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Review of Alan Acock's Discovering Structural Equation Modeling Using Stata, Revised Edition

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Abstract. In this article, I review *Discovering Structural Equation Modeling Using Stata, Revised Edition*, by Alan Acock (2013 [Stata Press]).

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1 Introduction

When I was a graduate student more than 30 years ago, one of the first advanced statistical software routines I used was Jöreskog and Sörbom's linear structural relations (LISREL) program (Sörbom and Jöreskog 1981). LISREL was one of the first, if not the first, programs that could estimate structural equation models (SEMs). By combining confirmatory factor analysis (CFA) with path modeling, LISREL theoretically made it possible—if the assumptions of the model were correct—to control for measurement error in observed variables and get unbiased estimates of causal effects.

My early experiences with LISREL are not among my favorite memories of graduate school. I found the program incredibly difficult to use. The matrix notation was bewildering; at times, I felt as if I were learning more about the Greek alphabet than about statistics. More experienced users, however, consoled me by saying that this was a virtue of the program because it kept people from using LISREL who should not be.

Luckily, software developers disagreed. LISREL itself is far more user friendly than it used to be, and it has been joined by several other programs, such as Amos (IBM 2015) and Mplus (Muthén and Muthén 2015). Stata itself joined the fray in version 12 when it added the `sem` command (which fits standard linear SEMs); in version 13, Stata took things a step further with the introduction of `gsem` (generalized SEMs, which include models such as logit and probit).

It was therefore with great interest that I agreed to review Alan Acock's *Discovering Structural Equation Modeling Using Stata, Revised Edition* (2013). Would this be the book I wished I had 30 years ago—and would it be a book that I would still like to have today? Acock asserts that the answers to both of my questions are yes. He claims that his work is aimed at two types of researchers: those who are new to structural equation modeling and those who already know structural equation modeling and want to learn how to estimate models using Stata. Can such diverse audiences really be satisfied by the same book? To answer these questions, I will first review the content of the book and then assess how well Acock achieves his stated goals.

2 Content

The approach of the book and the expectations of the reader's background are made implicitly or explicitly clear early on. Unlike many books, this one has no "introduction to Stata" chapter. I would be very surprised if this would be the first book that a new Stata user would read, so I think this is a wise decision. The preface describes the approach of the book as "Just do it"; that is, the book uses a kinetic learning approach and is not meant to replace books that are much more theoretical. Those who are interested in heated methodological debates about the suitability of observational data for making causal inferences will not find that discussion here. Acock says that readers should have a background in multiple regression and that experience with path analysis or factor analysis is helpful but not essential. I agree with his assessment.

After the preface, the book is logically divided into six chapters and two appendixes. In most chapters, only a few examples are given, but they tend to be explored in great depth, as Acock explains how to specify, modify, and test features of models. Later chapters tend to reinforce earlier chapters as concepts and procedures are reintroduced and applied in new ways.

Chapter 1 introduces CFA. With CFA, the researcher specifies how observed variables are related to unobserved latent variables. This is often referred to as the measurement part of a model. CFA differs from exploratory factor analysis in that, in the latter, it is the statistical method that tries to identify the underlying latent variables. Acock offers a very strong critique of traditional methods for factor analysis and scale construction. He notes, for example, that a high value for Cronbach's alpha does not guarantee that a set of items taps a single dimension. CFA may be more theoretically demanding, but it helps to better measure latent variables by isolating the shared variance among observed indicators.

The chapter also serves as an excellent introduction (or a review) of key basics for both CFA and SEM. Acock explains why some loadings need to be fixed (for example, you need reference indicators or some other means to identify the scale of latent variables). In a few pages, the chapter succinctly covers interpreting CFA results; assessing goodness of model fit (and how to decide whether the fit of a model is "good enough" in practice); modification indices, which help to highlight areas where the model might be improved (although Acock strongly stresses that any such modifications need to be theoretically justified); how both one-factor and multifactor models can be estimated; and model identification. He also illustrates how Stata's graphical SEM Builder can be used rather than syntax when specifying models.

Chapter 2 explains how to specify and estimate different types of path models. Path models describe how variables are assumed to be causally related to each other. This is often referred to as the structural part of the model. In this section, it is assumed that variables are measured without error; that is, there are no underlying latent variables. Acock gives an example of how attention-span skills at age 4 are related to achievement at age 7 and again at age 21. He explains direct, indirect, and total effects; shows how they can be estimated; and gradually introduces more complicated models, such as models with correlated residuals, models with cross-lagged panel designs, models with interaction effects, and nonrecursive models with reciprocal causation. As before, he shows how various hypotheses can be tested (for example, equality of coefficients).

Also of great interest is the discussion of how missing values can be handled via `sem`'s `mlmv` (maximum-likelihood missing values) option. Acock argues that `mlmv` is often superior to `sem`'s default approach of using listwise deletion because `mlmv` aims to retrieve as much information as possible from observations containing missing values and because `mlmv` makes less restrictive assumptions. Acock illustrates a "trick" I had not seen before by which auxiliary variables can be added to a model, which in many (but not all) situations will make the analysis even better at dealing with missing data.

In many ways, chapters 1 and 2 are merely a prelude to chapter 3, titled "Structural equation modeling". Here Acock shows how CFA (the measurement part of a model) and path modeling (which describes the theorized causal relationships among variables) can be combined. This ability may be SEM's greatest strength. Flawed measurement of observed variables can lead to biased and attenuated estimates of causal relationships. A good measurement model that includes multiple indicators of underlying latent variables can (in theory at least) overcome these problems. Having laid out major principles and procedures in the first two chapters, Acock probably presents little that is new in this section; still he provides detailed examples that should make points clear and serve as a useful template for those considering their own models.

Acock begins chapter 3 by discussing the classic example of Wheaton et al. (1977) of stability of attitudes across time. Previously, it had been argued that many social psychological concepts were so unstable that it was pointless to try to use them in models; for example, it made little sense to try to predict, or use as predictors, variables whose values might be changing hourly and that certainly changed from year to year. By using multiple indicators of key concepts, Wheaton and colleagues challenged these notions. Their model showed that alienation and socioeconomic status (SES) in 1966 and 1967 were strong predictors of alienation in 1971. Much as he did in earlier chapters, Acock then shows how the model can be estimated with `sem` and how it can be modified and improved upon.

This chapter also expands on the earlier discussion of measurement invariance, noting that if the measurement of latent variables seems to change across time, researchers have to realize that the meanings of variables to respondents may also be changing; for example, the meaning of alienation questions to respondents may vary from one time to the next, making it difficult to interpret results. Ideally, he says, the loadings for observed variables should be invariant across time, although the error variances may differ. The chapter also adds an important discussion of reflective versus formative indicators: Does the causal flow go from the latent variable to the indicators (reflective), or does it go the other way (formative)? For example, with SES, many would argue that a formative model (for example, income, education, and occupation all cause SES) makes much more sense than a reflective model (for example, SES is a cause of income, education, and occupation).

Chapter 4 shows how `sem` can be used to estimate latent growth curve models. Rather than predicting individuals' scores on a variable, latent growth curve models try to predict their trajectory. Acock gives the example of alcohol consumption, which increases dramatically between the ages of 18 and 23. But different individuals have very different trajectories. Some continue to have low levels of alcohol consumption, while others have much more dramatic increases. For me, this may have been the most interesting chapter in the book. There are many situations where a growth model may be useful, for example, when looking at children's learning trajectories. But I have never estimated such a model before, nor do I think I could have guessed how to do it without reading something like Acock's discussion. Those who are more familiar with these models will probably also appreciate Acock's comparisons of the `sem` and `mixed` commands. While `mixed` can also estimate latent growth models, Acock notes that `sem` is usually faster, offers additional measures of goodness of fit, provides modification indices that can give insight into how the model can be improved upon, and can estimate a broader range of growth models than can `mixed`.

Chapter 5 discusses group comparisons. Acock notes that interaction effects have typically been used to see how effects of variables differ across groups. He then explains how SEM approaches extend and enrich traditional methods. With SEM, models can be estimated separately for two or more groups. Overall differences can be tested, as can differences in specific individual parameters or sets of parameters. You can test for differences in means and variances as well as the size of structural paths. The ability to use multiple indicators of concepts is again another major advantage of the SEM approach over more traditional methods for group comparisons.

To illustrate his points, Acock gives an example where models for depression and support for government intervention in social welfare policies are estimated separately for men and women. He shows how cross-group constraints on parameters can easily be imposed, relaxed, and tested. He stresses how—if the loadings for the measurement model differ across groups—the researcher must proceed with caution because the groups may be interpreting the questions differently. He also cautions that standardized solutions can be problematic when making cross-group comparisons. If standard deviations differ across groups, the standardization will differ as well. The chapter offers a very thorough template for making group comparisons and also offers useful suggestions for presenting the results in published work.

Chapter 6 is the epilogue and suggests to readers what they should do now to learn more. Although it is very brief—only four pages—it provides a short introduction to the `gsem` command. Readers will not learn enough to actually use `gsem`, but they will get an idea of why and when they might want to employ it.

Finally, the two appendixes discuss `sem`'s graphical user interface and how to enter data using summary statistics, for example, means and correlations. I suspect many readers will turn to the appendixes long before they finish reading the rest of the book, and many may even want to start there.

3 Strengths and weaknesses

Acock says his book is aimed at two types of researchers: those who are new to structural equation modeling and those who already know structural equation modeling and want to learn how to estimate models using Stata. While neither group will be 100% satisfied with the book, both will find it very useful.

Those already familiar with structural equation modeling may find themselves skimming through much of the material (I probably would have read the book much less carefully if I were not reviewing it). Indeed, Acock's appendixes, and a careful reading of Stata's own excellent *Structural Equation Modeling Reference Manual*, may be enough for such researchers. Nonetheless, I found the book to be a good review of many principles I had learned long ago; it also introduced me to some models and ideas I was not familiar with. I especially liked the suggestions for using the graphical SEM Builder. My own previous haphazard efforts had typically resulted in clumsy and unprofessional-looking diagrams; thanks to Acock, I can do much better now (although I still wish Stata had some sort of "autofix" feature that would easily take care of many common formatting mistakes). I probably still prefer to use syntax to specify my models, but if I needed a diagram of my model, the SEM Builder would be invaluable. Further, many people may prefer a graphical interface, especially if the syntax is complicated.

Those not experienced with structural equation modeling will no doubt want additional theoretical background as well as examples of more types of models. Acock concedes this point right from the beginning and suggests excellent sources they can turn to. If I were teaching a course on structural equation modeling, I would almost certainly use Acock's book and couple it with several additional readings. Similarly, if a Stata user who wanted to learn structural equation modeling asked me what he or she should start with, Acock's book would be the first thing I would recommend.

There are several small ways in which the book could be improved. I would reverse the first two chapters. The causal model is more interesting (to me at least); hence, I would lead with it. Once you realize that the parameter estimates of the causal model can be biased and attenuated by measurement problems, the rationale for discussing the measurement model becomes more forceful.

Also, in the first two chapters, I often thought Acock was not making as compelling a case for the use of SEM as he could have, which might cause some readers to wonder if it was worth reading further. For example, chapter 1 makes a strong case against traditional factor-analysis methods and for CFA, but the actual examples do not make it clear how much CFA gains you in practice. Chapter 2 shows how to use `sem` for basic path analysis, but several other commands can be used for this as well, for example, `regress`, `reg3`, and Phil Ender's (2009) `pathreg`. Acock could have discussed why `sem` will often be preferable over these commands even for simple models, just as he later showed how `sem` could be superior to `mixed`. In particular, I would have liked to see him say much more about how `sem` includes an option (`mlmv`) for full-information maximum likelihood (FIML), which is a way to deal with missing data. Many sources (for example, Allison [2012]) maintain that when software supports it and statistical assumptions are met, FIML is superior to techniques such as multiple imputation. As it is, Acock notes that the option exists and lists its advantages; however, he does not underscore as forcefully as he could how incredibly useful it might be even for simple models that can be estimated via other programs. (My wish list for future versions of Stata includes support for FIML across a wide range of commands.)

I would also like a future edition to say much more about `gsem`. Given how new `gsem` is, it is a pleasant surprise that the book mentions it at all. But an entire chapter on `gsem`, or revising existing chapters to include examples with `gsem`, would be very useful; in fact, it might especially enhance the value of the book for those who already have a general background in structural equation modeling but who are not as familiar with the kinds of additional models that `gsem` can estimate.

4 Conclusion

Acock's work reminds me of Long and Freese's (2014) *Regression Models for Categorical Dependent Variables Using Stata, Third Edition.* Both emphasize a "learning by doing" approach, something that I myself tend to prefer and use in my own teaching. At the same time, underlying statistical theory is not ignored, although additional reading will be necessary to understand everything that these methods are capable of. Those already familiar with the SEM literature and programs such as LISREL or Mplus may find that the book is longer than they need or like, but even they will find the review of concepts and the discussion of Stata-specific commands very helpful. For those who are new to structural equation modeling, I can safely say that my younger self would have loved to have had software like Stata's `sem` command and a book like Acock's. It should not be the only thing new users read, but it is an excellent place to start.

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Richard Williams is an associate professor and a former chairman of the Department of Sociology at the University of Notre Dame. His teaching and research interests include methods and statistics, demography, and urban sociology. His work has appeared in *American Sociological Review*, *Social Forces*, *The Stata Journal*, *Social Problems*, *Demography*, *Sociology of Education*, *Journal of Urban Affairs*, *Cityscape*, *Journal of Marriage and the Family*, *Journal of Informetrics*, and *Sociological Methods and Research*. Recent research, which has been funded by grants from the Department of Housing and Urban Development and the National Science Foundation, focuses on the causes and consequences of inequality in American home ownership. He is the author of the Stata programs `gologit2` and `oglm` and is a frequent contributor to Statalist.