

Contents

1. Introduction	1
Historical Background, 4	
2. Model Notation, Covariances, and Path Analysis	10
Model Notation, 10	
Latent Variable Model, 11	
Measurement Model, 16	
Covariance, 21	
Covariance Algebra, 21	
Sample Covariances, 23	
Path Analysis, 32	
Path Diagrams, 32	
Decomposition of Covariances and Correlations, 34	
Total, Direct, and Indirect Effects, 36	
Summary, 39	
3. Causality and Causal Models	40
Nature of Causality, 40	
Isolation, 45	
Association, 57	
Direction of Causation, 61	
Limitations of “Causal” Modeling, 67	
Model-Data versus Model-Reality Consistency, 67	
Experimental and Nonexperimental Research, 72	

Criticisms of Structural Equation Models, 78
Summary, 79

4. Structural Equation Models with Observed Variables

80

Model Specification, 80

Implied Covariance Matrix, 85

Identification, 88

t-Rule, 93

Null B Rule, 94

Recursive Rule, 95

Rank and Order Conditions, 98

Summary of Identification Rules, 103

Estimation, 104

Maximum Likelihood (ML), 107

Unweighted Least Squares (ULS), 111

Generalized Least Squares (GLS), 113

Other Estimators, 115

Empirical Examples, 116

Further Topics, 123

Standardized and Unstandardized Coefficients, 123

Alternative Assumptions for \mathbf{x} , 126

Interaction Terms, 128

Intercepts, 129

Analysis of Variance (ANOVA)
and Related Techniques, 130

Summary, 131

Appendix 4A Derivation of F_{ML}
(\mathbf{y} and \mathbf{x} Multinormal), 131

Appendix 4B Derivation of F_{ML}
(\mathbf{S} Wishart Distribution), 134

Appendix 4C Numerical Solutions to Minimize
Fitting Functions, 136

Starting Values, 137

Steps in the Sequence, 138

Stopping Criteria, 143

Appendix 4D Illustrations of LISREL
and EQS Programs, 144

LISREL Program, 144	
EQS Program, 148	
5. The Consequences of Measurement Error	151
Univariate Consequences, 151	
Bivariate and Simple Regression Consequences, 154	
Consequences in Multiple Regression, 159	
Correlated Errors of Measurement, 167	
Consequences in Multiequation Systems, 168	
Union Sentiment Example, 168	
Unknown Reliabilities, 170	
Objective and Subjective Socioeconomic Status (SES), 172	
Summary, 175	
Appendix 5A Illustrations of LISREL and EQS Programs, 176	
LISREL Program, 176	
EQS Program, 178	
6. Measurement Models: The Relation between Latent and Observed Variables	179
Measurement Models, 179	
Validity, 184	
Content Validity, 185	
Criterion Validity, 186	
Construct Validity, 188	
Convergent and Discriminant Validity, 190	
Alternatives to Classical Validity Measures, 193	
Summary, 206	
Reliability, 206	
Empirical Means of Assessing Reliability, 209	
Alternatives to Classical Reliability Measures, 218	
Summary, 221	
Cause Indicators, 222	
Summary, 223	
Appendix 6A LISREL Program for the Multitrait-Multimethod Example, 223	

7. Confirmatory Factor Analysis**226**

- Exploratory and Confirmatory Factor Analysis, 226
- Model Specification, 233
- Implied Covariance Matrix, 236
- Identification, 238
 - t*-Rule, 242
 - Three-Indicator Rules, 244
 - Two-Indicator Rules, 244
 - Summary of Rules, 246
 - An Insufficient Condition of Identification, 246
 - Empirical Tests of Identification, 246
 - Recommendations for Checking Identification, 251
 - Political Democracy Example, 251
- Estimation, 254
 - Nonconvergence, 254
- Model Evaluation, 256
 - Overall Model Fit Measures, 256
 - Component Fit Measures, 281
 - Does the Sympathy and Anger Model Fit?, 289
- Comparisons of Models, 289
 - Likelihood Ratio (LR) Test, 292
 - Lagrangian Multiplier (LM) Test, 293
 - Wald (W) Test, 293
 - Summary of LR, LM, and W Tests, 295
- Respecification of Model, 296
 - Theory and Substantive-Based Revisions, 296
 - Exploratory LR, LM, and W Tests, 298
 - Other Empirical Procedures, 303
 - Summary of Respecification Procedures, 304
- Extensions, 305
 - Factor Score Estimation, 305
 - Latent Variable Means and Equation Intercepts, 306
 - Cause Indicators, 311
 - Higher-Order Factor Analyses, 313
- Summary, 315
- Appendix 7A Examples of Program Listings, 316

Example 1: Estimating Means and Intercepts, 316

Example 2: Estimating a Higher-Order Factor Analysis, 317

- 8. The General Model, Part I: Latent Variable and Measurement Models Combined** **319**
- Model Specification, 319
- Implied Covariance Matrix, 323
- Identification, 326
- t*-Rule, 328
- Two-Step Rule, 328
- MIMIC Rule, 331
- Summary of Identification Rules, 331
- Industrialization and Political Democracy Example, 332
- Estimation and Model Evaluation, 333
- Power of Significance Test, 338
- Standardized and Unstandardized Coefficients, 349
- Means and Equation Constants, 350
- Comparing Groups, 355
- Invariance of Intercepts and Means, 365
- Missing Values, 369
- Alternative Estimators of Covariance Matrix, 370
- Explicit Estimation, 373
- Systematic Missing Values, 375
- Total, Direct, and Indirect Effects, 376
- Specific Effects, 383
- Summary, 389
- Appendix 8A Asymptotic Variances of Effects, 390
- Appendix 8B Listing of the LISREL VI Program for Missing Value Example, 393
- 9. The General Model, Part II: Extensions** **395**
- Alternative Notations/Representations, 395
- Equality and Inequality Constraints, 401
- Quadratic and Interaction Terms, 403
- Instrumental-Variable (IV) Estimators, 409
- Distributional Assumptions, 415

Consequences, 416	
Detection, 418	
Correction, 425	
Categorical Observed Variables, 433	
Assumptions Violated and Consequences, 433	
Robustness Studies, 434	
Summary of Robustness to Categorization, 438	
Corrective Procedures, 439	
Summary, 446	
Appendix 9A LISREL Program for Model in Figure 9.1(c), 447	
Appendix A. Matrix Algebra Review	449
Scalars, Vectors, and Matrices, 449	
Matrix Operations, 450	
Appendix B. Asymptotic Distribution Theory	466
Convergence in Probability, 466	
Convergence in Distributions, 468	
References	471
Index	489