CS&SS 526/SOCIOLOGY 529
Structural Equation Models for the Social Sciences

SYLLABUS

This course introduces structural equation models, focusing on Jöreskog and Sörbom's LISREL approach. We use the LISREL approach because it allows students to understand specification of models in matrix form, the estimation problem, and other details of what is going on behind the scenes; it also will allow students to read the methodological literature on structural equation models. We begin with the notion of a causal structure underlying a set of observable moments (covariances). This notion is illustrated briefly with path analysis applied to a multiple equation recursive model of observable variables. We will discuss the implications of random measurement error in linear regression models, discuss the concept of unobservable variables, and review some elementary principles of classical test theory. We then introduce the LISREL model, describing the model in matrix form, and then briefly present the estimation issue and use of maximum likelihood estimation and likelihood ratio testing. We will discuss the LISREL and PRELIS software programs and mention other programs, such as lavaan in R, Mplus, and SEM in Stata. We will then examine model identification and examine specific classes of models, such as confirmatory factor models, MIMIC models, regression models with latent variables, and non-recursive models. We will also cover estimation when observed data are not multivariate normal, and observed variables are ordinal, dichotomous, or censored. Time permitting, we will survey other models used in recent research in the social sciences, such as models for panel data, growth curve models, models for nested data, mixture models for latent class and trajectory analysis, and models for data missing at random.

INSTRUCTOR

Professor Ross L. Matsueda
227 Savery Hall
Office Hours: Mon, 2-3pm; (Th 7:30-8pm Savery 409)
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616-2432

FORMAT

The course will be organized as a lecture course, which meets Thursdays 5:30-7:20pm. The lectures will combine discussion of the underlying statistical theory, application to social science problems, and practical issues in using the LISREL program. Course notes will be made available in advance of each class period for students enrolled (through the course web site). Students will be expected to complete homework assignments covering simple algebraic manipulations, interpretations of coefficients, and computer exercises using the PRELIS, LISREL programs. Lab sessions will cover PRELIS, LISREL, as well as some coverage of lavaan in R.

1. Students will have the option of completing a short 10-12 page paper in which they specify, estimate, and test a structural equation model and write up the results as in a journal article. The **paper is due Thursday June 7, 5pm**. It may be emailed to the professor. Alternatively, students may opt to take a **final exam** in lieu of the paper at the final exam period, **Tuesday, June 5, 6:30-8:20pm Savery 409**.

2. We will hold a couple of lab sessions in CSSCR classroom/lab Savery 117. Tentatively, we will hold a lab session on **Thursday, April 19** in Savery 117. Here, students will be introduced to computer tutorials. To facilitate student understanding of estimating and testing of models, we will focus on using PRELIS and LISREL syntax, rather than the graphical user interface. On Thursday, April 12, in Savery 409, Chuck Lanfear will present on using R packages SEM and lavaan to estimate structural equation models.

COURSE OBJECTIVES

1. Introduce students to the fundamentals of structural equation modeling, including specification, estimation, and testing.
2. Provide students with a critical understanding of SEM, including the assumptions required to use them.
3. Provide students with the tools to use SEM to address important social scientific problems when the problems and data are appropriate to the method.
4. Provide students experience in specifying, estimating, and testing a simple SEM and writing up the results in a short paper structured on the model of a research article.
5. Provide students with a solid foundation in SEM with which to pick up more advanced topics not covered here.

REQUIRED TEXT

Bollen, Kenneth A. 1989. *Structural Equations with Latent Variables*. New York: Wiley.

SOFTWARE MANUALS

Several user's guides and reference manuals for version 8.80 LISREL and PRELIS are available on the Scientific Software International Website: http://www.ssicentral.com/lisrel/resources.html#u. The following will be particularly useful:

A Brief Overview: *An Introduction to LISREL 8.80 for Windows*.
http://www.ssicentral.com/lisrel/techdocs/Session1.pdf

See the course website http://faculty.washington.edu/matsueda/courses/529/web529s18.htm for the following:

1. New Features in LISREL 9
2. LISREL Syntax Guide
3. PRELIS Syntax Guide
4. SIMPLIS Syntax Guide

Du Toit, Stephen, Mathilda Du Toit, Gerhard Mels, and Yan Cheng. 2006. *LISREL for Windows: PRELIS User's Guide.* Lincolnwood, IL: Scientific Software International, Inc.
http://www.ssicentral.com/lisrel/techdocs/IPUG.pdf

Mels, Gerhard. 2006. *LISREL for Windows: Getting Started Guide.* Lincolnwood, IL: Scientific Software International, Inc. http://www.ssicentral.com/lisrel/techdocs/GSWLISREL.pdf

Du Toit, Stephen, Mathilda Du Toit, Gerhard Mels, and Yan Cheng. 2006. *LISREL for Windows: PRELIS User's Guide.* Lincolnwood, IL: Scientific Software International, Inc.
http://www.ssicentral.com/lisrel/techdocs/LISRELSyntax.pdf#pagemode=bookmarks

The Mplus User's Guide (Version 7) is available from the Mplus website:
https://www.statmodel.com/download/usersguide/Mplus%20user%20guide%20Ver_7_r3_web.pdf and Version 8 User's Guide is now available: https://www.statmodel.com/ugexcerpts.shtml

Information on Stata's Structural equation modeling (SEM) can be found on the Stata sebsite:
http://www.stata.com/features/structural-equation-modeling/ and the manual can be found at:
http://www.stata.com/manuals13/sem.pdf

ADDITIONAL HELPFUL TEXTS

Jöreskog, Karl G., Ulf H. Olsson, and Fan Y. Wallentin. 2016. *Multivariate Analysis with LISREL*. Switzerland: Springer International Publishing.

Byrne, Barbara M. 1998. *Structural Equation Modeling with LISREL, PRELIS, and SIMPLIS: Basic Concepts, Applications, and Programming.* Mahwah, NJ: Lawrence Erlbaum.

Kline, Rex B. 2011. *Principles and Practice of Structural Equation Modeling*. New York: Guilford Press.

Hayduk, Leslie A. 1987. *Structural Equation Modeling with LISREL: Essentials and Advances*. Baltimore: Johns Hopkins.

Schumacker, Randall E., and Richard G. Lomax. 1996. *A Beginner's Guide to Structural Equation Modeling*. Mahwah, NJ: Lawrence Erlbaum.

Kaplan, David. 2000. *Structural Equation Modeling: Foundations and Extensions.* Thousand Oaks, CA: Sage.

Geiser, Christian. 2013. *Data Analysis with Mplus*. New York: Guilford Press.

Dunn, G., Brian S. Everitt, and Andrew Pickles. 1993. *Modelling Covariances and Latent Variables Using EQS*. Boca Raton, FL: CRC Press.

Acock, Alan C. 2013. *Discovering Structural Equation Modeling Using Stata*. Revised Edition. College Station, TX: Stata press.

Bollen, K.A. and P. J. Curran. 2006. *Latent Curve Models: A Structural Equation Perspective*. Wiley Series in Probability and Mathematical Statistics. New York: Wiley

Hoyle, Rick H. 2012. *Handbook of Structural Equation Modeling*. Edited by Rick H. Hoyle. New York: Guilford.

ADVANCED TEXT

Skrondal, Anders, and Sophia Rabe-Hesketh. 2004. *Generalized Latent Variable Modeling: Multilevel, Longitudinal, and Structural Equation Models*. Boca Raton: Chapman & Hall.

PREREQUISITES

Students should have a sound background in intermediate statistics for social scientists, including a basic course in statistical inference and the general linear model or multiple regression, as presented in Sociology 506. Also desirable is a knowledge of (or facility to learn independently) elementary tools of matrix algebra.

COURSE REQUIREMENTS

Students will be expected to complete semi-weekly exercises. Several computer assignments will allow students to analyze data provided by the instructor and write a brief (no more than 5 pages) report. Finally, students will complete a short (10 pages of text) seminar paper using the methods presented in the course using data provided by the instructor or data from the student. The paper will be due **Mon, June 6, 5pm**. Alternatively, students may opt to take **a final exam** in lieu of the paper. The final exam will be held during

the final exam period, **Tues, June 7 6:30-8:20pm Savery 409**. All assignments must be completed on time. **A grade of incomplete will not be given except under unusual circumstances, such as a family emergency**.

GRADING

Grades will be based on homework assignments, the seminar paper (or final exam), and possibly an unannounced (pop) exam.

COMPUTING

Windows versions of LISREL 8.8 and PRELIS 2, as well as Mplus 7 are available in the Center for Social Science Computation and Research microcomputer facility in 118 Savery Hall. The Center for Studies in Demography and Ecology terminal server, csde-ts1.csde.washington.edu has LISREL 9.3, Mplus 8, and lavaan in R are available to students (email CSDE computing for an account). A free student version of LISREL 9.3 can be downloaded free of charge from http://www.ssicentral.com/lisrel/student.html. A free demo version of Mplus Version 8 is available for download at no cost at http://www.statmodel.com/demo.shtml. A free demo version of EQS 6.2 can be downloaded from http://www.mvsoft.com/demos.htm. These student and demo versions generally limit the number of observed variables that can be used. To allow the enrolled students to complete their work on time, I ask that auditors yield to enrolled students whenever there is greater demand for the programs than supply. Other programs available include and SEM and GSEM in Stata, and John Fox's sem package amd Yves Rosseel's lavann package in R.

CONSULTATION

Ross Matsueda's office hours are Monday 2-3pm in 227 Savery Hall, and Thursday 7:30-8pm in 409 Savery Hall.

COURSE WEBSITE

Lecture notes, readings, and assignments will be posted on the course website:
http://faculty.washington.edu/matsueda/courses/529/web529s16.htm

TENTATIVE COURSE OUTLINE AND READINGS

The following is a *tentative* course outline. At various points in the semester, we will diverge from this outline, depending on student needs. Moreover, the number of topics listed cannot be covered adequately in one quarter. We will try to cover most of the core topics (I-X), although some topics, like maximum likelihood, we will cover only superficially.

INTRODUCTION TO THE COURSE

Required:
*Matsueda, Ross L. 2012. "Key Advances in the History of Structural Equation Modeling." Pp. 17-42 in *Handbook on Structural Equation Modeling*. Edited by Rick H. Hoyle. Guilford Press.

*Duncan, Otis Dudley. 1975. *Introduction to Structural Equation Models*. New York: Academic Press, Chapter 1.

Bollen, Kenneth A. 1989. *Introduction to Structural Equation Models with Latent Variables*, Chapter 1.

Recommended:
*Bielby, William T. and Robert M. Hauser. 1977. "Structural Equation Models." *Annual Review of Sociology* 3:137-61.

Bentler, Peter M. 1980. "Multivariate Analysis with Latent Variables: Causal Modeling." *Annual Review of Psychology* 31:419-56.

Bentler, Peter M. 1986. "Structural Modeling and Psychometrika: An Historical Perspective on Growth and Achievement." *Psychometrika* 51:35-51.

Browne, Michael W., and Gerhard Arminger. 1995. "Specification and Estimation of Mean- and Covariance-Structure Models." Pages 185-249 in *Handbook of Statistical Modeling for the Social and Behavioral Sciences*, edited by G. Arminger, C. C. Clogg, and M. E. Sobel. New York: Plenum.

I.   A BIVARIATE LINEAR STRUCTURAL EQUATION MODEL

Required:
*Duncan (1975), Chapters 1-2.

Bollen (1989), Chapter 2.

II.   RECURSIVE MODELS IN OBSERVABLES & DECOMPOSING EFFECTS

Required:
*Duncan (1975), Ch. 3-4.

Bollen, Kenneth A. 1989, Chapter 3.

Jöreskog, Karl G. and Dag Sörbom.1996-2001.*LISREL 8 User's Reference Guide.* Chicago: Scientific Software International, Chapter 4.

Recommended:
Alwin, Duane F. and Robert M. Hauser. 1975. "The Decomposition of Effects in Path Analysis. *American Sociological Review* 40:37-47.

Example:
Sewell, William H., Robert M. Hauser, and Wendy C. Wolf. 1980. "Sex, Schooling, and Occupational Status." *American Journal of Sociology* 86:551-83.

Additional Reading:
Sobel, Michael E. 1986. "Some New Results on Indirect Effects and Their Standard Errors in Covariance Structure Models." Pp. 159-86 in *Sociological Methodology 1986*, edited by N.B. Tuma. Washington, D.C.: American Sociological Association.

Bollen, Kenneth A. 1987. "Total, Direct, and Indirect Effects in Structural Equation Models." Pp. 37-69 in Clifford C. Clogg (ed.), *Sociological Methodology 1987*. Washington, D.C.: American Sociological Association.

III.   AN INTRODUCTION TO SEM USING THE R PACKAGE: SEM AND LAVAAN (GUEST LECTURER: CHARLES LANFEAR)

Required:
*Rosseel, Yves. 2012. "Lavaan: An R package for Structural Equation Modeling." *Journal of Statistical Software* 48:1-36.

*Rosseel, Yves. 2017. "The Lavaan Tutorial." Online access: http://lavaan.ugent.be/tutorial/tutorial.pdf.

IV. THE LISREL SEM MODEL & THE LISREL PROGRAM (118 Savery Hall)

Required:
Bollen (1989), Appendix A and Chapters 2 and 8 (pp. 319-333).

Bollen Chapter 8 (pp. 333-338; 349-50).

Jöreskog, Karl G. and Dag Sörbom. 1996-2001. *LISREL 8*, Chapter 1 (pp. 12-36), chapter 2 (pp. 37-122).

Jöreskog, Karl G. and Dag Sörbom. 1996-2002. *PRELIS 2,* Chapters 1-2 (pp 1-44)*,* skim pp. 45-100.

Jöreskog, Karl G. and Dag Sörbom.1996-2001.*LISREL 8*, pp. 1-12.

Recommended:
Hayduck (1987), Chapters 3 (pages 56-76) and 4.

Hayduk (1987), Chapters 7 and 8.

Bentler, Peter M. 1995. *EQS*, pp. i--100

Additional Reading:
Long (1983) "Covariance Structure Models: An Introduction to LISREL."

V. A SIMPLE STRUCTURAL MODEL WITH UNOBSERVED VARIABLES

Required:
Bollen (1989), Chapter 5.

Bollen (1989), Chapter 6.

Bollen (1989), Chapter 7 (pp. 226-254).

Examples:
*Bielby, William T., Robert M. Hauser, and David L. Featherman. 1977. "Response Errors of Black and Nonblack Males in Models of the Intergenerational Transmission of Socioeconomic Status." *American Journal of Sociology* 82:1242-88.*

*Matsueda, Ross L. 1982. "Testing Control Theory and Differential Association: A Causal Modeling Approach. American Sociological Review." American Sociological Review 47:489-504.
*Paxton, Pamela. 1999. "Is Social Capital Declining in the United States? A Multiple Indicator Assessment." *American Journal of Sociology* 105:88-127.

Recommended:

Hauser, Robert M., and Arthur S. Goldberger. 1971. "The Treatment of Unobservable Variables in Path Analysis." Pp. 81-87 in *Sociological Methodology 1971*, edited by H.L. Costner.

Jöreskog, Karl G. and Dag Sörbom. 1996-2001. *LISREL 8*, Chapter 5, pp. 172-178.

Alwin, Duane F. and David J. Jackson. 1979. "Measurement Models for Response Errors in Surveys: Issues and Applications." Pp. 68-119 in *Sociological Methodology 1980*, edited by Karl F. Schuessler. San Francisco: Jossey-Bass.

Bielby, William T. 1986. "Arbitrary Metrics in Multiple-Indicator Models of Latent Variables." *Sociological Methods and Research* 15:3-23.

Costner, Herbert L. 1969. "Theory, Deduction and Rules of Correspondence." *American Journal of Sociology* 75:245-263. Reprinted as Ch. 16, pp. 399-319 in Hubert M. Blalock (ed.), Causal Models in the Social Sciences. 1971. Chicago: Aldine.

Additional Reading:
Long, J. Scott. 1983. *Confirmatory Factor Analysis*. Beverly Hills: Sage, pp. 1-54.

VI.   ESTIMATION AND TESTING

Required:
Bollen (1989), Chapter 4 (pp. 104-122) and 7 (pp. 254-269).

Bollen (1989), Chapter 4 (pp. 266-305).

Jöreskog, Karl G. and Dag Sörbom. 1996-2001. *LISREL 8*, pp. 17-32, Chapter 11.

Jöreskog, Karl G. and Dag Sörbom. 1996-2001. *LISREL 8*, pp. 341-343 (lists the test statistics).

Recommended:
Hayduk (1987), Chapters 3, (pp. 77-85), 5, and 6 (pp. 190-218).

Bentler, Peter M. 1995. *EQS*, pp. 201-230.

Jöreskog, Karl G. 1973. "A General Method for Estimating a Linear Structural Equation System." Pp. 85-112 in *Structural Equation Models in the Social Sciences*, edited by A. S. Goldberger and O.D. Duncan. New York: Seminar Press.

Browne, Michael W., and Robert Cudeck. 1993. "Alternative Ways of Assessing Model Fit." Pp. 136-62 in *Testing Structural Equation Models*. Edited by K.A. Bollen, and J. Scott Long. Beverly Hills: Sage Publications.

Jöreskog, Karl G. 1993. "Testing Structural Equation Models." Pp. 294-316 in *Testing Structural Equation Models*. Edited by K.A. Bollen, and J. Scott Long. Beverly Hills: Sage Publications.

Chen, F., P.J. Curran, K. A. Bollen, J.B. Kirby, and P.M. Paxton. 2008. "An Empirical Evaluation of the Use of Fixed Cutoff Points in RMSEA Test Statistics in Structural Equation Models." *Sociological Methods and Research* 36:462-94.

Raftery, Adrian E. 1993. "Bayesian Model Selection in Structural Equation Models." Pp. 163-180 in *Testing Structural Equation Models*. Edited by K.A. Bollen, and J. Scott Long. Beverly Hills: Sage Publications.

Additional Readings:

Eliason, Scott R. 1*993. Maximum Likelihood Estimation: Logic and Practice*. Beverly Hills: Sage Publications.

Kendall, Sir Maurice, and Alan Stuart. 1979. *The Advanced Theory of Statistics. Vol. 3: Inference and Relationship*. London: Griffin.

Bollen, Kenneth A., and J. Scott Long (eds.). 1993. *Testing Structural Equation Models*. Beverly Hills: Sage.

Bentler, Peter M. and Douglas G. Bonett. 1980. "Significance Tests and Goodness of Fit in the Analysis of Covariance Structures." *Psychological Bulletin* 88:588-606.

Matsueda, Ross L. and William T. Bielby. 1986. "Statistical Power in Covariance Structure Models." Pp. 120-58 in *Sociological Methodology 1986*, edited by N.B. Tuma. Washington, D.C.: American Sociological Association.

Raftery, Adrian E. 1995. "Bayesian Model Selection in Social Research." Pp. 111-195 (including commentary and replies) in *Sociological Methodology 1995*, edited by Peter V. Marsden. Cambridge: Basil Blackwell.

Wheaton, Blair. 1988. "Assessment of Fit in Overidentified Models with Latent Variables." Pp. 193-225 in J. Scott Long (ed.), *Common Problems/Proper Solutions: Avoiding Error in Quantitative Research*. Beverly Hills, CA: Sage.

VII.   WLS ESTIMATION & MODELS FOR ORDINAL & LIMITED DEPENDENT VARIABLES

Required:
Bollen (1989), Chapter 9 (pp. 409-447).

Jöreskog, Karl G. and Dag Sörbom. 1996-2001. *LISREL 8*, Chapter 7.

Jöreskog, Karl G. and Dag Sörbom. 1996-2002. *PRELIS*, Chapter 4, and review Chapters 1-2.

Recommended:

*Lei, Pui-Wa Lei, and Qiong Wu. 2012. "Estimation in Structural Equation Modeling." Pp. 164-180 in *Handbook on Structural Equation Modeling*. Edited by Rick H. Hoyle. Guilford Press.

Satorra, Albert. 1994. "Asymptotic Robust Inferences in the Analysis of Mean and Covariance Structures." Pp. 249-278 in *Sociological Methodology 1994*, edited by P.V. Marsden. Oxford: Basil Blackwell.

Browne, Michael W. 1984. "Asymptotic Distribution Free Methods in Analysis of Covariance Structures." *British Journal of Mathematical and Statistical Psychology* 37:62-83.

Browne, Michael W., and A. Shapiro. 1988. "Robustness of Normal Theory Methods in the Analysis of Linear Latent Variate Models." *British Journal of Mathematical and Statistical Psychology* 41:193-208.

Bentler, Peter M. 1989. *EQS*, Chapter 10.

Hayduk (1987), Chapter 10.

Muthén, Béngt O. 1984. "A General Structural Equation Model with Dichotomous, Ordered Categorical and Continuous Latent Variable Indicators." *Psychometrika* 49:115-132.

Muthén, Béngt O. 1989. "Dichotomous Factor Analysis of Symptom Data." *Sociological Methods and Research* 18:19-65.

Browne, Michael W., and Gerhard Arminger. 1995. "Mean- and Covariance-Structure Models." Pp. 185-249 in *Handbook of Statistical Modeling for the Social and Behavioral Sciences*, edited by G. Arminger, C.C. Clogg, and M.E. Sobel. New York: Plenum Press.

Jöreskog, Karl G. 1994. "On the Estimation of Polychoric Correlations and their Asymptotic Covariance Matrix." *Psychometrika* 59:381-89.

Example:
*Matsueda, Ross L., and Kathleen Anderson. 1998. "The Dynamics of Delinquent Peers and Delinquency." *Criminology* 36:269-308.

VIII.   INSTRUMENTAL VARIABLES & NON-RECURSIVE MODELS.

Required:

Bollen (1989), Chapter 4 (pp. 80-103).

*Paxton, Pamela, John R. Hipp, and Sandra Marquart-Pyatt. 2011. *Nonrecursive Models: Endogeneity, Reciprocal Relationships, and Feedback Loops*. Beverly Hills: Sage Publications. (Chapter 2. "Specification in Simultaneous Equation Models," pages 4-22.)

Jöreskog, Karl G. and Dag Sörbom. 1996-2001. *LISREL 8*, Chapter 4.

Recommended:
Hayduk (1987), Chapter 8.

Duncan (1975), Chapters 5-7 (pp. 67-99).

*Bielby, William T., and Ross L. Matsueda. 1991. "Statistical Power in Non-Recursive Linear Models." In *Sociological Methodology 1991*, Vol. 20, edited by P. Marsden. Oxford: Basil Blackwell.*

Additional Reading:
Duncan, Otis D., Archibald O. Haller, and Alejandro Portes. 1971. "Peer Influences on Aspirations: A Reinterpretation." Pp. 219-244 in Hubert M. Blalock, Jr. (ed.), *Causal Models in the Social Sciences*. Chicago: Aldine.

Greene, William H. 2003. *Econometric Analysis*. Fifth Edition. New York: Wiley. (Chapter 15).

Examples:
*John Robert Warren. 2009. "Socioeconomic Status and Health across the Life Course: A Test of the Social Causation and Health Selection Hypotheses." Social Forces.87: 2125-2154.

Waite, Linda J., and Ross M. Stolzenberg. 1976. "Intended Childbearing and Labor Force Participation of Young Women: Insights from Nonrecursive Models." *American Sociological Review* 41:235-52.

Kohn, Melvin L. and Carmi Schooler. 1981. "Job Conditions and Intellectual Flexibility: A Longitudinal Assessment of Their Reciprocal Effects." Pp. 281-313 in David J. Jackson and Edgar F, Borgatta (eds.), *Factor Analysis and Measurement in Sociological Research: A Multi-Dimensional Perspective*. Beverly Hills, CA: Sage.

IX. MIMIC MODELS AND IDENTIFICATION

Required:
Bollen (1989), Chapters 7 (pp. 311-318) and 8 (pp. 319-338).

Bollen (1989), Chapters 4 (pp. 88-103), 7 (pp. 238-251), and 8 (pp. 326-32).

Jöreskog, Karl G. and Dag Sörbom. 1996-2001. *LISREL 8*, Chapter 5 (especially pages 185-187)

Recommended:
Hauser, Robert M., and Arthur S. Goldberger. 1971. "The Treatment of Unobservable Variables in Path Analysis." Pp. 81-87 in *Sociological Methodology 1971*, edited by H.L. Costner.

Jöreskog, Karl G. and Arthur S. Goldberger. 1975. "Estimation of a Model with Multiple Indicators and Multiple Causes of a Single Latent Variable." *Journal of the American Statistical Association* 70:631-39.

Hayduk (1987), Chapter 7.

Long, J. Scott. 1983. *Covariance Structure Models: An Introduction to LISREL.* Beverly Hills: Sage.

O'Brien, Robert M. 1994. "Identification of Simple Measurement Models with Multiple Latent Variables and Correlated Errors." Pp. 137-70 in *Sociological Methodology 1994*, edited by P.V. Marsden. Oxford: Basil Blackwell.

Hayduk (1987), Chapters 5 (pp. 139-55).

Kenny, David A., and Stephanie Milan. 2012. "Identification: A Nontechnical Discussion of a Technical Issue." Pp. 145-163 in *Handbook on Structural Equation Modeling*. Edited by Rick H. Hoyle. Guilford Press.

Examples:
Hodge, Robert W., and Donald J. Treiman. 1968. "Social Participation and Social Status." *American Sociological Review* 33:722-40.

Hauser, Robert M. 1969. "On Social Participation and Social Status." *American Sociological Review* 34:549-53.

*Paxton, Pamela. 1999. "Is Social Capital Declining in the United States? A Multiple Indicator Assessment." *American Journal of Sociology* 105:88-127.

X. MODELS FOR PANEL DATA.

Required:
Jöreskog, Karl G. and Dag Sörbom. 1996-2001. *LISREL 8*, Chapter 6 (especially pp. 213-238)

Recommended:

Kessler, Ronald C., and David F. Greenberg. 1981. *Linear Panel Analysis: Models of Quantitative Change*. New York: Academic Press.

Palmquist, Bradley, and Donald P. Green. 1994. "Estimation of Models with Correlated Measurement Errors from Panel Data." Pp. 119-46 in *Sociological Methodology 1994*, edited by P.V. Marsden. Oxford: Basil Blackwell.

Duncan, Otis D. 1972. "Unmeasured Variables in Linear Models for Panel Analysis." Pp. 36-82 in Herbert L. Costner (ed.), *Sociological Methodology 1972*. San Francisco: Jossey-Bass.

Additional Reading:
Jöreskog, Karl G. 1978. "An Econometric Model for Multivariate Panel Data." *Annals de l'INSEE*, No. 30-31.

Examples:
*Paxton, Pamela. 2002. "Social Capital and Democracy: An Interdependent Relationship." *American Sociological Review* 67:254-277.

Wheaton, Blair, Bengt Muthén, Duane F. Alwin, and Gene F. Summers. 1977. "Assessing Reliability and Stability in Panel Models." Pp. 84-136 in *Sociological Methodology 1977,* edited by D. R. Heise. San Francisco: Jossey-Bass.

*Matsueda, Ross L. 1989. "The Dynamics of Moral Beliefs and Minor Deviance. *Social Forces* 68:428-457.

XI.   MODELS FOR NESTED DATA: SIBLING MODELS.

Required:
Hauser, Robert M. 1988. "A Note on Two Models of Sibling Resemblance." *American Journal of Sociology* 93:1401-23.

Recommended:
Hauser Robert M., and Mossel, Peter A. 1988. "Some Structural Equation Models of Sibling Resemblance in Educational Attainment and Occupational Status." Pp. 108-137 in *Structural Equation Modeling by Example: Applications in Education and the Social and Behavioral Sciences*. Cambridge: Cambridge University Press.

Bielby, William T. 1981. "Neighborhood Effects: A LISREL Model for Clustered Samples." *Sociological Methods and Research* 10:82-111.

Hsiang-Hui, Daphne Kuo, and Robert M. Hauser. 1995. "Trends in Family Effects on the Education of Black and White Brothers." *Sociology of Education* 68:136-60.

XII.   LATENT GROWTH CURVE MODELS.

Required:
Bollen, K.A. and P. J. Curran. 2006. Latent Curve Models: A Structural Equation Perspective. New York: Wiley

Kaplan, David. 2000. *Structural Equation Modeling: Foundations and Extensions.* Thousand Oaks, CA: Sage. Chapter 8.

Muthén, Bengt O.,and Muthén, Linda K. *Mplus User's Guide, Version 3.* Los Angeles: Muthén and Muthén.

Recommended:

McArdle, J. J., and D. Epstein. 1987. "Latent Growth Curves within Developmental Structural Equation Models. *Child Development* 58:110-133.

Rogosa, D.R., D. Brand, and M. Zimowski. 1982. "A Growth Curve Approach to the Measurement of Change." *Psychological Bulletin* 90:726-748.

Example:

Curran, Patrick J., Bength O. Muthén, and Thomas C. Harford. 1998. "The Influence of Changes in Marital Status on Developmental Trajectories of Alcohol Use in Young Adults." *Journal of Studies of Alcohol* 59: 647-658.

XIII.   MODEL-FITTING AND STATISTICAL TESTING IN CONFIRMATORY FACTOR ANALYSIS.

Required:

Bollen (1989), Chapter 7.

Jöreskog, Karl G. and Dag Sörbom. 1996-2001. *LISREL 8*, Chapter 3.

Recommended:

Hayduk (1987), Chapter 6 (pp. 159-179).

Long, J. Scott. 1983. *Confirmatory Factor Analysis*. Beverly Hills: Sage, Pp. 55-88.

Additional Reading:

Saris and Stronkhorst (1984), Chs. 11-13.

XIV.   MULTIPLE-GROUP MODELS.

Required:

Bollen (1989), Chapter 8 (pp. 355-65).

Jöreskog, Karl G. and Dag Sörbom. 1996-2001. *LISREL 8*, Chapter 9.

Recommended:

Hayduk (1987), Chapter 9 (pp. 276-285).

Sörbom, Dag and Karl G. Jöreskog. 1981. "The Use of LISREL in Sociological Model Building." Pp. 179-199 in David J. Jackson and Edgar F. Borgotta (eds.), *Factor Analysis and Measurement in Sociological Research: A Multidimensional Perspective*. Beverly Hills: Sage.

Additional Reading:

Bentler, Peter M. 1989. *EQS*, Chapter 7.

Example:

*Bartusch, Dawn Jeglum, and Ross L. Matsueda. 1996. "Gender, Reflected Appraisals, and Labeling: A Cross-Group Test of an Interactionist Theory of Delinquency." *Social Forces* 75:145-176.

Heimer, Karen, and De Coster, Stacy. 1999. "The Gendering of Violent Delinquency." Criminology 37:277-318

XV.   MODELS FOR MEAN STRUCTURES.

Required:
Bollen (1989), Chapter 8 (pp. 350-55 and pp. 365-69).

Jöreskog, Karl G. and Dag Sörbom. 1996-2001. *LISREL 8*, Chapter 10.

Recommended:
Hayduk (1987), Chapter 9 (pp. 286-322).

Sörbom, Dag. 1982. "Structural Equation Models with Structured Means." Pp. 183-95 in *Systems Under Indirect Observation, Part 1,* edited by K. G. Jöreskog and H. Wold. Amsterdam: North-Holland.

Bentler, Peter M. 1989. *EQS*, Chapters 8 and 9.

Jones, F.L., and Jonathan Kelley. 1984. "Decomposing Differences Between Groups." *Sociological Methods and Research* 323-43.

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XVI.   STATISTICAL POWER OF TESTS.

Required:
Bollen (1989), Chapter 8 (pp. 338-349).

Jöreskog, Karl G. and Dag Sörbom. 1996-2001. *LISREL 8*, Chapter 8 (pp. 265-71).

Recommended:
*Matsueda, Ross L. and William T. Bielby. 1986. "Statistical Power in Covariance Structure Models." Pp. 120-58 in *Sociological Methodology 1986*, edited by N.B. Tuma. Washington, D.C.: American Sociological Association.

Saris, Willem E., J. Den Ronden, and A. Satorra. 1987. "Testing Structural Equation Models." Pp. 202-220 in Peter Cuttance and Russell Ecob (eds.), *Structural Modeling by Example*. Cambridge: Cambridge University Press.

Satorra, Albert and Willem E. Saris. 1985. "The Power of the Likelihood Ratio Test in Covariance Structure Analysis." *Psychometrika* 50:83-90.

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Saris, W. E., J. Den Ronden, and A. Satorra. "Testing Structural Equation Models." Pp. 202-20 in *Structural Equation Modeling by Example: Applications in Education and the Social and Behavioral Sciences*. Cambridge: Cambridge University Press.

XVII.   MODELS WITH MISSING DATA.

Required:
Bollen (1989), Chapter 9 (pp. 369-376).

Jöreskog, Karl G. and Dag Sörbom. 1996-2001. *LISREL 8*, pp. 310-312.

Recommended:

Allison, Paul. 1987. "Estimation of Linear Models with Incomplete Data." Pp. 71-103 in Clifford C. Clogg (ed.), *Sociological Methodology 1987*. Washington, D.C.: American Sociological Association.

Lee, Sik-Yum. 1986. "Estimation for Structural Equation Models with Missing Data." *Psychometrika* 51:93-99.

Arminger, Gerhard, and Michael E. Sobel. 1990. "Pseudo-Maximum Likelihood Estimation of Mean and Covariance Structures with Missing Data." *Journal of the American Statistical Association* 85:195-203.

Example:

Allison, Paul, and Robert M. Hauser, "Reducing Bias in Estimates of Linear Models by Remeasurement of a Random Subsample," *Sociological Methods and Research* 19 (May 1991):466-491.

XVIII.   MODELS FOR MULTI-LEVEL DATA.

Required:

Muthén, Béngt O. 1994. "Multilevel covariance structure analysis. *Sociological Methods and Research* 22:376-98.

Muthén, Bengt O.,and Muthén, Linda K. *Mplus User's Guide, Version 3.* Los Angeles: Muthén and Muthén.

McArdle, John J., and Fumiaki Hamagami. 1996. "Multilevel Models from a Multiple Group Structural Equation Perspective. PP. 89-124 in *Advanced Structural Equation Modeling*, edited by G.A. Marcoulides and R.E. Schumacker. Mahwah, NJ:Lawrence, Erlbaum.

Recommended:

Muthén, Béngt O., and Albert Sattora. 1989. "Multilevel aspects of varying parameters in structural models. In R.D. Bock (ed.), *Multilevel Analysis of Educational Data.* San Diego: Academic Press.

Willett, John B., and Aline G. Sayer. 1996. "Cross-Domain Analyses of Change Over Time: Combining Growth Modeling and Covariance Structure Analysis." Pp. 125-37 in *Advanced Structural Equation Modeling*, edited by G.A. Marcoulides and R.E. Schumacker. Mahwah, NJ:Lawrence, Erlbaum.

Bauer, Daniel J., Kristopher J. Preacher, and Karen M. Gil. 2006. "Conceptualizing and Testing Random Indirect Effects and Moderated Mediation in Multilevel Models: New Procedures and Recommendations." *Psychological Methods* 11(2): 42-163.

XIV. MIXTURE MODELS FOR LATENT CLASS AND TRAJECTORY ANALYSIS.

Required:

Bollen, K.A. and P. J. Curran. 2006. Latent Curve Models: A Structural Equation Perspective. New York: Wiley

Muthén, Béngt O., and Linda K. Muthén. 2000. "Integrating Person-Centered and Variable-Centered Analyses: Growth Mixture Modeling with Latent Trajectory Classes." *Alcoholism: Clinical and Experimental Research* 24: 882-891.

Muthén, Bengt O.,and Muthén, Linda K. *Mplus User's Guide, Version 3.* Los Angeles: Muthén and Muthén.

Recommended:

Nagin, Daniel S. 2005. *Group-Based Modeling of Development*. Cambridge, MA: Harvard University Press.

Bauer, Daniel J., and Patrick J. Curran. 2003. "Distributional Assumptions of Growth Mixture Models: Implications of Overextraction of Latent Trajectory Classes." *Psychological Methods* 8:338-63. (Also see commentary in the same issue.)

Arminger, G., P. Stein, and J. Wittenberg. 1999. "Mixtures of Conditional Mean- and Covariance-Structure Models. *Psychometrika* 64: 475-497.

Erosheva, Elena A., Ross L. Matsueda, and Donatello Telesca. 2014. "Breaking Bad: Two Decades of Life Course Data Analysis in Criminology, Developmental Psychology, and Beyond." *Annual Review of Statistics and Its Applications* 1:301-32. Edited by S.E. Fienberg, N. Reid, and S.M. Stigler.

Example:
Nagin, Daniel S., and R.E. Tremblay. 2005. "What has been Learned from Group-Based Trajectory Modeling? Examples from Physical Aggression and other Problem Behaviors." *Annals of the American Academy of Political and Social Science* 602:82-117.