This book is dedicated to Debra MacDonald
in appreciation for her tolerance during
my frequent absences to "run one more analysis."

Using LISREL for Structural Equation Modeling

A Researcher's Guide

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CHAPTER 1

Introduction

Social scientists have long been accustomed to seeing the phrase "data were analyzed with LISREL" (or a variant thereof) appear in their research literature. Indeed, some reviewers have expressed concern that LISREL analyses are dominating the literature (Brannick, 1995) at the expense of simpler forms of analyses, and some journal editors have felt compelled to point out that you do not need to use LISREL to publish in their journals (e.g., Schmitt, 1989).

Technically, of course, there is no such thing as a "LISREL" analysis. LISREL is a computer program (currently in its eighth version, Jöreskog & Sörbom, 1992) that performs structural equation modeling (SEM). The general point, however, remains. The use of structural equation modeling techniques in the social sciences is rapidly increasing (e.g., Kelloway, 1996), although there is very little evidence that such analyses are coming to dominate the literature (Kelloway, 1996; Stone-Romero, Weaver, & Glenar, 1996). One commentator has referred to the advent of SEM techniques as a statistical revolution (Cliff, 1983) and has suggested that not since the advent of analysis of variance has a statistical technique so transformed social science research. In addition to the increased usage of structural equation modeling, reviewers have pointed to the increased sophistication of such analyses (Kelloway, 1996; Medsker, Williams, & Holahan, 1994), with researchers becoming increasingly aware of the limits, constraints, and potential applications of SEM techniques.

Why Structural Equation Modeling?

Why is structural equation modeling becoming so popular? At least three reasons immediately spring to mind. First, social science research commonly uses measures to represent constructs. Most fields of social science research have a corresponding interest in measurement and measurement techniques. One form of structural equation modeling deals directly with how well our measures reflect their intended constructs. Confirmatory factor analysis, an application of structural equation modeling, is both more rigorous and more parsimonious than the "more traditional" techniques of exploratory factor analysis.

Moreover, unlike exploratory factor analysis, which is guided by intuitive and ad hoc rules, structural equation modeling casts factor analysis in the tradition of hypothesis testing, with explicit tests of both the overall quality of the factor solution and the specific parameters (e.g., factor loadings) composing the model. One of the most prevalent uses of structural equation modeling techniques is to conduct confirmatory factor analyses to assess the measurement properties of certain scales (Kelloway, 1996).

Second, aside from questions of measurement, social scientists are principally interested in questions of prediction. As our understanding of complex phenomena has grown, our predictive models have become more and more complex. Structural equation modeling techniques allow for the specification and testing of complex "path" models that incorporate this sophisticated understanding. For example, as research accumulates in an area of knowledge, our focus as researchers increasingly shifts to mediational relationships (rather than simple bivariate prediction) and the causal processes that give rise to the phenomena of interest. As I will demonstrate, the tests of these relationships available through structural equation modeling techniques are both more rigorous and more flexible than are the comparable techniques based on multiple regression.

Finally, and perhaps most important, structural equation modeling provides a unique analysis that simultaneously considers questions of both measurement and prediction. Typically referred to as "latent variable models," this form of structural equation modeling provides a flexible and powerful means of simultaneously assessing the quality of measurement and examining predictive relationships among constructs. Roughly analogous to doing a confirmatory factor analysis and path analysis at the same time, this form of structural equation modeling

allows researchers to frame increasingly precise questions about the phenomena in which they are interested. Such analyses, for example, offer the considerable advantage of estimating predictive relationships among "pure" latent variables that are uncontaminated by measurement error. It is the ability to frame and test such questions to which Cliff (1983) referred when he characterized structural equation modeling as a "statistical revolution."

As even this brief discussion of structural equation modeling indicates, the primary reason for adopting such techniques is the ability to frame and answer increasingly complex questions about our data. There is considerable concern that the techniques are not readily accessible to researchers, and James and James (1989) questioned whether researchers would invest the time and energy to master a complex and still evolving form of analysis. Others have extended the concern to question whether or not the "payoff" from using structural equation modeling techniques is worth mastering a sometimes esoteric and complex literature (Brannick, 1995).

I believe that there is such a payoff. The goal of this book is to present a researcher's approach to structural equation modeling. My assumption is that the knowledge requirements of using SEM techniques consist primarily of (a) knowing the kinds of questions that SEM can help you answer, (b) knowing the kinds of assumptions you need to make (or test) about your data, and (c) knowing how the most common forms of analysis are implemented in the LISREL environment. Most important, the goal of this book is to assist you in framing and testing research questions using LISREL. Those with a taste for the more esoteric mathematical formulations are referred to the literature.

The Remainder of This Book

The remainder of this book is organized in two major sections. In the next three chapters, I present an overview of structural equation modeling, including the theory and logic of structural equation models (Chapter 2), assessing the "fit" of structural equation models to the data (Chapter 3), and the implementation of structural equation models in the LISREL environment (Chapter 4). In the second section of the book, I consider specific applications of structural equation models, including confirmatory factor analysis (Chapter 5), observed variable path analysis (Chapter 6), and latent variable path analysis (Chapter 7). For each form of model, I present a sample application including the source code, printout, and results section. Chapter 8 presents some "tricks of the trade" for structural equation modeling, including the use of single indicator latent variables and reducing the cognitive complexity of models.

Although a comprehensive understanding of structural equation modeling is a worthwhile goal, I have focused in this book on the three most common forms of analysis. In doing so, I have "glossed over" many of the refinements and types of analyses that can be performed within a structural equation modeling framework. I have also tried to stay away from features of LISREL VIII (Jöreskog & Sörbom, 1992) that are implementation-dependent. For example, I do not discuss the implementation of the SIMPLIS language or the graphical interface available in LISREL VIII. Although this choice may limit the current presentation with respect to LISREL VIII, it also makes the book relevant to users of older versions of LISREL.

When all is said and done, the intent of this book is to give a "user-friendly" introduction to structural equation modeling. The presentation is oriented to researchers who want or need to use structural equation modeling techniques to answer substantive research questions. Those interested in a more mathematical presentation are referred to the ever growing body of literature on the derivation and implementation of structural equation models.

CHAPTER 2 *Structural Equation Models*

Theory and Development

To begin, let us consider what we mean by the term *theory.* At one level, a theory can be thought of as an explanation of why variables are correlated (or not correlated). Of course, most theories in the social sciences go far beyond the description of correlations to include hypotheses about causal relations. A necessary but insufficient condition for the validity of a theory would be that the relationships (i.e., correlations/covariances) among variables are consistent with the propositions of the theory.

For example, consider Fishbein and Ajzen's (1975) well-known theory of reasoned action. In the theory (see Figure 2.1), the best predictor of behavior is posited as being the intention to perform the behavior. In turn, the intention to perform the behavior is thought to be caused by (a) the individual's attitude toward performing the behavior and (b) the individual's subjective norms about the behavior. Finally, attitudes toward the behavior are thought to be a function of the individual's beliefs about the behavior. This simple presentation of the theory is sufficient to generate some expectations about the pattern of correlations between the variables referenced in the theory.

If the theory is correct, then one would expect that the correlation between behavioral intentions and behavior and the correlation between beliefs and attitudes should be stronger than the correlations between