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Bentler P M & Bonett D G. Significance tests and goodness of fit in the analysis of covariance structures. *Psychol. Bull.* 88:588-606, 1980.
[University of California, Los Angeles, CA]

Statistical methods for covariance structure analysis were reviewed and found to be inadequate in large samples due to almost certain rejection of any *a priori* structural hypothesis. Fit indices less influenced by sample size, ranging from zero to one, were proposed as additional guides for model evaluation. Pseudo chi-square tests for evaluating structural misspecification were introduced. [The *SCI*® and the *SSCI*® indicate that this paper has been cited in over 260 publications.]

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The problem of model evaluation addressed in this paper was widely known informally and, in the case of exploratory factor analysis, had a long history.

When their assumptions are met, statistical methods for evaluating models provide clear decision rules regarding model adequacy. Yet, in large samples virtually any model may be rejected, even if the degree of misspecification is very minor. In factor analysis widespread experience had suggested that reliance on a statistical decision rule might not be optimal for determining the number of factors, i.e., in model choice. Similar suspicions were beginning to arise in the newly developing area of covariance structure analysis, as epitomized by LISREL, a computer program. These methods were becoming popular not only because they could answer new types of questions about data, especially nonexperimental data, but also because they provided an aura of objectivity due to their use of maximum likelihood methods. However, many researchers were becoming frustrated with using these methods because they had to reject models that seemed to have only minor discrepancies between the estimated model and data. Clearly, what was needed was a new way to evaluate model adequacy.

In August 1979 we recognized that general hierarchical model comparisons, when standardized to a baseline or null model, could play a critical role in defining normed and nonnormed fit indices that are less influenced by sample size than a statistical goodness-of-fit test. We immediately understood the potential impact of our approach, and we were able to test the ideas and write them up within a few weeks—faster than any other paper either of us has ever written. In fact, the basic ideas were drafted over a weekend. Development of the pseudo chi-square test took much of our time.

Our fit indices have become very popular, and the citations to our article largely reflect this popularity. Variants that penalize number of parameters differently and that utilize alternative null models[1] or a nonnormed index that may be less influenced by sample size[2] have also been proposed. Different types of indices that do not depend on a null model, as developed more recently by LISREL and generalized by Bentler,[3] have been proposed, but the evidence appears to be that our original indices perform as well as or better than the newer alternatives.[4,5]

While we appreciate the impact that our article has had, we are also frustrated by the fact that its key original statistical contribution, the pseudo chi-square test for evaluating model misspecification, has been largely overlooked. However, recent work has acknowledged the importance of this test, especially in locating a fundamental misspecification of the measurement model.[6]

1. **Sobel M E & Bohrnstedt G W.** Use of null models in evaluating the fit of covariance structure models. (Tuma N B, ed.) *Sociological methodology 1985.* San Francisco: Jossey-Bass, 1985. p. 152-78.
2. **Bollen K A.** Sample size and Bentler and Bonett's nonnormed fit index. *Psychometrika* 51:375-7, 1986.
3. **Bentler P M.** Some contributions to efficient statistics in structural models: specification and estimation of moment structures. *Psychometrika* 48:493-517, 1983. (Cited 25 times.)
4. **Graham J W & Collins L M.** *Sample size and fit indices in analysis of covariance structure analysis.* Unpublished paper presented at the meetings of the Psychometric Society, June 1987, Montreal, Canada.
5. **Wheaton B.** Assessment of fit in overidentified models with latent variables. (Long J S, ed.) *Common problems in quantitative social research.* Beverly Hills: Sage. (In press.)
6. **Anderson J C & Gerbing D W.** Structural equation modeling in practice: a review and recommended two-step approach. *Psychol. Bull.* (In press.)