Review of Gana & Broc's Structural Equation Modeling with lavaan

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Review of Gana & Broc's *Structural Equation Modeling with* `lavaan`

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Kamel Gana & Guillome Broc (2018). *Structural Equation Modeling with* `lavaan`. Wiley, 304 pages. $116.99. ISBN: 978-1-786-30369-1

This book is written to be a practical guide to both structural equation modeling (SEM), and to using the R package `lavaan` (Rosseel, 2012) to apply SEM. As one can read in Gana and Broc's (2019) introduction, the book is meant to be "a didactic book presenting the basics of a technique for beginners who wish to gradually learn structural equation modeling and make use of its flexibility, opportunities, and upgrades and extenxions [sic]" (p. xi). The authors stress that they have put themselves in the shoes of the user with a limited statistical background, who should "easily find in it both a technical introduction and a practical introduction, oriented towards the use of SEM" (p. xii). Open-source software was chosen deliberately on Gana's part, as the preface mentions his experience "teaching SEM in African universities where it was impossible to have SEM commercial software" (p. ix).

Contribution to the Literature

There already existed two books about SEM in `lavaan` written to be accessible by nonexperts. Beaujean's (2014) *Latent Variable Modeling using R: A Step-by-Step Guide* only assumes familiarity with some basic statistical concepts, and it received positive reviews (see Helm, 2016; Koch & Schultze, 2016). The second alternative to Gana and Broc would be *Latent Variable Modeling in R* written by Finch and French (2015). Although Finch and French covered more latent variable models than SEM, and more R packages than `lavaan`, it is a candidate book to use when teaching a SEM course and received a positive albeit critical review (Oberski, 2016).

Despite the existence of two decent books that already serve this goal, in principle we support the availability of more such books so that potential readers can choose the one that best fits their needs or personal taste. Readers might find Gana and Broc's (2019) "simple

SEM software user's guide" (p. xii) of greater value once their R scripts and data are made available for readers to reproduce the analyses, which the authors indicated "will be available on a website dedicated to this manual" (p. xiii) but is still forthcoming[1]. The next section of our review summarizes the book's contents and its main advantages and disadvantages as an instructional text. The following section provides a critical evaluation of shortcomings that temper its purported didactic value.

Summary of the Core Content

Gana and Broc's (2019) main text spans 250 pages and contains a brief introduction followed by four chapters. This has the advantage of dividing the labor of instruction into two relatively short chapters narrowly focusing on introductions to SEM and to the software, respectively, followed by two more in-depth chapters taking readers through the process of specifying, fitting, and interpreting some basic and advanced models. The authors almost exclusively use easy-to-understand language, which makes the text largely accessible to a wide audience of nonexperts. However, the ease of reading was undercut by their frequently awkward use of the English language, including numerous grammatical errors that could have been improved if the authors had received adequate help from an editor beyond their "novice students in SEM in order to assess its clarity and comprehensibility" (p. ix). Of greater concern is that the authors often use terminology that is not merely uncommon in the SEM literature and community, but actually at odds with it (e.g., latent factors were referred to as categories, p. 11; phantom constructs were referred to as dummy variables, p. 150; and factor loadings were referred to as local fit indices throughout the book). This could unnecessarily impede their readers communicating with consultants or experienced SEM experts on online forums such as SEMNET (Rigdon, 1994) or `lavaan`'s Google group[2] when seeking help

[1] https://www.researchgate.net/post/Where_can_readers_find_data_and_R_scripts_associated_with_this_book
[2] https://groups.google.com/d/forum/lavaan

with their own models.

Chapter 1 (*Structural Equation Modeling*) begins with introducing bivariate and partial correlation, multiple regression, and (exploratory) factor analysis, followed by the introduction of some basic concepts in SEM (assumptions, model-implied covariance matrix, covariance residuals, estimators, fit-indices, modification indices, confirmatory analysis, and path diagrams). Note that this chapter can be downloaded as an excerpt from the book on the publisher's site[3]. The example analyses include SEM path diagrams and interpretation of parameters only in a standardized metric (i.e., correlations and standardized slopes), consistent with the authors' claim that SEMs can be fitted to "either a correlation matrix or a variance–covariance matrix" (p. 33), failing to inform readers until Chapter 2 that analyzing a correlation matrix requires additional constraints to avoid biased *SE*s and test statistics. They provide an easy-to-follow description of iteratively estimating model parameters to reproduce an observed correlation/covariance matrix, but without explaining (with matrix algebra or path-tracing rules) how a model-implied covariance matrix is a function of model parameters. This may well be in line with their goal of avoiding complex formulae, yet that makes their cumbersome decomposition of a variable's R^2 as a function of standardized slopes and zero-order correlations seem quite out of place in this chapter.

Chapter 2 (*Structural Equation Modeling Software*) is quite a short chapter (14 pages) that introduces `lavaan` as the software used in this book. It provides an example of importing a dataset into R, nicely supplemented by both screenshots (only using the Windows distribution of R) and syntax snippets (which are unfortunately provided as figures even in the ebook, arguably undermining the book's value as a user manual). The authors provided useful tables, such as an overview the main operators used in `lavaan` syntax (but omitting operators associated with categorical data, such as defining thresholds, despite analyzing

[3] https://www.wiley.com/en-us/Structural+Equation+Modeling+with+lavaan-p-9781786303691

ordinal data later in the book); an overview of the main steps in the sequence used by the authors throughout all analysis examples in the remainder of the book; and a description of `lavaan`'s three "wrapper" functions—`cfa()`, `sem()`, and `growth()`—but without explaining that they simply call the main `lavaan()` function with certain default settings appropriate for those analyses. In fact, `cfa()` and `sem()` call the same defaults and so are functionally identical, which the authors fail to recognize when describing the different functions as "not innocuous" (p. 144), demonstrating that the authors could have exerted more effort to learn about the software (available even in its seminal publication: Rosseel, 2012, p. 10) for which they provide a manual. Their readers could also benefit from reading the free tutorial provided online[4] by `lavaan`'s developer, which the book failed to mention.

Chapter 3 (*Steps in Structural Equation Modeling*) presents seven steps in the procedure of SEM: (1) theoretical frameworks, (2) conceptual specification of the model, (3) operationalization of constructs, (4) data collection (5) model estimation, (6) results, and (7) interpretation, the latter of which loops back to the first step in their Figure 3.1. The authors state their primary focus is "on model estimation and … examining its solution" (p. 69), and provide only cursory descriptions of specification and identification. All further discussion is couched firmly in the context of applied examples: two path models (one of which is the Actor–Partner Interdependence Model: APIM), a CFA model, and general SEMs with both single- and multiple-indicator constructs. Syntax for all examples follows the same format, which has pedagogical value by reiterating a template that can remain largely consistent across the fitting of various SEMs. A disadvantage of this approach is that the same names are always used when fitting nested models to the same data, preventing their comparison with a likelihood ratio test—a fundamentally important method in SEM—even when they

[4] http://lavaan.ugent.be/tutorial/index.html

specifically discuss doing so to evaluate structural regression models in the two-step approach (p. 144) or to compare bifactor vs. hierarchical representations of a multidimensional scale (p. 125). They only discuss and demonstrate model comparison in the fourth and final chapter (*Advanced topics: Principles and Applications*) to establish measurement invariance in a multiple-group CFA. Chapter 4 also contains examples of latent state–trait models and latent growth models, the latter of which included (without testing) measurement invariance constraints across occasions in a second-order growth model. In the later examples of chapter 4, they compare nested models instead using information criteria (p. 229).

Cautionary Notes

We acknowledge that it takes much time and effort to write 250 pages of instructional text, so we hesitate to provide too critical a review. However, our opinion as SEM users and educators is that the current edition of this book contains too many serious misconceptions, inaccuracies, and questionable advice to make it a trustworthy resource to be recommended for beginners in SEM. Textbook companion sites sometimes include lists of errata to let readers know what corrections to expect in future editions; this relatively new text does not yet provide such a list. Thus, in preparing this review we compiled an Excel file listing instances in the book where the authors used confusing language (including the improperly used terms listed above), introduced concepts without sufficient explanation for readers to understand how to operate in practice, provided questionable advice, made inaccurate claims or interpretations, and miscellaneous issues (excluding many minor errata). We provide the file online[5] to inform potential readers and to assist the authors in improving any future editions of this text. Below, we discuss only the issues we found most problematic, justifying our hesitation against recommending it as an instructional text.

Indirect and Total Effects

[5] https://osf.io/9up3s/

The treatment of (in)direct and total effects is neither correct nor consistent. In Section 3.3.3, direct and indirect effects (in the first paragraph) and total effects (in the third paragraph) are correctly defined in plain language, and the first syntax example correctly specifies indirect effects of two different exogenous variables on the same outcome (via the same mediator), although the text confusingly describes the direct effects of exogenous predictors on the mediator as indirect effects (rather than the products of those with the downstream effect of the mediator on the outcome). However, that same syntax example incorrectly specifies a "total effect" as the sum of those indirect effects and all direct effects on the outcome, despite those effects originating from different predictors. The following example is a four-variable system in their Figure 3.5, in which two exogenous variables predict a mediator that then predicts a distal outcome. This example (p. 87) incorrectly describes and specifies the indirect effect as the product of all three paths, despite some paths originating from different predictors. The following example (p. 133) is exactly the same model except that the four variables are common factors measured by multiple indicators, yet the text correctly describes separate indirect effects originating from the different predictors; however, the corresponding syntax example (p. 147) still incorrectly specifies the indirect effect as the product of all three paths, and the total effect as the sum of those and the direct effect of the mediator on the outcome. A closer review of their cited literature about how to evaluate hypotheses of mediation in SEM would be warranted before writing a future edition.

Measurement Invariance

Multiple examples in chapter 4 imposed equality constraints on measurement parameters across groups or occasions. The introduction to the basic concepts generally matches many introductory texts on the subject, but there are some problematic mistakes. After correctly describing configural and metric invariance as equivalence of form and factor loadings, respectively, their interpretation of scalar invariance (p. 160) mistakenly repeated the interpretation of metric invariance, rather than as equivalence of expected values of observed variables across groups (or occasions) when common-factor scores are equal across groups (or occasions). The description of strict invariance (i.e., the additional equivalence of residual variances) inaccurately claims (p. 160) that it implies not only *equal* reliability across groups (which in fact additionally requires equivalence of common-factor variances) but also *perfect* reliability (which would instead imply that the residual variances equal zero).

The example syntax equates intercepts of items whose loadings are not constrained (p. 172), but equating an indicator's expected value across groups is entirely arbitrary when its expected value increases at different rates with the common factor across groups. The lack of familiarity with `lavaan` was also revealed in these syntax examples, in the incorrect claim that it is necessary to model mean structure in multiple-group models (p. 158)—that is simply `lavaan`'s default behavior when fitting multiple-group models to raw data. Readers are told (p. 172) that they can obtain modification indices for equality constraints using the `modIndices()` function, when they actually need to use the more general function `lavTestScore()`. No output accompanied that particular syntax, so it is difficult to surmise whether the authors discovered this and simply forgot to remove the false claim.

Promoting Poor Practice

The book includes some questionable advice, such as misleading readers that parceling (which the authors recommend to resolve nonnormality) requires both unidimensionality (which is false; Little, Rhemtulla, Gibson, & Schoemann, 2013) and random allocation of items to parcels (which is highly problematic unless that source of randomness is properly accounted for; Sterba & Rights, 2016). Some advice directly contradicts the literature cited to justify it. For example, Rhemtulla, Brosseau-Liard, and Savalei (2012) showed 5–7 ordinal categories are necessary to treat categorical indicators as continuous (with robust ML estimation), depending on how asymmetric the distributions are. But the book's Table 1.10 (p.

33) simply recommends doing so with as few as four categories, which would yield biased results. Our Excel file lists additional examples of advice that we consider questionable or worse, along with other categories of shortcoming listed earlier, which we hope provides the impetus for constructive improvement in any future editions.

Conclusion

This book provides a gateway for novices to learn about the flexibility and conceptual power of SEM to represent complex theories as statistical models. Given how the advice and language within the book is frequently inconsistent with those of SEM experts, we are apprehensive that the self-described SEM manual resembles a case of the blind leading the blind. Given that other texts already exist that use the same software and are targeted to the same audience (i.e., accessible to readers without requiring much technical expertise), its only unique contribution seems to be syntax examples for a couple novel models (the APIM and latent state–trait models) not included in competing introductory texts. Coupled with a notably more expensive price tag and numerous pedagogical deficiencies, we feel it would be irresponsible to recommend this edition of the book to the intended audience of nonexperts, and we could not find anything of value to experts (e.g., those merely transitioning from different SEM software to use `lavaan`) that would not already be (perhaps better) served by one of the competing texts mentioned above.

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