

# Contents

<b>1</b>	<b>Getting Started</b>	<b>1</b>
1.1	Importing Data . . . . .	1
1.2	Graphs . . . . .	4
1.3	Splitting the Data into Two Groups . . . . .	9
1.4	Introduction to LISREL Syntaxes . . . . .	11
1.5	Estimating Covariance or Correlation Matrices . . . . .	15
1.6	Missing Values . . . . .	18
1.7	Data Management . . . . .	26
<b>2</b>	<b>Regression Models</b>	<b>35</b>
2.1	Linear Regression . . . . .	35
2.1.1	Estimation and Testing . . . . .	37
2.1.2	Example: Cholesterol . . . . .	39
2.1.3	Importing Data . . . . .	39
2.1.4	Checking the Assumptions . . . . .	45
2.1.5	The Effect of Increasing the Sample Size . . . . .	52
2.1.6	Regression using Means, Variances, and Covariances . . . . .	52
2.1.7	Standardized Solution . . . . .	53
2.1.8	Predicting y When $\ln(y)$ is Used as the Dependent Variable . . . . .	55
2.1.9	Example: Income . . . . .	55
2.1.10	ANOVA and ANCOVA . . . . .	58
2.1.11	Example: Biology . . . . .	59
2.1.12	Conditional Regression . . . . .	61
2.1.13	Example: Birthweight . . . . .	61
2.1.14	Testing Equal Regressions . . . . .	63
2.1.15	Example: Math on Reading by Career . . . . .	64
2.1.16	Instrumental Variables and Two-Stage Least Squares . . . . .	70
2.1.17	Example: Income and Money Supply . . . . .	72
2.1.18	Example: Tintner's Meat Market Model . . . . .	75
2.1.19	Example: Klein's Model I of US Economy . . . . .	76
2.2	General Principles of SIMPLIS Syntax . . . . .	79

2.2.1	Example: Income and Money Supply Using <b>SIMPLIS</b> Syntax . . . . .	86
2.2.2	Example: Prediction of Grade Averages . . . . .	88
2.2.3	Example: Prediction of Test Scores . . . . .	90
2.2.4	Example: Union Sentiment of Textile Workers . . . . .	92
2.3	The General Multivariate Linear Model . . . . .	95
2.3.1	Introductory <b>LISREL</b> Syntax . . . . .	97
2.3.2	Univariate Regression Model . . . . .	98
2.3.3	Multivariate Linear Regression . . . . .	101
2.3.4	Example: Prediction of Test Scores with <b>LISREL</b> Syntax . . . . .	102
2.3.5	Recursive Systems . . . . .	105
2.3.6	Example: Union Sentiment of Textile Workers with <b>LISREL</b> Syntax . . . .	105
2.3.7	Non-Recursive Systems . . . . .	107
2.3.8	Example: Income and Money Supply with <b>LISREL</b> syntax . . . . .	107
2.3.9	Direct, Indirect, and Total Effects . . . . .	109
2.4	Logistic and Probit Regression . . . . .	112
2.4.1	Continuous Predictors . . . . .	112
2.4.2	Example: Credit Risk . . . . .	113
2.4.3	Pseudo- $R^2$ s . . . . .	115
2.4.4	Categorical Predictors . . . . .	115
2.4.5	Example: Death Penalty Verdicts . . . . .	116
2.4.6	Extensions of Logistic and Probit Regression . . . . .	119
2.5	Censored Regression . . . . .	119
2.5.1	Censored Normal Variables . . . . .	120
2.5.2	Censored Normal Regression . . . . .	122
2.5.3	Example: Affairs . . . . .	123
2.5.4	Example: Reading and Spelling Tests . . . . .	126
2.6	Multivariate Censored Regression . . . . .	127
2.6.1	Example: Testscores . . . . .	130

### **3 Generalized Linear Models 135**

3.1	Components of Generalized Linear Models . . . . .	135
3.2	Exponential Family Distributions . . . . .	136
3.2.1	Distributions and Link Functions . . . . .	136
3.3	The Poisson-Log Model . . . . .	137
3.3.1	Example: Smoking and Coronary Heart Disease . . . . .	139
3.3.2	Example: Awards . . . . .	144
3.4	The Binomial-Logit/Probit Model . . . . .	148
3.4.1	Example: Death Penalty Verdicts Revisited . . . . .	149
3.5	Log-linear Models . . . . .	152

3.5.1	Example: Malignant Melanoma . . . . .	153
3.6	Nominal Logistic Regression . . . . .	156
3.6.1	Example: Program Choices 1 . . . . .	158
3.6.2	Example: Program Choices 2 . . . . .	162
3.7	Ordinal Logistic Regression . . . . .	164
3.7.1	Example: Mental Health . . . . .	165
3.7.2	Example: Car Preferences . . . . .	167
<b>4</b>	<b>Multilevel Analysis</b>	<b>171</b>
4.1	Basic Concepts and Issues in Multilevel Analysis . . . . .	171
4.1.1	Multilevel Data and Multilevel Analysis . . . . .	171
4.1.2	Examples of Multilevel Data . . . . .	171
4.1.3	Terms Used for Two-level Models . . . . .	172
4.1.4	Multilevel Analysis vs Linear Regression . . . . .	172
4.1.5	Other Terminology . . . . .	173
4.1.6	Populations and Subgroups . . . . .	173
4.1.7	The Interaction Question . . . . .	173
4.2	Within and Between Group Variation . . . . .	174
4.2.1	Univariate Analysis . . . . .	174
4.2.2	Example: Netherlands Schools, Univariate Case . . . . .	174
4.2.3	Multivariate Analysis . . . . .	181
4.2.4	Example: Netherlands Schools, Multivariate Case . . . . .	181
4.3	The Basic Two-Level Model . . . . .	183
4.3.1	Example: Math on Reading with Career-Revisited . . . . .	185
4.4	Two-Level Model with Cross-Level Interaction . . . . .	189
4.5	Likelihood, Deviance, and Chi-Square . . . . .	190
4.5.1	Example: Math Achievement and Socioeconomic Status . . . . .	191
4.6	Multilevel Analysis of Repeated Measurements . . . . .	197
4.6.1	Example: Treatment of Prostate Cancer . . . . .	198
4.6.2	Example: Learning Curves of Air Traffic Controllers . . . . .	201
4.6.3	Example: Growth Curves for the Weight of Mice . . . . .	208
4.6.4	Example: Growth Curves for Weight of Chicks on Four Diets . . . . .	210
4.7	Multilevel Generalized Linear Models . . . . .	217
4.7.1	Example: Social Mobility . . . . .	217
4.8	The Basic Three-Level Model . . . . .	223
4.8.1	Example: CPC Survey Data . . . . .	224
4.9	Multivariate Multilevel Analysis . . . . .	228
4.9.1	Example: Analysis of the Junior School Project Data (JSP) . . . . .	230

<b>5</b>	<b>Principal Components (PCA)</b>	<b>237</b>
5.1	Principal Components of a Covariance Matrix . . . . .	237
5.1.1	Example: Five Meteorological Variables . . . . .	241
5.2	Principal Components vs Factor Analysis . . . . .	248
5.3	Principal Components of a Data Matrix . . . . .	252
5.3.1	Example: PCA of Nine Psychological Variables . . . . .	253
5.3.2	Example: Stock Market Prices . . . . .	255
<b>6</b>	<b>Exploratory Factor Analysis (EFA)</b>	<b>257</b>
6.1	The Factor Analysis Model and Its Estimation . . . . .	258
6.2	A Population Example . . . . .	265
6.2.1	Example: A Numeric Illustration . . . . .	265
6.3	EFA with Continuous Variables . . . . .	268
6.3.1	Example: EFA of Nine Psychological Variables (NPV) . . . . .	268
6.4	EFA with Ordinal Variables . . . . .	273
6.4.1	EFA of Binary Test Items . . . . .	274
6.4.2	Example: Analysis of LSAT6 Items . . . . .	274
6.4.3	EFA of Polytomous Tests and Survey Items . . . . .	277
6.4.4	Example: Attitudes Toward Science and Technology . . . . .	278
<b>7</b>	<b>Confirmatory Factor Analysis(CFA)</b>	<b>283</b>
7.1	General Model Framework . . . . .	284
7.2	Measurement Models . . . . .	286
7.2.1	The Congeneric Measurement Model . . . . .	286
7.2.2	Congeneric, parallel, and tau-equivalent measures . . . . .	287
7.2.3	Example: Analysis of Reader Reliability in Essay Scoring . . . . .	288
7.3	CFA with Continuous Variables . . . . .	290
7.3.1	Continuous Variables without Missing Values . . . . .	290
7.3.2	Example: CFA of Nine Psychological Variables . . . . .	291
7.3.3	Estimating the Model by Maximum Likelihood . . . . .	292
7.3.4	Analyzing Correlations . . . . .	304
7.3.5	Continuous Variables with Missing Values . . . . .	311
7.3.6	Example: Longitudinal Data on Math and English Scores . . . . .	311
7.4	CFA with Ordinal Variables . . . . .	318
7.4.1	Ordinal Variables without Missing Values . . . . .	318
7.4.2	Ordinal Variables with Missing Values . . . . .	328
7.4.3	Example: Measurement of Political Efficacy . . . . .	329

<b>8</b>	<b>Structural Equation Models (SEM) with Latent Variables</b>	<b>341</b>
8.1	Example: Hypothetical Model . . . . .	341
8.1.1	Hypothetical Model with SIMPLIS Syntax . . . . .	342
8.2	The General LISREL Model in LISREL Format . . . . .	343
8.3	General Framework . . . . .	344
8.3.1	Scaling of Latent Variables . . . . .	345
8.3.2	Notation for LISREL Syntax . . . . .	346
8.4	Special Cases of the General LISREL Model . . . . .	347
8.4.1	Matrix Specification of the Hypothetical Model . . . . .	347
8.4.2	LISREL syntax for the Hypothetical Model . . . . .	349
8.5	Measurement Errors in Regression . . . . .	350
8.5.1	Example: Verbal Ability in Grades 4 and 5 . . . . .	350
8.5.2	Example: Role Behavior of Farm Managers . . . . .	351
8.6	Second-Order Factor Analysis . . . . .	355
8.6.1	Example: Second-Order Factor of Nine Psychological Variables . . . . .	357
8.7	Analysis of Correlation Structures . . . . .	359
8.7.1	Example: CFA Model for NPV Estimated from Correlations . . . . .	360
8.8	MIMIC Models . . . . .	363
8.8.1	Example: Peer Influences and Ambition . . . . .	363
8.8.2	Example: Continuous Causes and Ordinal Indicators . . . . .	367
8.9	A Model for the Theory of Planned Behavior . . . . .	371
8.9.1	Example: Attitudes to Drinking and Driving . . . . .	371
8.10	Latent Variable Scores . . . . .	374
8.10.1	Example: Panel Model for Political Democracy . . . . .	374
<b>9</b>	<b>Analysis of Longitudinal Data</b>	<b>379</b>
9.1	Two-wave Models . . . . .	379
9.1.1	Example: Stability of Alienation . . . . .	379
9.1.2	Example: Panel Model for Political Efficacy . . . . .	384
9.2	Simplex Models . . . . .	396
9.2.1	Example: A Simplex Model for Academic Performance . . . . .	398
9.3	Latent Curve Models . . . . .	399
9.3.1	Example: Treatment of Prostate Cancer . . . . .	402
9.3.2	Example: Learning Curves for of Traffic Controllers . . . . .	413
9.4	Latent Growth Curves and Dyadic Data . . . . .	420
9.4.1	Example: Quality of Marriages . . . . .	420
<b>10</b>	<b>Multiple Groups</b>	<b>427</b>
10.1	Factorial Invariance . . . . .	427
10.2	Multiple Groups with Continuous Variables . . . . .	429

10.2.1	Equal Regressions . . . . .	429
10.2.2	Example: STEP Reading and Writing Tests in Grades 5 and 7 . . . . .	429
10.2.3	Estimating Means of Latent Variables . . . . .	432
10.2.4	Confirmatory Factor Analysis with Multiple Groups . . . . .	436
10.2.5	Example: Chicago Schools Data . . . . .	436
10.2.6	MIMIC Models for Multiple Groups . . . . .	439
10.2.7	Twin Data Models . . . . .	444
10.2.8	Example: Heredity of BMI . . . . .	447
10.3	Multiple Groups with Ordinal Variables . . . . .	454
10.3.1	Example: The Political Action Survey . . . . .	454
10.3.2	Data Screening . . . . .	455
10.3.3	Multigroup Models . . . . .	458
<b>11</b>	<b>Appendix A: Basic Matrix Algebra and Statistics</b>	<b>469</b>
11.1	Basic Matrix Algebra . . . . .	469
11.2	Basic Statistical Concepts . . . . .	477
11.3	Basic Multivariate Statistics . . . . .	479
11.4	Measurement Scales . . . . .	480
<b>12</b>	<b>Appendix B: Testing Normality</b>	<b>481</b>
12.1	Univariate Skewness and Kurtosis . . . . .	481
12.2	Multivariate Skewness and Kurtosis . . . . .	484
<b>13</b>	<b>Appendix C: Computational Notes on Censored Regression</b>	<b>487</b>
13.1	Computational Notes on Univariate Censored Regression . . . . .	487
13.2	Computational Notes on Multivariate Censored Regression . . . . .	489
<b>14</b>	<b>Appendix D: Normal Scores</b>	<b>491</b>
<b>15</b>	<b>Appendix E: Assessment of Fit</b>	<b>493</b>
15.1	From Theory to Statistical Model . . . . .	493
15.2	Nature of Inference . . . . .	495
15.3	Three Situations . . . . .	495
15.4	Selection of One of Several Specified Models . . . . .	497
15.5	Model Assessment and Modification . . . . .	498
15.6	Chi-squares . . . . .	499
15.7	Goodness-of-Fit Indices . . . . .	500
15.8	Population Error of Approximation . . . . .	500
15.9	Other Fit Indices . . . . .	501

<b>16 Appendix F: General Statistical Theory</b>	<b>503</b>
16.1 Continuous Variables . . . . .	503
16.1.1 Data and Sample Statistics . . . . .	503
16.1.2 The Multivariate Normal Distribution . . . . .	503
16.1.3 The Multivariate Normal Likelihood . . . . .	504
16.1.4 Likelihood, Deviance, and Chi-square . . . . .	506
16.1.5 General Covariance Structures . . . . .	507
16.1.6 The Independence Model . . . . .	511
16.1.7 Mean and Covariance Structures . . . . .	511
16.1.8 Augmented Moment Matrix . . . . .	513
16.1.9 Multiple Groups . . . . .	513
16.1.10 Maximum Likelihood with Missing Values (FIML) . . . . .	515
16.1.11 Multiple Imputation . . . . .	516
16.2 Ordinal Variables . . . . .	516
16.2.1 Estimation by FIML . . . . .	517
16.2.2 Estimation via Polychorics . . . . .	519
<b>17 Appendix G: Iteration Algorithms</b>	<b>523</b>
17.1 General Definitions . . . . .	523
17.2 Technical Parameters . . . . .	524
17.3 The Davidon-Fletcher-Powell Method . . . . .	526
17.4 Convergence Criterion . . . . .	526
17.5 Line Search . . . . .	526
17.6 Interpolation and Extrapolation Formulas . . . . .	532
<b>Bibliography</b>	<b>535</b>
<b>Subject Index</b>	<b>551</b>

Multivariate Analysis with LISREL

Jöreskog, K.G.; Olsson, U.H.; Wallentin, F.Y.

2016, XV, 557 p. 155 illus., 89 illus. in color., Hardcover

ISBN: 978-3-319-33152-2