

Maximum Likelihood Estimation for Generalized Linear Models

PS 818, Fall, 1999

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This course is about a number of new and very useful statistical models which can better or more appropriately address the substantive questions you encounter as a social scientist. Among the topics we cover are logit and probit models for both binary and ordinal dependent variables, event count models (such as wars in a decade, or coups in a year, or Supreme Court appointments in a presidential term, or incumbents defeated in an election), discrete choice models for multiple alternatives (such as voting for Clinton or Bush or Perot, or vote choices among multiple parties as in any system with more than two parties), models for non-random selection (as when you observe the preferences of voters but not non-voters). The applications are almost endless.

Each of these models has two things in common: you *can't* estimate them correctly using OLS regression but you *can* using maximum likelihood. Thus our course teaches you what maximum likelihood estimation is all about (just as you learned about least squares estimation in your regression class) and how each of these substantively important models can be estimated using it. Maximum likelihood, then, is just a technique of estimation which allows us to develop a wide variety of substantively useful models which are otherwise unavailable. The great advantage of maximum likelihood is that it provides a single, unified, approach to estimation which spans this great variety of statistical models.

While the title of the course emphasizes the method of maximum likelihood estimation, I want to stress that the course is focused on substantive models which should be highly useful in your work. Maximum likelihood is as crucial a part of this process as is least squares for a regression course. I will teach you a lot about the method of maximum likelihood. But just as you didn't take your regression course to learn about least squares, so you won't be taking this course to learn about maximum likelihood. The payoff comes in the substantive work you can do with the new models you will learn but which you cannot do with any regression model.

The background required for the course is a good introduction to statistical inference and at least one good regression course (something covering multiple regression using matrix algebra). Some familiarity with matrix algebra is assumed, though we won't use a lot of it. Likewise, a speaking acquaintance with calculus is very helpful.

Grading will be based on students' written and computer assignments. Computer exercises will be set up to use the Stata statistical package. There is also a required term paper. The paper is half the grade and the exercises are weighted equally for the other half.

Reading

All readings are to be done during the week indicated as they are keyed to lecture materials. Some of the readings serve as background for the lectures; others explicitly cover the lecture materials. All materials marked with an asterisk will be on reserve in your department. In addition, the following books will be available for purchase:

- Long, J. Scott. 1997. *Regression Models for Categorical and Limited Dependent Variables*. Thousand Oaks, CA: Sage. (An excellent treatment of most of the basic models covered in the course, very clearly and consistently presented. Source of most core readings.)
- Greene, William C. 2000. *Econometric Analysis* 4th Edition. New York: Prentice Hall. (An excellent reference, though we will not read the entire book by any means.)
- King, Gary. 1989. *Unifying Political Methodology: The Likelihood Theory of Statistical Inference*. Cambridge University Press. (The book that made maximum likelihood required study for political scientists. Now out of print from Cambridge. University of Michigan Press will be reissuing it soon.)
- Edwards, A. W. F. 1992. *Likelihood* (expanded edition). Baltimore: Johns Hopkins University Press. (More of a philosophical work on inference and likelihood than a statistical text. Well worth reading.)
- Eliason, Scott R. 1993. *Maximum Likelihood Estimation: Logic and Practice* Newbury Park: Sage. (A very good introduction to maximum likelihood.)
- Aldrich, John and Forrest Nelson. 1984. *Linear Probability, Logit and Probit Models*. Newbury Park: Sage. (Standard introductory treatment of logit and probit. Good if you need a refresher before getting into Greene and King.)
- Evans, Merran, Nicholas Hastings, and Brian Peacock. 1993. *Statistical Distributions*, Second Edition. New York: John Wiley. (An excellent and inexpensive handbook and guide to a variety of probability distributions.)

If you are serious about learning and using maximum likelihood methods, you will eventually want to own all of these books.

An excellent supplement to the reading list is:

Davidson, Russell and James G. Mackinnon. 1993. *Estimation and Inference in Econometrics*. Oxford: Oxford University Press.

This is a slightly more advanced treatment of a number of models, but it is almost always very lucid. Treatment of a number of special topics is particularly good.

A Word about the Syllabus

The syllabus is organized around each topic, rather than by day. Usually we will spend one or perhaps two days per topic. You should read through the material before we start each topic, and read it again after we've discussed it in class. Even a fast skim of the material before class will pay substantial dividends. Then a more serious reading after class should clarify and strengthen your grasp of the material.

Each topic is organized around up to four subsections: fundamentals, advanced topics, applications and exercises. The material under fundamentals is just what it says— the basics necessary to understand what a model is all about. *You should always read the material marked by an asterisk.* Additional material may also appear under fundamentals. This is an alternative approach to essentially the same material. If you find one author less than lucid, you may wish to try one of these additional readings. Fundamentals *not* marked by an asterisk are optional reading.

The advanced topics section is for reading more deeply into a subject, probably when you are trying to apply what you've learned to more demanding problems. I draw parts of my lectures from these sources, so whether you know it or not, you will be exposed to some of the content.

The applications section is a way of showing you what people actually do with these methods. You should read the application marked with an asterisk before and after class. Others are listed so you may see a variety of examples. Many of these applications are from political science, but I have tried to include some from sociology as well. If you know of good applications which would be appropriate for a section, please tell me and I'll add them to the syllabus. You should read the methods sections of these articles closely, and be prepared to ask questions about the methods and their use.

The exercises are an integral part of this course. You cannot learn statistics by merely watching lectures!! You only really learn this material when you apply it to an actual problem, make decisions about model specification, estimate models and interpret the results. Therefore, there are a substantial number of exercises, usually one per class. You are encouraged to work together in groups on these. I've found that you learn the material better if you have to explain it to one another than if you lock yourself in a room and do the work entirely on your own. So please feel free to talk, run programs and discuss interpretations with other students. But when you write up your exercise, you should do this step on your own. I've tried to select datasets which address meaningful problems for social scientists. If you know of additional good datasets which could be used, I'd be happy to hear about them.

Finally, I assume the "Preliminaries" section is background material, and I will not cover this in class. You should read through some of this material to be sure you are up to speed. I doubt anyone will be a complete master of all the material under "Preliminaries", but I also assume everyone will have had some exposure to each of these topics and can read on their own where they are weak.

Talking In Class

While this class is organized around lectures, I strongly encourage you to feel free to ask questions and to interrupt me in class when a point is less than crystal clear. I think the entire class benefits from an active give and take in class, and I don't mind dealing with both substantive and technical questions in class. At the same time, I may defer a question that will be answered later in the lecture or I may ask you to talk to me after class if I think the issue is either too complex or too far from my focus of the day. This makes me freer to stick to the subject, but it also makes you freer to ask whatever is on your mind, since there is no shame in a question deferred.

And this is not to say that class will be a free-for-all. I will have an agenda and will stick pretty close to the topic of the day. If I have to cut off discussion to get through the topic, I will.

Grading

Grades will be based on your completed exercise assignments and the term paper. These will be graded both for the statistical analysis and for the interpretation you provide. The work you turn in should be neat and include appropriate printout. You must email me your assignments, as attachments to a message. I can handle Word, Wordperfect or Postscript files, as well as ascii text files. I'll ask you to send me test messages in advance in order to verify that the attachments are readable before an actual assignment is due.

Assignments are due by 6:00 PM on the Tuesday following class. This will allow me to look at them before the next class and spot problems in time to address them in class. Late assignments are strongly discouraged. A pattern of late assignments will result in a grade penalty.

The term paper is due no later than Friday, December 17th. The paper should be a substantive application of your choice, using some of the methods we develop in the class. You should pay considerably more attention to the methodological issues of your paper than you would in a purely substantive paper. Thus, you should consider alternative models, discuss the issues involved in selecting one approach over another, and attempt to estimate more inclusive models, even if these turn out to be substantively disappointing. The length should be appropriate to a conference paper, approximately 20 pages. I'll be happy to discuss the details with you.

If you are auditing the course, I STRONGLY urge you to complete and turn in the assignments. Most importantly, you should do this so you will learn something instead of wasting your time. If you come to every class and read every assignment but do none of the exercises, I guarantee you will learn little of lasting value. I will grade and comment on assignments of auditors as well as credit students.

Syllabus

1 Preliminaries

The following readings cover prerequisite material. You need not be a master of matrix algebra, calculus or asymptotic theory for this course. You should, however, have a speaking acquaintance with each. I assume you have encountered matrix algebra in a previous regression class, and once spoke calculus in an earlier life (as a freshman, perhaps). Asymptotic theory I do not assume. We will cover what we need in class. I also assume you have been introduced to probability and have met a few probability distributions.

1.1 Fundamentals

Kleppner, Daniel and Norman Ramsey. 1985. *Quick Calculus*, 2nd edition. New York: John Wiley. Ch. 1, Ch 2 (pp 50-108, 116-137. Ch. 3, (pp. 151-174, 185-189.)

Namboodiri, Krisgnan. 1984. *Matrix Algebra, An Introduction*. Beverly Hills: Sage. Ch. 1 & 2.

Hughes-Hallett, Deborah. 1980. *The Math Workshop: Elementary Functions*. New York: W.W. Norton. Ch. 10 (as needed), Ch. 11 (pp. 220-223, 229-257.) Ch. 12 (according to interest.)

This is an excellent review of logarithms, but note that all our work will use natural logs, not base 10.

Evans, Merran, Nicholas Hastings, and Brian Peacock. 1993. *Statistical Distributions*, Second Edition. New York:John Wiley. This is a wonderful, compact, relatively comprehensive, paperback

coverage of 39 common probability distributions. A very handy reference.

Greene, William H. 2000. *Econometric Analysis*. Chapters 2, 3, 4.1-4.4.

Davidson, Russell and James G. Mackinnon. 1993. *Estimation and Inference in Econometrics*. Oxford: Oxford University Press. Appendix A and B. (This is a more demanding treatment than Greene.)

1.2 Applications

Achen, Christopher H. 1983. "Towards Theories of Data: The State of Political Methodology," in Ada W. Finifter (ed), *Political Science: The State of the Discipline*. Washington: American Political Science Association.

King, Gary. 1991. "On Political Methodology." *Political Analysis* 2:1-29.

Bartels, Larry M. and Henry E. Brady. 1993. "The State of Quantitative Political Methodology," in Ada W. Finifter (ed), *Political Science: The State of the Discipline II*. Washington: American Political Science Association.

Jackson, John E. 1996. "Political Methodology: An Overview," in Robert E. Goodin and Hans-Dieter Kingemann (eds), *A New Handbook of Political Science*. Oxford: Oxford University Press.

2 Methods of Estimation and the Likelihood Model of Inference

2.1 Fundamentals

*Long, J. Scott. 1997. *Regression Models for Categorical and Limited Dependent Variables*. Thousand Oaks, CA: Sage. Chapters 1-2.

*King, Gary. 1989. *Unifying Political Methodology*. Chapter 1, 2, 3 (skim), 4.1-4.3)

*Greene, William H. 2000. *Econometric Analysis*. Chapter 4.5

Kmenta, Jan. 1986. *Elements of Econometrics* (2nd edition), Chapter 6.

2.2 Exercise!

Calculating Maximum Likelihood Estimates by Hand!

3 Properties of ML Estimators; Application to regression

3.1 Fundamentals

*Long, J. Scott. 1997. *Regression Models for Categorical and Limited Dependent Variables*. Thousand Oaks, CA: Sage. Chapter 2.6.4.

*King, Gary. 1989. *Unifying Political Methodology*. Chapter 4.4-4.5, 4.7-4.8.

*Eliason, Scott R. 1993. *Maximum Likelihood Estimation: Logic and Practice* Newbury Park: Sage. Chaps 1-2.

3.2 Advanced Topics

Davidson, Russell and James G. Mackinnon. 1993. *Estimation and Inference in Econometrics*. Oxford: Oxford University Press. Chapter 8.

Amemiya, Takeshi. 1985. *Advanced Econometrics* chapter 4. (Chapter 3 gives the asymptotic theory required for chapter 4.)

White, Halbert. 1981. *Asymptotic Theory for Econometricians*. New York: Academic Press.

3.3 Exercise!

Computer Exercise: OLS via MLE.

4 An MLE Approach to Heteroskedastic Regression

4.1 Fundamentals

*Greene, William H. 2000. *Econometric Analysis*. Chapter 12.

Greene, William H. 1995. *Limdep Version 7.0 User's Manual*. Chapter 15.

4.2 Advanced Topics

Davidson, Russell and James G. Mackinnon. 1993. *Estimation and Inference in Econometrics*. Oxford: Oxford University Press. Chapter 9.

White, Halbert. 1980. "A Heteroskedastic-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity." *Econometrica* 48:817–838.

Newey, W. K. and K. West. 1987. "A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix." *Econometrica* 55:703-708.

4.3 Applications

*Franklin, Charles H. 1991. "Eschewing Obfuscation? Campaigns and the Perception of Senate Incumbents", *American Political Science Review*, 85:1193-1214.

4.4 Exercise!

Computer exercise: Estimation of a heteroskedastic regression model

5 Binary Dependent Variables

5.1 Fundamentals

*Long, J. Scott. 1997. *Regression Models for Categorical and Limited Dependent Variables*. Thousand Oaks, CA: Sage. Chapter 3.

*King, Gary. 1989. *Unifying Political Methodology*. Chapter 5.1, 5.3.

*Greene, William H. 2000. *Econometric Analysis*. Chapter 19.1–19.4.

Aldrich, John H. and Forrest D. Nelson. 1984. *Linear Probability, Logit and Probit Models*. Sage. Entire.

Greene, William H. 1992. *Limdep Version 7.0 User's Manual*. Chapter 21.

Maddala, G. S. 1983. *Limited-Dependent and Qualitative Variables in Econometrics*. Cambridge: Cambridge University Press. Chapter 2.1–2.5.

5.2 Advanced Topics

Greene, William H. 2000. *Econometric Analysis*. Chapter 19.5, 19.6.

Davidson, Russell and James G. Mackinnon. 1993. *Estimation and Inference in Econometrics*. Oxford: Oxford University Press. Chapter 15.1-15.4.

Nagler, Jonathan. 1994. "Scobit: An Alternative Estimator to Logit and Probit." *American Journal of Political Science* 38: 230-255.

5.3 Applications

*Ragsdale, Lyn. 1984. "The Politics of Presidential Speechmaking, 1949-1980." *American Political Science Review*, 78: 971-984.

Franklin, Charles H. and Liane C. Kosaki. 1995. "Media, Knowledge and Public Evaluations of the Supreme Court", in Lee Epstein, (ed), *Contemplating Courts*, Washington DC: Congressional Quarterly Press.

McCarthy, John D., Clark McPhail, and Jackie Smith. 1996. "Images of Protest: Dimensions of Selection Bias in Media Coverage of Washington Demonstrations, 1982 and 1991." *American Sociological Review* 61:478-499.

5.4 Exercise!

Computer exercise: Estimating probit and logit models.

6 Applications of Binary Models

6.1 Fundamentals

*Long, J. Scott. 1997. *Regression Models for Categorical and Limited Dependent Variables*. Thousand Oaks, CA: Sage. Chapter 4.

*King, Gary. 1989. *Unifying Political Methodology*. Chapter 5.3.

6.2 Advanced Topics

Hosmer, David W. and Stanley Lemeshow. 1989. *Applied Logistic Regression* New York: John Wiley and Sons. Sections on reporting results and predicted probabilities.

6.3 Applications

*Zaller, John R. 1992. *The Nature and Origins of Mass Opinion*. New York: Cambridge University Press. Chapter 7. (Read the entire chapter, but focus on pp. 132-150.)

Brooks, Clem and Jeff Manza. 1997. "U.S. Middle-Class Political Realignment, 1972 to 1992." *American Sociological Review* 62: 191-208.

6.4 Exercise

Estimating a logit model with floor parameter.

7 Ordered Probit

7.1 Fundamentals

- *Long, J. Scott. 1997. *Regression Models for Categorical and Limited Dependent Variables*. Thousand Oaks, CA: Sage. Chapter 5.
- *King, Gary. 1989. *Unifying Political Methodology*. Chapter 5.4.
- *Greene, William H. 2000. *Econometric Analysis*. Chapter 19.8.
- Greene, William H. 1992. *Limdep Version 7.0 User's Manual*. Chapter 23.
- Richard D. McKelvey and William Zavoina, "A Statistical Model for the Analysis of Ordinal Level Dependent Variables", *Journal of Mathematical Sociology*, 1975, vol.4, pp.103-120.

7.2 Advanced Topics

- Newey, W. K. 1987. "Efficient Estimation of Limited Dependent Variable Models with Endogenous Explanatory Variables." *Journal of Econometrics* 36:231-250.

7.3 Applications

- *Franklin, Charles H. and Liane C. Kosaki. 1989. "Republican Schoolmaster: The Supreme Court, Public Opinion and Abortion." *American Political Science Review*, 83:751-771.
- Franklin, Charles H. 1992. "Measurement and the Dynamics of Party Identification", *Political Behavior*, September, 1992.
- Franklin, Charles H. and John E. Jackson. 1983. "The Dynamics of Party Identification." *American Political Science Review*, 77: 957-973.
- Espenshade, Thomas J. and Haishan Fu. 1997. "An Analysis of English Language Proficiency among U.S. Immigrants." *American Sociological Review* 62:288-305.

7.4 Exercise!

Computer Exercise: Ordinal Probit and Statistical Inference.

8 Statistical Inference in ML Models.

8.1 Fundamentals

- *King, Gary. 1989. *Unifying Political Methodology*. Chapter 4.6.
- *Greene, William H. 2000. *Econometric Analysis*. Chapter 4.9.
- Greene, William H. 1992. *Limdep Version 7.0 User's Manual*. Chapter 9.

8.2 Advanced Topics

- Davidson, Russell and James G. Mackinnon. 1993. *Estimation and Inference in Econometrics*. Oxford: Oxford University Press. Chapter 13.
- Amemiya, Takeshi. 1985. *Advanced Econometrics* chapter 4.5.

9 Multiple Choice Models

9.1 Fundamentals

- *Long, J. Scott. 1997. *Regression Models for Categorical and Limited Dependent Variables*. Thousand Oaks, CA: Sage. Chapter 6.
- *Greene, William H. 2000. *Econometric Analysis*. Chapter 19.7.
- Greene, William H. 1992. *Limdep Version 7.0 User's Manual*. Chapter 24.
- G.S. Maddala, *Limited dependent and qualitative variables in econometrics*, pp. 34-46 and 62-64.

9.2 Advanced Topics

- Pudney, Stephen. 1989. *Modeling Individual Choice*. Cambridge MA: Blackwell. Chapter 3 and Appendix 1.
- Davidson, Russell and James G. Mackinnon. 1993. *Estimation and Inference in Econometrics*. Oxford: Oxford University Press. Chapter 16.7-16.8.
- Hausman, J.A. and D. L. McFadden. 1978. "Specification Tests for the Multinomial Logit Model." *Econometrica* 48:1219-1249.
- Hausman, J. A. and D. A. Wise. 1978. "A Conditional Probit Model for Qualitative Choice: Discrete Decisions Recognizing Interdependence and Heterogeneous Preferences." *Econometrica* 46: 406-426.
- McFadden, D. L. 1984. "Econometric Analysis of Qualitative Response Models". In Z. Griliches and M. Intriligator (eds), *The Handbook of Econometrics*, Vol 2, Chapter 24. North Holland.
- McFadden, D. L. 1987. "Regression-Based Specification Tests for the Multinomial Logit Model." *Journal of Econometrics*, 34:63-82.

9.3 Applications

- *Whitten, Guy D. and Harvey D. Palmer. 1996. "Heightening Comparativists' Concern for Model Choice: Voting Behavior in Great Britain and the Netherlands." *American Journal of Political Science* 40:231-260.
- *Alvarez, R. Michael and Jonathan Nagler. 1998. "When Politics and Models Collide: Estimating Models of Multiparty Elections." *American Journal of Political Science*, 42:55-96.
- Richard Born, "Surge and Decline, Negative Voting, and the Midterm Loss Phenomenon: A Simultaneous Choice Analysis", *American Journal of Political Science*, Vol.34, Aug.1990, pp.615-45.
- Alvarez, R, Michael and Jonathan Nagler. 1995. "Economics, Issues and the Perot Candidacy: Voter Choice in the 1992 Presidential Election." *American Journal of Political Science* 39:714-744.
- Entwisle, Barbara, Gail E. Henderson, Susan E. Short, Jill Bouma, and Zhai Fengying. 1995. "Gender and Family Businesses in Rural China." *American Sociological Review* 60:36-57.
- Hao, Lingxin and Mary C. Brinton. 1997. "Productive Activities and Support Systems of Single Mothers." *American Journal of Sociology* 102: 1305-1344.

9.4 Exercise!

Computer Exercise: A Discrete Choice Problem

10 Event Count Models

10.1 Fundamentals

- *Long, J. Scott. 1997. *Regression Models for Categorical and Limited Dependent Variables*. Thousand Oaks, CA: Sage. Chapter 8.
- *King, Gary. 1989. *Unifying Political Methodology*. Chapter 5.5-5.10.
- *King, Gary. 1988. "Statistical Models for Political Science Event Counts: Bias in Conventional Procedures and Evidence for The Exponential Poisson Regression Model," *American Journal of Political Science*, 32, 3 (August): 838–863.
- *Greene, William H. 2000. *Econometric Analysis*. Chapter 19.9.

10.2 Advanced Topics

- Hausman, J. A., B. H. Hall and Z. Griliches. 1984. "Econometric Models for Count Data with and Application to the Patents–R&D Relationship." *Econometrica* 52:909-938.
- Cameron, A. Colin and Pravin K. Trivedi. 1986. "Econometric Models Based on Count Data: Comparisons and Applications of Some Estimators and Tests," *Journal of Applied Econometrics*, 1:29-53.
- Cameron, A. C. and P. K. Trivedi. 1990. "Regression-based Tests for Overdispersion in the Poisson Model." *Journal of Econometrics* 46:347-364.

10.3 Applications

- *King, Gary. 1987. "Presidential Appointments to the Supreme Court: Adding Systematic Explanation to Probabilistic Description," *American Politics Quarterly*, 15, 3 (July): 373–386.
- Sampson, Robert J. and John H. Laub. 1996. "Socioeconomic Achievement in the Life Course of Disadvantaged Men: Military Service as a Turning Point, Circa 1940-1965." *American Sociological Review* 61:347-367.
- Rasler, Karen. 1996. "Concessions, Repression and Political Protest in the Iranian Revolution." *American Sociological Review* 61:132-152.

10.4 Exercise!

Computer Exercise: Models of Supreme Court Appointments.

11 Generalized Event Count Models

11.1 Fundamentals

- *King, Gary. 1989. *Unifying Political Methodology*. Chapter 8.3, 9.4-9.5.
- *King, Gary. 1989b. "Variance Specification in Event Count Models: From Restrictive Assumptions to a Generalized Estimator," *American Journal of Political Science*, 33, 3 (August, 1989): 762–784.

11.2 Advanced Topics

- King, Gary. 1989c. "A Seemingly Unrelated Poisson Regression Model," *Sociological Methods and Research*. 17, 3 (February, 1989): 235–255.
- Winkelmann, Rainer; Curtis Signorino; Gary King. 1993. "A Correction for an Underdispersed Event Count Probability Distribution," *Political Analysis*
- Achen, Christopher H. 1996. "Implicit Substantive Assumptions Underlying the Generalized Event Count Estimator," in John R. Freeman, ed, *Political Analysis*, volume 6. Ann Arbor: University of Michigan Press. pp. 155-174.
- Amato, Timothy W. 1996. "On Difference Equations, Probability Models and the 'Generalized Event Count' Distribution," in John R. Freeman, ed, *Political Analysis*, volume 6. Ann Arbor: University of Michigan Press. pp. 175-212.
- Londregan, John. 1996. "Some Remarks on the 'Generalized Event Count' Distribution," in John R. Freeman, ed, *Political Analysis*, volume 6. Ann Arbor: University of Michigan Press. pp. 213-224.
- King, Gary and Curtis S. Signorino. 1996. "The Generalization in the Generalized Event Count Model, with Comments on Achen, Amato and Londregan," in John R. Freeman, ed, *Political Analysis*, volume 6. Ann Arbor: University of Michigan Press. pp. 225-252.
- Mullahy, John. 1986. "Specification and Testing of Some Modified Count Data Models," *Journal of Econometrics*. 33: 341–65.

11.3 Applications

- *King, Gary. 1989d. "Event Count Models for International Relations: Generalizations and Applications," *International Studies Quarterly*, 33, 2 (June, 1989): 123–147.
- Hannan, Michael T., Glenn R. Carroll, Elizabeth A. Dundon, and John Charles Torres. 1995. "Organizational Evolution in a Multinational Context: Entries of Automobile Manufacturers in Belgium, Britain, France, Germany and Italy." *American Sociological Review* 60:509-528.

11.4 Exercise!

Computer exercise: Event Count Models

12 Models with Nonrandom Selection I

12.1 Fundamentals

- *Long, J. Scott. 1997. *Regression Models for Categorical and Limited Dependent Variables*. Thousand Oaks, CA: Sage. Chapter 7.
- *King, Gary. 1989. *Unifying Political Methodology*. Chapter 9.1-9.3.

12.2 Advanced Topics

- Heckman, James J. 1979. "Sample Selection Bias as a Specification Error." *Econometrica* 47:153-161.

13 Models with Nonrandom Selection II

13.1 Advanced Topics

Amemiya, Takeshi. 1985. *Advanced Econometrics*, Chapter 10.

Dubin, Jeffrey A. and R. Douglas Rivers. 1989/90 “Selection Bias in Linear Regression, Logit and Probit Models.” *Sociological Methods and Research* November 1989/February 1990: 360-390.

Dubin, Jeffrey A. and Douglas Rivers. 1990. “Selection Bias in Linear Regression, Logit and Probit Models.” In John Fox and J. Scott Long (eds) *Modern Methods of Data Analysis* Newbury Park: Sage, 410-442. (Reprint of their *Sociological Methods and Research* article.)

13.2 Exercise!

Computer exercise: Nonrandom selection models

14 Duration Models—An Introduction

14.1 Fundamentals

Allison, Paul D. 1986. *Event History Analysis* Newbury Park: Sage. Chapters 1-2.

Blossfeld, Hans-Peter, Alfred Hamerle and Karl Ulrich Mayer. 1989. *Event History Analysis: Statistical Theory and Applications in the Social Sciences*. Hillsdale, NJ: Erlbaum. Chapters 1-4.

14.2 Applications

*King, Gary, James Alt, Michael Laver and Nancy Burns. 1990. “A unified model of cabinet dissolution in parliamentary democracies” *American Journal of Political Science*, 34:847-71.

Bienen, H. and van de Walle, N. 1989. “Time and Power in Africa”. *American Political Science Review* 83:19-34.

Bienen, H. and van de Walle, N. 1991. *Of Time and Power: Leadership Duration in the Modern World*. Stanford: Stanford University Press.

Bienen, H. and van de Walle, N. 1992. “A Proportional Hazard Model of Leadership Duration.” *Journal of Politics*. 54:685-717.

14.3 Exercise!

Computer Exercise: Coalition Government

15 Duration Models— More Complicated Parametric Models

15.1 Fundamentals

Allison, Paul D. 1986. *Event History Analysis* Newbury Park: Sage. Chapter 3.

Blossfeld, Hans-Peter, Alfred Hamerle and Karl Ulrich Mayer. 1989. *Event History Analysis: Statistical Theory and Applications in the Social Sciences*. Hillsdale, NJ: Erlbaum. Chapter 6.

15.2 Advanced Topics

- Heckman, James and Burton Singer. 1984. "Economic Duration Analysis." *Econometrica* 24:63-132.
- Kalbfleisch, J. D. and R. L. Prentice. 1980. *The Statistical Analysis of Failure Time Data*. New York: John Wiley and Sons.
- Sueyoshi, Glenn. 1992. "Semi-Parametric Proportional Hazards Estimation of Competing Risk Models with Time-Varying Covariates." *Journal of Econometrics* 51:25-57.

15.3 Applications

- *Alt, James and Gary King. 1994. "Transfers of Government Power: The Meaning of Time Dependence." *Comparative Political Studies*, 27:190-210.
- *Warwick, Paul and Stephen T. Easton. 1992. "The Cabinet Stability Controversy: New Perspectives on a Classic Problem." *American Journal of Political Science*. 36:122-146.
- Hannan, Michael T. and Glenn R. Carroll. 1981. "Dynamics of Formal Political Structure: An Event-History Analysis." *American Sociological Review*, 46:19-35.

15.3.1 Further Reading on Cabinet Duration Models

- Warwick, Paul. 1992b. "Rising Hazards: An Underlying Dynamic of Parliamentary Government." *American Journal of Political Science*. 36:857-876.
- Warwick, Paul. 1992c. "Economic Trends and Government Survival in Western European Parliamentary Systems". *American Political Science Review*, 875-87.
- Browne, Eric C., John P. Frendreis and Dennis W. Gleiber. 1984. "An 'Events' Approach to the Problem of Cabinet Stability." *Comparative Political Studies*. 17:167-197.
- Strom, Kaare. 1985. "Party Goals and Government Performance in Parliamentary Democracies." *American Political Science Review* 79:738-754.
- Browne, Eric C., John P. Frendreis and Dennis W. Gleiber. 1986. "The Process of Cabinet Dissolution: An Exponential Model of Duration and Stability in Western Democracies." *American Journal of Political Science* 30:628-650.
- Strom, Kaare. 1988. "Contending Models of Cabinet Stability." *American Political Science Review*. 82:923-930.
- Browne, Eric C., John P. Frendreis and Dennis W. Gleiber. 1988. "Contending Models of Cabinet Stability: A Rejoinder." *American Political Science Review*. 82:923-930.
- Warwick, Paul. 1992a. "Ideological Diversity and Government Survival in Western European Parliamentary Democracies." *Comparative Political Studies*. 25:332-361.
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15.4 Exercise!

Computer exercise: Duration models of cabinet stability