Econ 607 Bayesian Methods in Econometrics

COURSE AIMS & OBJECTIVES, KEY SKILLS AND LEARNING OUTCOMES

Course Aims & Objectives: This course will provide an introduction to simulation-based methods that are commonly used in microeconometrics. The emphasis will be Bayesian, although we will also contrast posterior analysis with maximum likelihood estimation. Despite the technical content, the course begins with an introduction to the Bayesian paradigm, and introduces key concepts and vernacular.

Key Skills: By the end of this course, students should have some knowledge and understanding of:

- The basis and motivation for Bayesian Econometrics
- The distinction between inference and estimation in Bayesian versus classical methods
- How to construct posterior distributions of unknown parameters
- The application of Bayesian methods to problems in microeconometrics

Desired Outcomes: By the end of this course, students should be able to:

- Communicate and present complex arguments in oral and written form with clarity
- Appreciate instances where the application of Bayesian methods is appropriate
- Work with R and/or python to operationalize Bayesian methods

COURSE STRUCTURE

Econ 607 is a 10 credits course and therefore students are expected to input approximately 100 hours of study into the course. The total number of contact hours on Econ 607 is 15 hours. This leaves 85 hours for private study. Course Delivery comes in the form of Lectures with 15 hours delivered over the first 3 weeks of the term (10 hours of lectures and 5 hours of tutorials). There will be optional clinics on the last day of the course.

During your private study you should strike a balance between reading the course material (which is the primary source of information) and the recommended textbooks, thinking critically about how these fit in to the body of knowledge on the subject and about how our level of knowledge can be improved, performing exercises, completing coursework and revising for examinations. You can expect to perform well on this course only if you work consistently through the year.

COURSE CONVENOR

Dr. Lennart Hoogerheide

LECTURERS CONTACT INFORMATION (Including Office Hours)

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COURSEWORK ASSESSMENT

The CWA mark will be calculated as 100% coursework. The coursework will be assigned at the end of the course.

The coursework will be delivered to students at the end of week 6 of each term and is due for submission at the end of week 10, allowing students 4 weeks for completion.

Coursework must be submitted electronically through the Moodle site for this course.

FEEDBACK ON COURSEWORK:

The coursework will be marked and returned to students within 4 weeks of the submission deadline. Feedback will consist of marker's notes appended to the pdf of your coursework.

MARKING CRITERIA AND PENALTIES

Marking criteria can be found in the Economics Undergraduate Handbook and the general course information paper. An electronic copy of this can be found via the Current Student page of the university website then follow the Academic Regulations link https://gap.lancs.ac.uk/ASQ/QAE/MARP/Documents/UG-Assess-Regs.pdf

FINAL MARK INFORMATION

This course is assessed 100% by means of coursework. The final mark is the average of the marks obtained in the two pieces of coursework.

COURSE TEXT AND RECOMMENDED READING

Main texts

The primary source of information will be the lecture slides and the exercises of the course. Copies of the lecture slides and exercises will be made available on the course web pages.

Further, the following chapter and textbook can be useful:

Hoogerheide, L.F., Van Dijk, H.K., Van Oest, R.D. (2009), "Simulation based Bayesian econometric inference: principles and some recent computational advances", Chapter 7 in *Handbook of Computational Econometrics*, Wiley & Sons, 215-280.

Koop, G. (2003): *Bayesian Econometrics*. Chichester, John Wiley & Sons.

Some articles about the topics of the course:

Monte Carlo simulation methods

[1] Casella, G., George, E.I. (1992). Explaining the Gibbs Sampler. *The American Statistician* 46, 167-174.

[2] Chib, S., Greenberg, E. (1995). Understanding the Metropolis-Hastings Algorithm. *The American Statistician* 49 (4), 327-335.

[3] Metropolis, N., A.W. Rosenbluth, M.N. Rosenbluth, A.H. Teller & E. Teller (1953). Equation of state calculations by fast computing machines. *Journal of Chemical Physics* 21: 1087-1092.

[4] Tanner, M.A., Wong, W.H. (1987). The Calculation of Posterior Distributions by Data Augmentation. *Journal of the American Statistical Association* 82 (398), 528-540.

[5] Ardia, D., Hoogerheide, L.F., Van Dijk, H.K. (2012). A comparative study of Monte Carlo methods for efficient evaluation of marginal likelihoods. *Computational Statistics & Data Analysis* 56 (11), 3398-3414.

[6] Hoogerheide, L.F., Opschoor, A., Van Dijk, H.K. (2012). A class of adaptive importance sampling weighted EM algorithms for efficient and robust posterior and predictive simulation. *Journal of Econometrics* 171 (2), 101-120.

[7] Malsiner-Walli, G., Frühwirth-Schnatter, S., Grün, B. (2016). Model-based clustering based on sparse finite Gaussian mixtures. *Statistics and Computing* 26, 303-324.

Basics of Bayesian Inference

[8] Geweke J. (1993). Bayesian Treatment of the Independent Student-t Linear Model. *Journal of Applied Econometrics* 8: S19-S40.

[9] Kass R., Raftery A. (1995). Bayes Factors. Journal of the American Statistical Association 90(430): 773-95.

[10] Basturk, N., Cakmakli, C., Ceyhan, S.P., Van Dijk, H.K. (2014). On the Rise of Bayesian Econometrics after Cowles Foundation Monographs 10, 14. Tinbergen Institute Discussion Paper TI 2014-085/III.

Bayesian analysis of particular econometric models (GARCH models and Instrumental Variables models):

[11] Hoogerheide, L.F., Ardia, D., Corré, N. (2012). Stock Index Returns' Density Prediction using GARCH Models: Frequentist or Bayesian Estimation? *Economics Letters* 116 (3), 322-325.

[12] Hoogerheide, L.F., Block, J.H., Thurik, R. (2012). Family background variables as instruments for education in income regressions: A Bayesian analysis. *Economics of Education Review* 31 (5), 515-523.

COURSE OUTLINE/LECTURE SCHEDULE

Lecture 1: Introduction to Bayesian statistics and its differences versus the classical/frequentist approach:

- Advantages of the Bayesian approach over the frequentist approach: general theory and simple examples
- Bayes' rule: prior density, likelihood, posterior density and posterior density kernel
- Informative versus non-informative priors
- Bayesian analysis of model with Bernoulli/binomial distribution under uniform prior

Lecture 2: Prior specification in simple econometric models, Gibbs sampling:

- Conjugate priors
- Bayesian analysis of model with Bernoulli/binomial distribution under conjugate (beta) prior distribution
- Bayesian analysis of model with Geometric distribution
- Proper versus improper priors
- Bayesian analysis of model with normal distribution with known and unknown variance (under normal and flat prior distributions)
- Markov chain Monte Carlo (MCMC) methods: burn-in, Gibbs sampling method

Lecture 3: Metropolis-Hastings algorithms (methods and applications in econometric models):

- Markov chain Monte Carlo (MCMC) methods: random walk Metropolis(-Hastings) method, candidate distribution, diagnostic checks, acceptance percentage
- Bayesian estimation of (G)ARCH models
- Bayesian estimation of Poisson regression model
- Markov chain Monte Carlo (MCMC) methods: independence chain Metropolis-Hastings method, candidate distribution, diagnostic checks, acceptance percentage

Lecture 4: Posterior model probabilities, normal linear regression model, Bayesian Model Averaging for forecast combination of autoregressive models:

- Posterior model probabilities: posterior odds ratio, prior odds ratio, Bayes factor, marginal likelihood
- Monte Carlo methods: importance sampling method, acceptance-rejection method
- Bayesian analysis of model with normal distribution with unknown variance under flat prior: Student-t marginal posterior of the mean

- Bayesian analysis of normal linear regression model under flat prior: Student-t marginal posterior of the coefficients, symmetry and differences between Bayesian and classical/frequentist results
- Savage-Dickey density ratio for computing the Bayes factor of nested models
- Posterior predictive density in autoregressive (AR) models
- Bayesian Model Averaging (BMA) for forecast combination
- Jeffreys-Lindley-Bartlett paradox and the need for proper priors in BMA

Lecture 5: Gibbs sampling with data augmentation (method and applications in econometric models), hierarchical prior, Jeffreys prior, numerical standard errors:

- Markov chain Monte Carlo (MCMC) methods: Gibbs sampling with data augmentation
- Bayesian estimation of a mixture model with known/fixed number of components
- Bayesian estimation of a mixture model with unknown/flexible number of components: hierarchical priors, sparse finite mixture
- Bayesian estimation of probit, tobit models
- Jeffreys prior
- Numerical precision of simulation results: numerical standard errors, relative numerical efficiency