Modern Choice Modeling:
Simulation Methods for Maximum Likelihood and Bayesian Estimation
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This course focuses on the modern statistical analysis of discrete choices of the form, "There are K options and you must choose one." Inevitably, an empirical model of such discrete choices revolves around the computation of Probability$[\varepsilon_1 > \max\{\varepsilon_2, \ldots \varepsilon_K\}]$. In first-generation choice models, very special probability distributions were forced on us to make the multi-dimensional integration of this probability computational feasible (as in the multinomial logit model). With the recent advent of Markov chain Monte Carlo simulation procedures, the new generation of choice models are not restricted to such special distributions. Not only can we estimate the maximum likelihood of more satisfying models, but the simulation capability has dramatically increased the applicability of Bayesian estimation. This course will develop skills in applying modern modeling tools to real empirical data of discrete choices, both through homework exercises and a term project. In addition, the student will gain experience using the statistical programming language R, which has become a *de facto* standard among statisticians for the development of statistical software (R is the free version of the commercial S+ language).

Prerequisite: A doctoral level statistics or econometrics course.

Textbook: Train, Kenneth (2009), *Discrete Choice Methods with Simulation*, Cambridge University Press.

Additional Readings:
Long , J. Scott (1997), *Regression Models for Categorical and Limited Dependent Variables*, Sage Publications.
Lancaster, Tony (2004), *An Introduction to Modern Bayesian Econometrics*, Blackwell Publishing.
Kennedy, Peter (208), *A Guide to Econometrics*, 6th edition, Wiley-Blackwell.

Session	Topic	Readings
1	Theory of Discrete Choice	McFadden (2001) *AER* Nobel Prize Lecture, Train 1, 2
2	Simulation Based Statistics	Stern (1997) *JEL*
3	Maximum Likelihood Estimation	Myung (2003) *J Math Psychol*
4	Introduction to R: CRAN, data i/o, object manipulation, functions, if & for, vector calculations, random variables, graphs, optimization	Kuhnert and Venables, "An Introduction to R."
5	Review of Regression Analysis and LPM	Kennedy, Long 2
6	Binary Logit	Amemiya (1981) *JEL*; Long 3
7	Logistic regression examples and hypothesis tests	Long 4
8	Marginal Effect on Probabilities, Moderation effects	Greene 23.4, Ai and Norton
9	Multinomial Logit	Train 3
10	GEV/Nested Logit	Train 4
11	Drawing from Densities	Train 9.1-9.2
12	Simulation in R	
13	Numerical Maximization	Train 8, 14
14	Probit	Train 5

15	Examples of Probit	
16	Mixed Logit	Train 6
17	Estimation with simulation: MSL, MSM, MSS	Train 10
18	Examples of MSL	
19	Variance reduction: antithetics and Halton draws	Train 9.3
20	Conditional Distributions of Individual-level Parameters	Train 11
21	Bayesian Statistics	Rossi and Allenby (2003) *MktSci*, Lancaster 1
22	Hierarchical Bayes	Train 12
24	Examples of Bayesian choice modeling	
25	Other models: variations on our themes	Train 7
26	Endogeniety	Train 13
27	Student presentations	
28	Student presentations	

Supplemental Readings:

Chandukala, Sandeep R., Jaehwan Kim, Thomas Otter, Peter E. Rossi and Greg M. Allenby, "Choice Models in Marketing: Economic Assumptions, Challenges and Trends", *Foundations and Trends in Marketing*: Vol. 2: No 2, pp 97-184, 2007.

D. McFadden, "Conditional Logit Analysis of Qualitative Choice Behavior," in P. Zarembka (ed.), *Frontiers of Econometrics,* New York, NY, Academic Press, 1974

D. McFadden, "Quantal Choice Models: A Survey," *Annals Econ and Soc Meas*, 5/4. 363-390, 1976

K. Train, "A Validation Test of a Disaggregate Mode Choice Model," Transportation Research, Vol. 12, pp. 167-174, 1978.

D. McFadden, "Modeling the Choice of Residential Location," in A. Karlquist, *et al.* (eds.), *Spatial Interaction Theory and Planning Models*, Amsterdam, North-Holland Publishing Company, 1978.

K. Train, *Qualitative Choice Analysis*, Cambridge, MA, MIT Press, 1986, Ch. 8

K. Train, D. McFadden, and M. Ben-Akiva, "The Demand for Local Telephone Service: A Fully Discrete Model of Residential Calling Patterns and Service Choices," *RAND Journal of Economics*, Vol. 18, No. 1, pp. 109-123, 1987.

J. Hausman and D. Wise, "A Conditional Probit Model for Qualitative Choice: Discrete Decisions Recognizing Interdependence and Heterogenous Preferences," *Econometrica*, Vol. 48, No. 2, pp. 403-426, 1978.

S. Lerman and C. Manski, "On the Use of Simulated Frequencies to Approximate Choice Probabilities," in C. Manski and D. McFadden (eds.), *Structural Analysis of Discrete Data with Econometric Applications*, Cambridge, MA, MIT Press, 1981.

M. Ben-Akiva and D. Bolduc, "Multinomial Probit with a Logit Kernel and a General Parametric Specification of the Covariance Structure," working paper, 1996, Department d'Economique, Universite Laval, Quebec, Canada.

A. Boersch-Supan and V. Hajivassiliou, "Smooth Unbiased Multivariate Probability Simulators for Maximum Likelihood Estimation of Limited Dependent Variables," J*ournal of Econometrics*, Vol. 58, pp. 347-368, 1993.

V. Hajivassiliou, D. McFadden, and P. Ruud, "Simulation of Multivariate Normal Rectangle Probabilities and Their Derivatives," *Journal of Econometrics*, Vol. 72, No. 1-2, pp. 85-134, 1996.

D. Revelt and K. Train, "Mixed Logit with Repeated Choices," *Review of Economics and Statistics*, Vol. LXXX, No. 4, pp. 647-657, 1998. Preprint version is viewable here , but not the published reprint.

D. Brownstone and K. Train, "Forecasting New Product Penetration with Flexible Substitution Patterns," *Journal of Econometrics*, Vol. 89, No. 1-2, pp. 109-129, 1998/99.

D. McFadden and K. Train, "Mixed MNL Models of Discrete Response,"*Journal of Applied Econometrics*, Vol. 15, No. 5, pp. 447-470, 2000. Preprint version is viewable here , but not the published reprint.

K. Train, "Recreation Demand Models with Taste Variation," *Land Economics*, Vol. 74, No. 2, pp. 230-239, 1998. Preprint version is viewable here , but not the published reprint.

M. Ben-Akiva, Denis Bolduc, and Joan Walker, "Specification, Identification, and Estimation of the Logit Kernel (or Continuous Mixed Logit) Model," DRAFT, February 2001.

D. McFadden, "Lectures on Simulation-Assisted Statistical Inference," [PostScript] presented at EC^2 Conference, Florence, Italy, 1996.

D. McFadden, "A Method of Simulated Moments for Estimation of Discrete Choice Models without Numerical Integration," *Econometrica*, Vol. 57, No. 5, pp. 995-1026, 1989.

A. Pakes and D. Pollard, "Simulation and the Asymptotics of Optimization Estimators," *Econometrica*, Vol. 57, No. 5, pp. 1027-1057, 1989.

L.-F. Lee, "On the Efficiency of Methods of Simulated Moments and Simulated Likelihood Estimation of Discrete Response Models," *Econometric Theory*, Vol. 8, No. 4, pp. 518-552, 1992.

V. Hajivassiliou and D. McFadden, "The Method of Simulated Scores with Application to Models of External Debt Crises," *Econometrica*, Vol. 66, No. 4, pp. 863-896, 1998.

M. Keane, "A Computationally Practical Simulation Estimator for Panel Data," *Econometrica*, Vol. 62, No. 1, pp. 95-116, 1994.

V. Hajivassiliou and P. Ruud, "Classical Estimation Meethods for LDV Models using Simulation," in *Handbook of Econometrics*, R. Engle and D. McFadden (eds.), New York, NY, Elsevier Science, 1994.

C. Bhat, "Quasi-Random Maxium Simulated Likelihood Estimation of the Mixed Multinomial Logit Model," working paper, Department of Civil Engineering, University of Texas, Austin, 1999, forthcoming in Transportation Research

K. Train, "Halton Sequences for Mixed Logit," working paper no. E00-278, Department of Economics, University of California, Berkeley, 2000.

C. Bhat, "Simulation Estimation of Discrete Choice Models Using Randomized and Scrambled Halton Sequences," working paper, Department of Civil Engineering, University of Texas, Austin, 2001.

D. Revelt and K. Train, "Customer-Specific Taste Parameters and Mixed Logit," working paper no. E00-274, Department of Economics University of California, Berkeley, 2000.

S. Chib and E. Greenberg, "Understanding the Metropolis-Hastings Algorithm," *The American Statistician*, Vol. 49, pp. 327-335, 1995.

J. Huber and K. Train, "On the Similarity of Classical and Bayesian Estimates of Individual Mean Partworths," working paper no. E00-289, Department of Economics, University of California, Berkeley, 2000. Subsequently published in Marketing Letters, Vol. 12, No. 3, pp. 257-267, 2001.

J. Albert and S. Chib, "Bayesian Analysis of Binary and Polychomotomous Response Data,"*Journal of the American Statistical Association*, Vol. 88, No. 422, June 1993, Theory and Methods.

R. McCulloch and P. Rossi, "An Exact Likelihood Analysis of the Multinomial Probit Model," Journal of Econometrics, Vol. 64, No. 1-2, pp. 207-240, 1994.

G. Allenby and P. Rossi, "Marketing Models of Consumer Heterogeneity," *Journal of Econometrics*, Vol. 89, No. 1-2, pp. 57-78, 1998/99.