

ECON 7960/STAT 6574: Bayesian Theory

University of Utah - Department of Economics
Spring 2020

Instructor: Ellis Scharfenaker
Department: Economics
Email: ellis.scharfenaker@economics.utah.edu
Tel: 801-581-7481
Office: Gardner Commons 4333
Office Hours: Wednesdays 1-3pm and by appointment

Location: BU C 305
Time: Wed 3:00 – 6:00 p.m.
Credit Hours: 3

Course Description:

Student Learning Outcomes: This course aims at introducing students to the philosophy of Bayesian inference and applied methods in Bayesian statistics from an information theoretic perspective. By the end of the course, students will have a firm understanding of the logic of inference and be able to construct useful analysis with data using modern Bayesian and information theoretic techniques. Students will have a working understanding the foundations of Bayesian analysis and information theory, including exchangeability, priors, posterior density reporting, model comparison, stochastic complexity, and the maximum entropy principle. Depending on time and interest we may also cover special topics such as Bayesian spectral analysis, mixture models, and statistical equilibrium models. Emphasis will be placed on students leaving this course with a command over Markov Chain Monte Carlo (MCMC) methods for posterior inference.

Assignments: Students will be required to complete several written assignments as well as a final project.

Teaching and Learning Methods:

This course is a traditional lecture based course.

Prerequisites: College algebra and Elementary calculus. ECON 4010, 4020, 4650 and 6610.

Attendance: Attendance is required for this course. If for any reason you cannot attend a lecture please contact me ahead of time.

	Scale	Score
	A	93-100
	A-	90-92
	B+	87-89
	B	83-86
	B-	80-82
Grading Policy: Assignments (50%), Final (50%)	C+	77-79
	C	73-76
	C-	70-72
	D+	67-69
	D	63-66
	D-	60-62
	E	0-59

Important Dates:

Martin Luther King Jr. Day holiday January 20
Presidents' Day holiday February 17
Spring Break March 9-13

Main References: This is a list of various interesting and useful books that will be touched on during the course. All books can be found at <http://used.addall.com/>.

Required (***)

Highly Recommended (*)

Probability Theory

- ***E. T. Jaynes, *Probability Theory, The Logic of Science*, Cambridge University Press, 2003.
- *D. V. Lindley, *An Introduction to Probability and Statistics from a Bayesian Viewpoint Part 1 and 2*, Wiley, 1965.
- *A. Zellner, *An Introduction to Bayesian Inference in Econometrics*, Wiley, 1971.
- *J. M. Bernardo and A. F. M. Smith, *Bayesian Theory*, Wiley, 2000.
- D. S. Sivia and J. Skilling, *Data Analysis: A Bayesian Tutorial*, Oxford University Press, 2006.
- M. H. DeGroot and M. J. Schervish, *Probability and Statistics*, Pearson, 4th Ed. 2012.

Applied Bayesian Statistics

- ***A. Gelman, J. Carlin, H. Stern, D. Dunson, A. Vehtari, and D. Rubin, *Bayesian Data Analysis.*, Chapman & Hall/CRC Texts in Statistical Science; 3rd ed. 2013.
- *A. Gelman, J. Hill, *Data Analysis Using Regression and Multilevel/Hierarchical Models*, Cambridge University Press, 2007.
- J. K. Kruschke *Doing Bayesian Data Analysis: A Tutorial with R, JAGS, and Stan*, Elsevier; 2nd ed. 2015.
- T. Lancaster, *An Introduction to Modern Bayesian Econometrics*, Blackwell, 2004.

Information Theory

- ***D. MacKay, *Information Theory, Inference, and Learning Algorithms*, Cambridge University Press, 2003. (Available at <http://www.inference.phy.cam.ac.uk/itila/book.html>)
- P. Gründwald, *The Minimum Description Length Principle*, MIT Press. 2007.

Philosophy of Probability

- F. Ramsey, *The Foundations of Mathematics and Other Logical Essays*, Martino Fine Books, 2013.
- J. M. Keynes, *A Treatise on Probability: The Connection Between Philosophy and the History of Science*, Wildside Press, 2010.
- L. J. Savage, *The Foundations of Statistics*, Dover, 1972.
- H. Jeffreys, *Theory of Probability*, Oxford Classic Texts in the Physical Sciences, 1998.
- B. D. Finetti, *Theory of Probability. A Critical Introductory Treatment*, John Wiley & Sons Ltd.; Vol. 1 and 2, 1974 and 1975.
- R. Von Mises, *Probability, Statistics and Truth*, Dover, 1982.

Useful Resources:

- R - <http://www.r-project.org>
- RStudio - <http://www.rstudio.com>
- RStan - <http://mc-stan.org/rstan.html>
- Essays by E.T. Jaynes - <http://bayes.wustl.edu/etj/node1.html>

Tentative Course Outline:

Required readings (*)

1. *Laws of Probability*

Readings:

- *E.T. Jaynes (2003) Preface and Ch. 1-3.
- *E. T. Jaynes, “Bayesian Methods: General Background: An Introductory Tutorial,” in *Maximum Entropy and Bayesian Methods in Applied Statistics*, J. H. Justice, (ed.), Cambridge University Press. 1985.
- C. Sims, “Understanding Non-Bayesians,” withheld chapter from Oxford University Press Handbook of Bayesian Econometrics.
- M. H. DeGroot and M. J. Schervish (2012) Ch. 1-3.

2. *Probabilities and Information*

Readings:

- *A. Golan (2018) *Foundations of Info-Metrics* Ch. 1-4.
- *C. E. Shannon (1948). “A Mathematical Theory of Communication.” Bell System Technical Journal.
- E. T. Jaynes (1978). Where do we stand on maximum entropy? pp. 1-74.
- S. Kullback and R.A. Leibler (1951). “On information and sufficiency.” *Annals of Mathematical Statistics*.
- R. Niven (2007) “Combinatorial Information Theory: Philosophical Basis of Cross-Entropy and Entropy,” <https://arxiv.org/abs/cond-mat/0512017v5>.

3. *Randomness*

Readings:

- P. Vitányi and M. Li (2001) “Simplicity, Information, Kolmogorov Complexity and Prediction,” in *Simplicity, Inference and Modeling: Keeping it Sophisticatedly Simple* ed. A. Zellner, H.A. Keuzenkamp, and M. McAlerr.
- G. Chaitin (1975) “Randomness and Mathematical Proof,” *Scientific American*, 232(5).
- J. Rissanen (1987) “Stochastic Complexity,” *Journal of the Royal Statistical Society. Series B*, 49(3).
- A. N. Kolmogorov and V. A. Uspenskii (1987) “Algorithms and Randomness,” *Theory of Probability and its Applications*. 32(3).
- P. Adriaans (2012) “Facticity as the amount of self-descriptive information in a data set.”
- M. Gell-Mann and S. Lloyd (2003) “Effective Complexity.” Santa Fe Institute.

4. *Data Compression*

Readings:

- *D. MacKay (2003) *Information Theory, Inference, and Learning Algorithms* Ch.1-2
- P. Gründwald (2017) *The Minimum Description Length Principle* Ch.1
- C. Sims, “Macroeconomics and Methodology,” *The Journal of Economic Perspectives*, 10, 1, 1996.

5. *Frequency Model of Probability*

Readings:

- R.T. Cox (1946) “Probability, Frequency, and Reasonable Expectation.” *American Journal of Physics* 14(1).
- R. von Mises (1957) *Probability, Statistics, and Truth*. Dover. Lectures 1-2.
- *E. T. Jaynes (2003) *Probability Theory, The Logic of Science*, Ch. 9.
- E.T. Jaynes, “Foundations of Probability Theory and Statistical Mechanics,” in *Delaware Seminar in the Foundations of Physics*, M. Bunge (ed.), Springer-Verlag, 1967.

6. *Exchangeability and Priors: Natural Conjugacy, Ignorance, Jeffreys*

Readings:

- *G. Box and G. Tiao (1973) *Bayesian Inference in Statistical Analysis*, Ch.1.3
- *A. Zellner, *An Introduction to Bayesian Inference in Econometrics*, Wiley, 1971.
- *D. S. Sivia and J. Skilling (2006) Ch. 2: Parameter Estimation 1.
- Bernardo and Smith (2000) Ch. 4: Modelling

7. *Scalar Data Statistics and Regression*

Readings:

- *D. V. Lindley, *An Introduction to Probability and Statistics from a Bayesian Viewpoint* Part 1 and 2, Wiley, 1965.
- *A. Zellner (1971) *An Introduction to Bayesian Inference in Econometrics*, Ch. 3-4.
- *A. Gelman et al. (2013) Ch. 3-4
- *E. T. Jaynes (2003) *Probability Theory, The Logic of Science*, Ch. 6.

8. *Markov Chain Monte Carlo*

Readings:

- *J. K. Kruschke (2015) Ch. 7: MCMC Methods, Ch. 9: Stan
- C. P. Robert and G. Casella (2010) Ch. 2,3,6,7
- A. Gelman et al. (2013) Part 3: Advanced Computation
- S. Chibb and E. Greenberg (1995). Understanding the Metropolis-Hastings Algorithm, *American Statistical Association*, 49(4).
- G. Casella and E. George (1992). Explaining the Gibbs Sampler, *The American Statistician*, 46(3).

9. *Hierarchical Bayes*

Readings:

- *A. Gelman and J. Hill (2007) Ch. 11, 12
- *A. Gelman et al. (2013) Ch. 5: Hierarchical Models
- J. Kruschke (2015) Ch. 9

10. *Model Checking*

Readings:

- *A. Golan (2018) *Foundations of Info-Metrics* Ch. 10
- *E. Soofi (2002) “Information indices: unification and applications,” *Journal of Econometrics*, 107.
- *D. S. Sivia and J. Skilling (2006) Ch. 4: Model Selection
- A. Gelman et al. (2013) Ch. 6: Model Checking

11. *Mixture Models*

Readings:

- *A. Gelman et al. (2013) Ch. 12: Finite Mixture Models
- G. J. McLachlan, S. X. Lee, and S. I. Rathnayake (2019) “Finite mixture models,” *Annual review of statistics and its application*, 6, pp. 355–378

12. *Bayesian Spectral Analysis*

Readings:

- *L. G. Bretthorst (1997) *Bayesian Spectrum Analysis and Parameter Estimation*, Springer. Ch.1-2
- P. Gregory (2005) *Bayesian Logical Data Analysis for the Physical Sciences*, Cambridge. Ch. 13: Bayesian Revolution in Spectral Analysis.

Note: This syllabus is meant to serve as an outline and guide for our course. Please note that I may modify it with reasonable notice to you. I may also modify the Course Schedule to accommodate the needs of our class. Any changes will be announced in class and posted on Canvas under Announcements.

Academic Honesty:

“The term plagiarism includes, but is not limited to: (i) use by paraphrase or direct quotation of the published or unpublished work of another person without fully and properly crediting the author with footnotes, citations or bibliographical reference; (ii) unacknowledged use of materials prepared by another person or agency engaged in the selling of term papers or other academic materials; or (iii) unacknowledged use of original work/material that has been produced through collaboration with others without release in writing from collaborators.”

There are many types of plagiarism, all are serious offenses and will be treated according to the University of Missouri Rules and Procedures of Student Conduct Matters. Using another author’s or researcher’s work without attribution is plagiarism. Rewriting another author’s or researcher’s work (changing words or word order) while retaining the structure and ideas of the work is plagiarism. Submitting your own work from other courses without permission is plagiarism. Sloppy citations, such as missing quotations marks even when a footnote appears, are plagiarism. Any incidents of plagiarism will result in a grade of zero for the assignment. All essays and assignments must be written in your own words with proper citations.

See the The Code of Student Rights and Responsibilities at <https://regulations.utah.edu/academics/6-400.php> for more details.

University Policies:

1. The Americans with Disabilities Act. The University of Utah seeks to provide equal access to its programs, services, and activities for people with disabilities. If you will need accommodations in this class, reasonable prior notice needs to be given to the Center for Disability Services, 162 Olpin Union Building, (801) 581-5020. CDS will work with you and the instructor to make arrangements for accommodations. All written information in this course can be made available in an alternative format with prior notification to the Center for Disability Services. [The Addressing Sexual Misconduct

Statement is strongly suggested on every course syllabus. According to University policy, at minimum instructors must include the contact information of the Title IX Coordinator.]

2. Addressing Sexual Misconduct. Title IX makes it clear that violence and harassment based on sex and gender (which Includes sexual orientation and gender identity/expression) is a civil rights offense subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories such as race, national origin, color, religion, age, status as a person with a disability, veteran's status or genetic information. If you or someone you know has been harassed or assaulted, you are encouraged to report it to the Title IX Coordinator in the Office of Equal Opportunity and Affirmative Action, 135 Park Building, 801-581-8365, or the Office of the Dean of Students, 270 Union Building, 801-581-7066. For support and confidential consultation, contact the Center for Student Wellness, 426 SSB, 801-581-7776. To report to the police, contact the Department of Public Safety, 801-585-2677(COPS).
3. All students are expected to maintain professional behavior in the classroom setting, according to the Student Code, spelled out in the Student Handbook. Students have specific rights in the classroom as detailed in Article III of the Code. The Code also specifies proscribed conduct (Article XI) that involves cheating on tests, plagiarism, and/or collusion, as well as fraud, theft, etc. Students should read the Code carefully and know they are responsible for the content. According to Faculty Rules and Regulations, it is faculty responsibility to enforce responsible classroom behaviors, beginning with verbal warnings and progressing to dismissal from class and a failing grade. Students have the right to appeal such action to the Student Behavior Committee.