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July 21, 2023

References

Boettiger et al.: An introduction to Rocker: Docker containers for R

Boettiger-Eddelbuettel-2017

Carl Boettiger and Dirk Eddelbuettel. "An introduction to Rocker: Docker containers for R". In: *The R Journal* 9.2 (2017), p. 527. DOI: 10.32614/rj-2017-065.

Abstract: We describe the Rocker project, which provides a widely-used suite of Docker images with customized R environments for particular tasks. We discuss how this suite is organized, and how these tools can increase portability, scaling, reproducibility, and convenience of R users and developers.

Chow et al.: Equivalence and differences between structural equation modeling and state-space modeling techniques **Chow-Ho-Hamaker-etal-2010**

Sy-Miin Chow et al. "Equivalence and differences between structural equation modeling and state-space modeling techniques". In: *Structural Equation Modeling: A Multidisciplinary Journal* 17.2 (Apr. 2010), pp. 303–332. DOI: 10.1080/10705511003661553.

Abstract: State-space modeling techniques have been compared to structural equation modeling (SEM) techniques in various contexts but their unique strengths have often been overshadowed by their similarities to SEM. In this article, we provide a comprehensive discussion of these 2 approaches' similarities and differences through analytic comparisons and numerical simulations, with a focus on their use in representing intraindividual dynamics and interindividual differences. To demonstrate the respective strengths and weaknesses of the 2 approaches in representing these 2 aspects, we simulated data under (a) a cross-sectional common factor model, (b) a latent difference

score model with random effects in intercept and slope, and (c) a bivariate dynamic factor analysis model with auto- and cross-regression parameters. Possible ways in which SEM and state-space modeling can be utilized as complementary tools in representing human developmental and other related processes are discussed.

Deboeck et al.: No Need to be Discrete: A Method for Continuous Time Mediation Analysis **Deboeck-Preacher-2015**

Pascal R. Deboeck and Kristopher J. Preacher. "No Need to be Discrete: A Method for Continuous Time Mediation Analysis". In: *Structural Equation Modeling: A Multidisciplinary Journal* 23.1 (June 2015), pp. 61–75. DOI: 10.1080/10705511.2014.973960.

Abstract: Mediation is one concept that has shaped numerous theories. The list of problems associated with mediation models, however, has been growing. Mediation models based on cross-sectional data can produce unexpected estimates, so much so that making longitudinal or causal inferences is inadvisable. Even longitudinal mediation models have faults, as parameter estimates produced by these models are specific to the lag between observations, leading to much debate over appropriate lag selection. Using continuous time models (CTMs) rather than commonly employed discrete time models, one can estimate lag-independent parameters. We demonstrate methodology that allows for continuous time mediation analyses, with attention to concepts such as indirect and direct effects, partial mediation, the effect of lag, and the lags at which relations become maximal. A simulation compares common longitudinal mediation methods with CTMs. Reanalysis of a published covariance matrix demonstrates that CTMs can be fit to data used in longitudinal mediation studies.

Hunter: State Space Modeling in an Open Source, Modular, Structural Equation Modeling Environment **Hunter-2017**

Michael D. Hunter. "State Space Modeling in an Open Source, Modular, Structural Equation Model-

ing Environment". In: *Structural Equation Modeling: A Multidisciplinary Journal* 25.2 (Oct. 2017), pp. 307–324. DOI: 10.1080/10705511.2017.1369354.

Abstract: State space models (SSMs) are introduced in the context of structural equation modeling (SEM). In particular, the OpenMx implementation of SSMs using the Kalman filter and prediction error decomposition is discussed. In reflection of modularity, the implementation uses the same full information maximum likelihood missing data procedures for SSMs and SEMs. Similarly, generic OpenMx features such as likelihood ratio tests, profile likelihood confidence intervals, Hessian-based standard errors, definition variables, and the matrix algebra interface are all supported. Example scripts for specification of autoregressive models, multiple lag models (VAR(p)), multiple lag moving average models (VARMA(p, q)), multiple subject models, and latent growth models are provided. Additionally, latent variable calculation based on the Kalman filter and raw data generation based on a model are all included. Finally, future work for extending SSMs to allow for random effects and for presenting them in diagrams is discussed.

Jones et al.: Computing confidence intervals for standardized regression coefficients. Jones-Waller-2013a

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Jeff A. Jones and Niels G. Waller. "Computing confidence intervals for standardized regression coefficients." In: *Psychological Methods* 18.4 (2013), pp. 435–453. DOI: 10.1037/a0033269.

Abstract: With fixed predictors, the standard method (Cohen, Cohen, West, & Aiken, 2003, p. 86; Harris, 2001, p. 80; Hays, 1994, p. 709) for computing confidence intervals (CIs) for standardized regression coefficients fails to account for the sampling variability of the criterion standard deviation. With random predictors, this method also fails to account for the sampling variability of the predictor standard deviations. Nevertheless, under some conditions the standard method will produce CIs with accurate coverage rates. To delineate these conditions, we used a Monte Carlo simulation to compute empirical CI coverage rates in samples drawn from 36 populations with a wide range of data characteristics. We also computed the empirical CI coverage rates for 4 alternative methods

that have been discussed in the literature: noncentrality interval estimation, the delta method, the percentile bootstrap, and the bias-corrected and accelerated bootstrap. Our results showed that for many data-parameter configurations–for example, sample size, predictor correlations, coefficient of determination (R^2), orientation of β with respect to the eigenvectors of the predictor correlation matrix, R_X–the standard method produced coverage rates that were close to their expected values. However, when population R^2 was large and when β approached the last eigenvector of R_X, then the standard method coverage rates were frequently below the nominal rate (sometimes by a considerable amount). In these conditions, the delta method and the 2 bootstrap procedures were consistently accurate. Results using noncentrality interval estimation were inconsistent. In light of these findings, we recommend that researchers use the delta method to evaluate the sampling variability of standardized regression coefficients.

Jones et al.: The Normal-Theory and Asymptotic Distribution-Free (ADF) Covariance Matrix of Standardized Regression Coefficients: Theoretical Extensions and Finite Sample Behavior **Jones-Waller-2013b**

Jeff A. Jones and Niels G. Waller. "The Normal-Theory and Asymptotic Distribution-Free (ADF) Covariance Matrix of Standardized Regression Coefficients: Theoretical Extensions and Finite Sample Behavior". In: *Psychometrika* 80.2 (Dec. 2013), pp. 365–378. DOI: 10.1007/s11336-013-9380-y.

Abstract: Yuan and Chan (Psychometrika, 76, 670–690, 2011) recently showed how to compute the covariance matrix of standardized regression coefficients from covariances. In this paper, we describe a method for computing this covariance matrix from correlations. Next, we describe an asymptotic distribution-free (ADF; Browne in British Journal of Mathematical and Statistical Psychology, 37, 62–83, 1984) method for computing the covariance matrix of standardized regression coefficients. We show that the ADF method works well with nonnormal data in moderate-to-large samples using both simulated and real-data examples. R code (R Development Core Team, 2012) is available from the authors or through the Psychometrika online repository for supplementary materials.

Jones et al.: The normal-theory and asymptotic distribution-free (ADF) covariance matrix of standardized regression coefficients: Theoretical extensions and finite sample behavior **Jones-Waller-2013c**

Jeff A. Jones and Niels G. Waller. *The normal-theory and asymptotic distribution-free (ADF) covariance matrix of standardized regression coefficients: Theoretical extensions and finite sample behavior*. Tech. rep. University of Minnesota-Twin Cities, May 25, 2013. URL: http://users.cla.umn.edu/~nwaller/downloads/techreports/TR052913.pdf (visited on 07/22/2022).

Abstract: Yuan and Chan (2011) recently showed how to compute the covariance matrix of standardized regression coefficients from covariances. In this paper, we describe a new method for computing this covariance matrix from correlations. We then show that Yuan and Chan's original equations can also be used when only correlational data are available. Next, we describe an asymptotic distribution-free (ADF; Browne, 1984) method for computing the covariance matrix of standardized regression coefficients. We show that theADF method works well with non-normal data in moderate-to-large samples using both simulated and real-data examples. Finally, we provide R code (R Development Core Team, 2012) in an Appendix to make these methods accessible to applied researchers.

Kurtzer et al.: Singularity: Scientific containers for mobility of compute **Kurtzer-Sochat-Bauer-2017**

Gregory M. Kurtzer, Vanessa Sochat, and Michael W. Bauer. "Singularity: Scientific containers for mobility of compute". In: *PLOS ONE* 12.5 (May 2017). Ed. by Attila Gursoy, e0177459. DOI: 10.1371/journal.pone.0177459.

Kwan et al.: Comparing standardized coefficients in structural equation modeling: A model reparameterization approach **Kwan-Chan-2011**

Joyce L. Y. Kwan and Wai Chan. "Comparing standardized coefficients in structural equation modeling: A model reparameterization approach". In: *Behavior Research Methods* 43.3 (Apr. 2011), pp. 730–745. DOI: 10.3758/s13428-011-0088-6.

Abstract: We propose a two-stage method for comparing standardized coefficients in structural equation modeling (SEM). At stage 1, we transform the original model of interest into the standardized model by model reparameterization, so that the model parameters appearing in the standardized model are equivalent to the standardized parameters of the original model. At stage 2, we impose appropriate linear equality constraints on the standardized model and use a likelihood ratio test to make statistical inferences about the equality of standardized coefficients. Unlike other existing methods for comparing standardized coefficients, the proposed method does not require specific modeling features (e.g., specification of nonlinear constraints), which are available only in certain SEM software programs. Moreover, this method allows researchers to compare two or more standardized coefficients simultaneously in a standard and convenient way. Three real examples are given to illustrate the proposed method, using EQS, a popular SEM software program. Results show that the proposed method performs satisfactorily for testing the equality of standardized coefficients.

Kwan et al.: Comparing squared multiple correlation coefficients using structural equation modeling **Kwan-Chan-2014**

Joyce L. Y. Kwan and Wai Chan. "Comparing squared multiple correlation coefficients using structural equation modeling". In: *Structural Equation Modeling: A Multidisciplinary Journal* 21.2 (Apr. 2014), pp. 225–238. DOI: 10.1080/10705511.2014.882673.

Abstract: In social science research, a common topic in multiple regression analysis is to compare the squared multiple correlation coefficients in different populations. Existing methods based on asymptotic theories (Olkin & Finn, 1995) and bootstrapping (Chan, 2009) are available but these can only handle a 2-group comparison. Another method based on structural equation modeling (SEM) has been proposed recently. However, this method has three disadvantages. First, it requires the user to explicitly specify the sample R2 as a function in terms of the basic SEM model parameters, which is sometimes troublesome and error prone. Second, it requires the specification of nonlinear constraints, which is not available in some popular SEM software programs. Third, it is for a 2-group comparison primarily. In this article, a 2-stage SEM method is proposed as an alternative. Unlike all other existing methods, the proposed method is simple to use, and it does not require any specific programming features such as the specification of nonlinear constraints. More important, the method allows a simultaneous comparison of 3 or more groups. A real example is given to illustrate the proposed method using EQS, a popular SEM software program.

Merkel: Docker: Lightweight Linux containers for consistent development and deployment **Merkel-2014**

Dirk Merkel. "Docker: Lightweight Linux containers for consistent development and deployment". In: *Linux Journal* 2014.239 (2014), p. 2. URL: https://www.linuxjournal.com/content/docker-lightweight-linux-containers-consistent-development-and-deployment.

Neale et al.: OpenMx 2.0: Extended Structural Equation and Statistical Modeling **Neale-Hunter-Pritikin-etal-2015**

Michael C. Neale et al. "OpenMx 2.0: Extended Structural Equation and Statistical Modeling". In: *Psychometrika* 81.2 (Jan. 2015), pp. 535–549. DOI: 10.1007/s11336-014-9435-8.

Abstract: The new software package OpenMx 2.0 for structural equation and other statistical modeling is introduced and its features are described. OpenMx is evolving in a modular direction and now allows a mix-and-match computational approach that separates model expectations from fit functions and optimizers. Major backend architectural improvements include a move to swappable open-source optimizers such as the newly written CSOLNP. Entire new methodologies such as item factor analysis and state space modeling have been implemented. New model expectation functions including support for the expression of models in LISREL syntax and a simplified multigroup ex-

pectation function are available. Ease-of-use improvements include helper functions to standardize model parameters and compute their Jacobian-based standard errors, access to model components through standard R $ mechanisms, and improved tab completion from within the R Graphical User Interface.

Ou et al.: What's for dynr: A package for linear and nonlinear dynamic modeling in R **Ou-Hunter-Chow-2019**

Lu Ou, Michael D. Hunter, and Sy-Miin Chow. "What's for dynr: A package for linear and nonlinear dynamic modeling in R". In: *The R Journal* 11.1 (2019), p. 91. DOI: 10.32614/rj-2019-012.

Abstract: Intensive longitudinal data in the behavioral sciences are often noisy, multivariate in nature, and may involve multiple units undergoing regime switches by showing discontinuities interspersed with continuous dynamics. Despite increasing interest in using linear and nonlinear differential/difference equation models with regime switches, there has been a scarcity of software packages that are fast and freely accessible. We have created an R package called dynr that can handle a broad class of linear and nonlinear discreteand continuous-time models, with regime-switching properties and linear Gaussian measurement functions, in C, while maintaining simple and easy-to learn model specification functions in R. We present the mathematical and computational bases used by the dynr R package, and present two illustrative examples to demonstrate the unique features of dynr.

Preacher et al.: Advantages of Monte Carlo Confidence Intervals for Indirect Effects **Preacher-Selig-2012**

Kristopher J. Preacher and James P. Selig. "Advantages of Monte Carlo Confidence Intervals for Indirect Effects". In: *Communication Methods and Measures* 6.2 (Apr. 2012), pp. 77–98. DOI: 10.1080/19312458.2012.679848.

Abstract: Monte Carlo simulation is a useful but underutilized method of constructing confidence intervals for indirect effects in mediation analysis. The Monte Carlo confidence interval method has several distinct advantages over rival methods. Its performance is comparable to other widely accepted methods of interval construction, it can be used when only summary data are available, it can be used in situations where rival methods (e.g., bootstrapping and distribution of the product methods) are difficult or impossible, and it is not as computer-intensive as some other methods. In this study we discuss Monte Carlo confidence intervals for indirect effects, report the results of a simulation study comparing their performance to that of competing methods, demonstrate the method in applied examples, and discuss several software options for implementation in applied settings.

Rosseel: lavaan: An R package for structural equation modeling **Rosseel-2012**

Yves Rosseel. “lavaan: An R package for structural equation modeling”. In: *Journal of Statistical Software* 48.2 (2012). DOI: 10.18637/jss.v048.i02.

Abstract: Structural equation modeling (SEM) is a vast field and widely used by many applied researchers in the social and behavioral sciences. Over the years, many software packages for structural equation modeling have been developed, both free and commercial. However, perhaps the best state-of-the-art software packages in this field are still closed-source and/or commercial. The R package lavaan has been developed to provide applied researchers, teachers, and statisticians, a free, fully open-source, but commercial-quality package for latent variable modeling. This paper explains the aims behind the development of the package, gives an overview of its most important features, and provides some examples to illustrate how lavaan works in practice.

Tofighi et al.: Indirect effects in sequential mediation models: Evaluating methods for hypothesis testing and confidence interval formation **Tofighi-Kelley-2019**

Davood Tofighi and Ken Kelley. “Indirect effects in sequential mediation models: Evaluating methods for hypothesis testing and confidence interval formation". In: *Multivariate Behavioral Research* 55.2 (June 2019), pp. 188–210. DOI: 10.1080/00273171.2019.1618545.

Abstract: Complex mediation models, such as a two-mediator sequential model, have become more prevalent in the literature. To test an indirect effect in a two-mediator model, we conducted a large-scale Monte Carlo simulation study of the Type I error, statistical power, and confidence interval coverage rates of 10 frequentist and Bayesian confidence/credible intervals (CIs) for normally and nonnormally distributed data. The simulation included never-studied methods and conditions (e.g., Bayesian CI with flat and weakly informative prior methods, two model-based bootstrap methods, and two nonnormality conditions) as well as understudied methods (e.g., profile-likelihood, Monte Carlo with maximum likelihood standard error [MC-ML] and robust standard error [MC-Robust]). The popular BC bootstrap showed inflated Type I error rates and CI under-coverage. We recommend different methods depending on the purpose of the analysis. For testing the null hypothesis of no mediation, we recommend MC-ML, profile-likelihood, and two Bayesian methods. To report a CI, if data has a multivariate normal distribution, we recommend MC-ML, profile-likelihood, and the two Bayesian methods; otherwise, for multivariate nonnormal data we recommend the percentile bootstrap. We argue that the best method for testing hypotheses is not necessarily the best method for CI construction, which is consistent with the findings we present.

Tofighi et al.: Monte Carlo confidence intervals for complex functions of indirect effects

Tofighi-MacKinnon-2015

Davood Tofighi and David P. MacKinnon. "Monte Carlo confidence intervals for complex functions of indirect effects". In: *Structural Equation Modeling: A Multidisciplinary Journal* 23.2 (Aug. 2015), pp. 194–205. DOI: 10.1080/10705511.2015.1057284.

Abstract: One challenge in mediation analysis is to generate a confidence interval (CI) with high coverage and power that maintains a nominal significance level for any well-defined function of indirect and direct effects in the general context of structural equation modeling (SEM). This study discusses a proposed Monte Carlo extension that finds the CIs for any well-defined function of the coefficients of SEM such as the product of k coefficients and the ratio of the contrasts of indirect effects, using the Monte Carlo method. Finally, we conduct a small-scale simulation study to compare CIs produced by the Monte Carlo, nonparametric bootstrap, and asymptotic-delta methods. Based on our simulation study, we recommend researchers use the Monte Carlo method to test a complex function of indirect effects.

Yuan et al.: Biases and Standard Errors of Standardized Regression Coefficients

Yuan-Chan-2011

Ke-Hai Yuan and Wai Chan. "Biases and Standard Errors of Standardized Regression Coefficients". In: *Psychometrika* 76.4 (Aug. 2011), pp. 670–690. DOI: 10.1007/s11336-011-9224-6.

Abstract: The paper obtains consistent standard errors (SE) and biases of order O(1/n) for the sample standardized regression coefficients with both random and given predictors. Analytical results indicate that the formulas for SEs given in popular text books are consistent only when the population value of the regression coefficient is zero. The sample standardized regression coefficients are also biased in general, although it should not be a concern in practice when the sample size is not too small. Monte Carlo results imply that, for both standardized and unstandardized sample regression coefficients, SE estimates based on asymptotics tend to under-predict the empirical ones at smaller sample sizes.