesian statistical analysis at a level that goes beyond the introductory course at ICPSR. Therefore knowledge of basic Bayesian statistics (such as that obtained from the Introduction to Applied Bayesian Modeling for the Social Sciences workshop) is assumed. The course will consist of four modules. First, we will discuss model checking, model assessment, and model comparison, with an emphasis on computational approaches. Second, the course will cover Bayesian stochastic simulation (Markov chain Monte Carlo) in depth with an orientation towards deriving important properties of the Gibbs sampler and the Metropolis Hastings algorithm. Extensions and hybrids will be discussed. The third module will focus on Bayesian item response theory (IRT) models, looking at theoretical foundations as well as practical issues such as identification and specification of hierarchies. The fourth week introduces the Bayesian approach to modeling time series data. This includes basic forms as well as recent developments such as Bayesian vector autoregression methods. Throughout the workshop, estimation with modern programming software (R, C, C++, and WinBUGS) will be emphasized.
Week I: Introduction to Posterior Calculation with Bayesian Stochastic Simulation.

Skyler Cranmer (University of North Carolina)

The first week has three components: assessing model quality and comparing models in a Bayesian context, approaches to dealing with missing data, and standard statistical computing tools that are useful for Bayesian analysis. The emphasis is on in-depth technical understanding of the mathematical statistics that justify and govern the use of these tools.

A. Assessing Model Quality
   1. Posterior Probability Comparison
   2. Posterior Predictive Probability
   3. Cross-Validation
   4. Bayes Factors
   5. AIC, BIC, DIC
   6. Software Issues

B. Bayesian Approaches to Missing Data
   1. Defining Terms: MAR, MCAR, Nonignorable
   2. Hot-decking and Other Traditional Approaches
   3. Multiple Imputation
4. Modern Bayesian Approaches
5. Implementations in R
6. Essential Reading: TBD.

C. Basic Monte Carlo Integration
1. Rejection Sampling
2. Classical Numerical Integration
3. Importance Sampling/Sampling Importance Resampling
4. Mode Finding and the EM Algorithm
5. Convergence of the EM Algorithm
6. EM for Exponential Families
7. Computing Topic: Introduction to WinBUGS for MCMC estimation
9. Additional Reading


Week II: Hierarchical Models and Markov Chain Monte Carlo. Jeff Gill (Washington University)

The second week also has two components: specifying and fitting Bayesian hierarchical models, and the use of Markov chain Monte Carlo methods. In the first part we will explore model forms beyond those discussed in the introductory course. The Bayesian paradigm is uniquely suited to modeling hierarchies in data specifications and parameter levels. In the second part we continue our focus on MCMC tools by discussing: theory, application, diagnostics and hybrid algorithms.

A. Bayesian Hierarchical Models

1. Basic Structure of the BHM

2. A Poisson-Gamma Hierarchical Model in Detail

3. The General Role of Priors and Hyperpriors

4. Exchangeability

5. The General Bayesian Hierarchical Linear Model


8. Additional Reading:


B. The Theory and Practice of Markov Chain Monte Carlo

1. General Properties of Markov Chains
2. The Chapman-Kolmogorov Equations
3. Marginal Distributions
4. Stationarity
5. Ergodicity
6. The Gibbs Sampler
7. The Metropolis-Hastings Algorithm
8. Data Augmentation
9. Random Number Generation
12. Additional Reading:


C. The Convergence and Behavior of Markov Chains
1. Autocorrelation
2. Graphical Techniques for Demonstrating Nonconvergence
3. Empirical Diagnostics
4. Customized Diagnostics
5. Why We Shouldn't Worry Too Much About Stationarity
6. Mixing and Acceleration
7. Simulated Annealing
8. Rao-Blackwellizing for Improved Variance Estimation
9. The Slice Sampler.
12. Additional Reading:


WEEK III: Bayesian Methods for Ideal Point Estimation. Jong Hee Park (University of Chicago).

This week covers theoretical foundations and Bayesian estimations of item response theory (IRT) models. We start from the history of roll call data analysis in political science and social sciences and discuss the connection between spatial voting models and item response theory models. We learn Bayesian implementation of item response theory models using Markov chain Monte Carlo methods. Then, we review important extensions of IRT models such as the issue of multidimensionality, dynamic ideal points, hierarchical modeling, and agenda constraints in IRT models. Students are expected to have basic understandings of Bayesian statistics and working knowledge of R programming.

A. Review: History of Roll Call Data Analysis


B. Empirical Estimation of Theoretical Models: Spatial Voting Models and IRT Models


C. Bayesian Estimation of IRT Models


D. Extension 1: Multidimensionality and Dynamics

E. Extension 2: Agenda Constraints and Hierarchical Models

**Week IV:** Bayesian Time Series. Patrick Brandt (University of Texas, Dallas).

This week’s material is divided into five parts corresponding roughly to the presentations on each of the five days. We begin with a brief review of frequentist approaches to analyzing multiple time series. Topics covered include Granger causality, innovation accounting and unit root testing. The role that asymptotic theory plays in these and other aspects of the frequentist approach is stressed (e.g., in the construction of error bands for impulse responses in (S)VAR models and in knife-edge type tests for non-stationarity). An application from international political economy is presented. We then turn, in parts two and three, to Bayesian time series analysis. We discuss time series priors and how elicitation and elucidation are used to construct these priors. The Minnesota prior is presented and we review Williams’ applications of it in international relations. Part three studies the Sims-Zha prior and analyzes in more depth such things as the way error bands are constructed for impulse responses. We illustrate the application of this prior and of likelihood shaped error bands. This includes a presentation of a recent piece on forecasting conflict and cooperation in the Levant.

Problems of computation and of model evaluation are studied in part four. An illustration from American political economy is presented. A topic from the frontiers of Bayesian time series analysis is presented on the last day of the week--Markov-switching.

Frequentist approaches to studying Markov switching are reviewed. Then some new
developments in the Bayesian approach to analyzing switching are presented. The application on this last day is an application of a Markov-switching BVAR for forecasting. Students will be given some experience using two software packages: RATS and Brandt's MSBVAR. Details of the week follow.

A. Review. The frequentist approach to analyzing multiple time series

1. Principles/basic time series concepts

2. Granger causality, impulse responses, DFEVS (and relationships to univariate analogs).

3. Topics
   a. Vector autoregressions
   b. Error correction models
   c. Structural VARs

4. Fitting frequentist models in STATA

5. Required Reading:


6. Reference Readings


B. Bayesian time series analysis, Part One

1. Principles
2. Time series priors, elicited and elucidated
3. VAR v. BVAR example
4. Fitting BVARs in RATS and MSBVAR
5. Required Reading:


6. Reference papers


C. Bayesian time series analysis, Part Two

1. Error bands for impulse response functions, The concept of Bayesian shape error bands

2. Testing theories with Bayesian SVAR models

3. Forecasting with Bayesian VAR models

4. Introduction to the package MSBVAR

5. Required readings


6. Reference papers


D. Practical problems in using Bayesian time series models

1. Computational challenges
2. Formulating priors
3. Assessing model fit
4. More on MSBVAR
5. Required readings:


- Notes on MSBVAR, R Package for B-(S)VAR models.
6. Reference papers:


E. Frontiers of research in Bayesian time series analysis--The concept of switching

1. Frequentist approaches, Testing for structural change with frequentist methods, Hamilton's switching model

2. Application: the political economy of exchange rates

3. The MSBVAR model

4. Applications: monetary policy, early warning systems

5. Required readings:


6. Reference papers:
- Sims, C.A., D. Waggoner, and T. Zha. 2008. METHODS FOR INference in LARGE
MULTIPLE-EQUATION MARKOV-SWITCHING MODELS Forthcoming Journal of
Switching. Cambridge: MIT Press
Statistical Inference, and Application to Business Cycle Analysis. Berlin: Springer.
regression models with endogenous switching." Journal of Econometrics. 143: 263-
273.