
REVIEW SECTION

LISREL Issues, Debates, and Strategies. Leslie A. Hayduk. Baltimore, MD: The Johns Hopkins University Press, 1996, 256 pages (cloth).

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For some of us, our initial foray into structural equation modeling (SEM) was guided by Leslie Hayduk's *Structural Equation Modeling With LISREL: Essentials and Advances* (1987). Besides serving as a springboard into understanding the various matrices (one subheading was aptly titled: "LISREL Is Greek to Me!", p. 88) and the attendant algebra, the text also provided a nice summary of such crucial topics as identification and colinearity. Since the publication of Hayduk's text, SEM has not only experienced a surge of popularity (partially due to the user-friendliness of such programs as SIMPLIS), but also a dramatic increase in the complexity of the LISREL output, as evidenced by the numerous fit indices currently generated. Thus, it is timely that Hayduk should provide current insights as he does in the recent text *LISREL Issues, Debates, and Strategies*.

The preface makes clear the relevance of SEM given its application to such wide-ranging areas as human genetics, cultural studies, aging, medicine, and marketing as well as the number of SEM programs that have cropped up since the advent of LISREL. Hayduk captures nicely his primary objective for this text, which is

not to examine the details of statistical estimation, but to examine the fundamentals of the use, application, and interpretation of models ... investigating how structural equation models can prod us to think differently, and how they can assist us in the research enterprise. (p. xv)

Chapter 1 discusses "Constraints and Deceptions of Factor Models." Constraints are extensively reviewed under the umbrella of multiple indicators, common causes, and the factor models. The notion is advanced that applying reasonable and logical constraints to our models may serve us in being less "apologetic about the fictitious, or iffy, nature of models" (p. xx). Hayduk emphasizes that a constraint

employed in one's hypothetical model should correspond with the constraints inherent in the theory one is exploring. Proportionality constraints are then discussed within the context of multiple indicators. Especially of interest are the sections devoted to the use of multiple indicators and some of the accompanying concerns, especially in regard to parsimony. Coming from the school of three to four indicators per latent variable, Hayduk's comments had me rescruiting this issue. Hayduk asserts that models with multiple indicators have a tendency to fail given certain proportionality demands. If multiple indicators are to be analyzed, the suggestion is that the best two or three indicators should be used. Subsequently, it is recommended that the estimate of the best indicator (λ) be fixed at 1.0 and the attendant error variance (θ) be fixed at a specific value. The rest of the indicators are then freely estimated (or fixed if the modeler is so bold). Quite a bit of this chapter pertains to the factor analytic approach, even though its pertinence to SEM is made evident. A section demonstrating the modeling of multiple indicators is also provided.

Chapter 2, titled "Two Steps: The Factor Model Before Any Other Structural Model," will likely generate some controversy. Anderson and Gerbing's classic 1988 article articulated the logic behind the two-step approach, which encompassed the sequence of estimating the measurement model and testing the structural model. This was suggested in lieu of the one-step approach given concerns with interpretational confounding in the presence of misspecification. Hence, this sequence of estimation has been frequently incorporated in the researcher's arsenal. However, a central focus of this chapter revolves around four major assertions that the two-step process assumes but may be unjustifiable (two sample assertions, based on an article by Fornell & Yi, 1992, are that theory and measurement are independent of one another and can be treated as such, and that the statistical test done during the first step is independent of the test done at the second step). Arguments for and against each of the assertions are provided. One argument, for instance, is that the general norm has been to make measurement modifications at the first step and structural changes at the second step. Hayduk asks: "why should modifications at step two be restricted to modifications that do not involve effects from the concepts to the indicators?" (p. 58). In proposing the viability of a one-step approach, once again it is suggested that the parameter estimates of the observed variables be fixed at 1.0 and the error variances be fixed. The contention is that by fixing the aforementioned parameters the researcher's theoretical conceptualization will be more closely approximated, and the structural model is such that it "forces these concepts to be placed into a clear and unambiguous context" (p. 62). If the two-step approach is to be employed, Hayduk then provides a list of caveats, including: Do not consider the two-step process if the model has a concept with no indicators; if the first-step fails, do not proceed to the second step; and use no free measurement parameters (λ s and θ s) at the second step. If there is one unifying

theme for the first two chapters it is the urging that the modeler be sufficiently committed to or educated about their model (e.g., their respective psychometric properties) and attendant concepts, thus minimizing the number of model coefficient's that are to be freely estimated.

The following chapter, "Equivalence, Loops, and Longitudinal Models," commences with a brief treatise regarding equivalence and self-deception, and the need to pay attention to equivalent models. The bulk of the chapter deals with loops and equivalent models. The notion of loops (L) is introduced in Hayduk's 1987 text (chap. 8, pp. 244–272). *Loops* are defined as a special type of indirect effect, of which there are repeated cyclings through the designated loops. A simple loop model is graphically portrayed by having an arrow start and end at the same variable (e.g., η_2). Arriving at the model coefficients, taking into account the repeated cyclings through the loop (multiplied/enhanced by $1/(1-L)$) is illustrated, including the matrix algebra. The applicability of loop equivalents within a longitudinal context is given extensive discussion using the alienation example in the Two-Wave Models section from the LISREL 7 guide (Jöreskog & Sörbom, 1989, p. 168). Quite frankly, I found this discussion of loops and their pertinence to equivalent models intriguing but somewhat arcane. For instance, in the longitudinal example Hayduk states that the loop model posits "unmeasured or phantom concepts representing the respondents' alienation during each of the intervening years" (p. 106). Even though practically and methodologically that makes perfect sense, and in the text he presents the coefficient estimation process, I still found the notion of measuring and estimating loops and their respective coefficients problematic. It is probably best to leave this to the experts!

One of the more challenging steps within the scope of SEM is the specification of one's model. Developing a model is a culmination of logic, literature review, experience, and prudent judgment. However, even in the best of circumstances, and as Hayduk makes clear in the previous chapter, there may exist alternative models that are equivalent to the modeler's hypothesized model. One program that may be used as an adjunct to LISREL is TETRAD, a program that is designed as an aid to "specifying the right models, in recognizing when a proposed model may be defective, and in recognizing when there are empirically adequate and plausible alternative models" (Spirtes, Scheines, Glymour, & Meek, 1993, p. 1). An overview of this computer program is provided in chapter 4: "Equivalent Models: TETRAD and Model Modification." A fundamental distinction between TETRAD and the SEM programs is that the former does not provide coefficient estimates or any type of fit indices; it only attempts to determine the location of additional useful effects. The program is called TETRAD because four (*tetra*) observed variables are examined at a time and the tetrad equation is composed of four correlations. All possible partial or triad differences are created and then tested to see if they differ from zero. The program provides diagnostics and indicates if an "edge" (known in the SEM lexicon as a *path*) between two variables should be added to the model.

Following a technical discussion of TETRAD, comparisons of this program with LISREL and EQS, and their competence at delineating misspecified models, are made. Hayduk ultimately recommends that researchers should develop competing models prior to estimating their hypothesized model. Moreover, the researcher should create a list of meaningful or likely additional coefficients that might be included in the theoretical model. It is apparent that the logic behind TETRAD is also symmetrical with the recommendations starting from the first chapter: providing alternative models, adding constraints when appropriate, awareness of equivalent models.

Chapter 5, titled "Stacked Models With Differing Sets of Indicator Variables," provides a novel twist in analyzing multisample data. Even though Hayduk comments that the use of stacked models has been relatively sparse, a cursory review of the Internet site devoted to structural equation modeling, SEMNET, finds that quite a few researchers have employed multisample analysis. The novelty associated with this chapter is the use of unequal number of indicators across groups. It is pointed out that each of the multisample examples in the LISREL manual have groups with equal numbers of indicator variables, that being the prevailing method of analyzing covariance matrices across groups. However, there may be times when the same indicators are not used across each of the groups; possibly the measure was unavailable for the other group or it was deemed inappropriate (e.g., a certain instrument may be applicable to male but not female participants). Hayduk then provides a strategy (referred to as a "bit of modeling trickery") that will enable the researcher to circumvent LISREL's requirement of equal number of indicators across groups. This trickery involves creating "filler indicators" (p. 177). These variables, specified as having unit variances, are assumed to be uncorrelated and independent of all other variables in the model; hence, they "do nothing in the model" (p. 177). An example of the syntax associated with the stacked model with filler variables is provided in this chapter.

The final chapter, titled "Tidying Up," is a miscellaneous assortment of odds and ends, reviewing some of the advances made since his prior text. The first section argues for the deficiency of the coefficient of determination (R^2) and disputes the notion that this statistic can be useful in assessing model adequacy. Hayduk discusses the coefficient of determination in the context of η s (endogenous constructs) and their corresponding ζ error variables. Next under discussion is the use of Monte Carlo studies and the challenge to develop models that are more realistic. Hayduk asserts that the traditional factor model that serves as the test model for Monte Carlo tests may not always be appropriate. The standard or realistic model that he refers to is described as a "motif model," which incorporates reciprocal and looped effects; shared indicators; indirect effects; concepts with one, two, or three indicators; and so forth. The assumption is that this motif model will better reflect current modeling practices, and ultimately the phenomenon at hand. The rest of the

chapter briefly reviews current literature as it pertains to goodness-of-fit indices, modification indices, multitrait-multimethod analyses, and multilevel data.

Overall, I found this text to be an intriguing companion piece to Hayduk's prior text. Given that Hayduk makes liberal references to his 1987 text, it would be advantageous for the reader to acquire this book. I found myself frequently referring to *Essentials*, especially when clarifying such concepts as loops. Moreover, the chapter on TETRAD might tend to have more appeal (or intelligibility) to readers who have had some exposure to this computer program. Because the text is primarily geared toward the LISREL program and the attendant matrix algebra, the Greek notation may be offputting for those versed in alternative programs. However, regardless of one's favored computer application, there is much in this text that is applicable for the modeler. I also believe that there is an idiosyncratic approach or philosophy that Hayduk takes toward modeling that some may not see as compatible with their own. Thus, if one does not agree with some of Hayduk's recommendations, at least it will provoke some lively discussions.

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