A Note on How to Conduct a Factor-Based PLS-SEM Analysis

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ABSTRACT

The composite-factor estimation dichotomy has been the epicenter of a long and ongoing debate among proponents and detractors of the use of the partial least squares (PLS) approach for structural equation modeling (SEM). In this brief research note the author discusses the implementation of a new method to conduct factor-based PLS-SEM analyses, which could be a solid step in the resolution of this debate. This method generates estimates of both true composites and factors, in two stages, fully accounting for measurement error. The author’s discussion is based on an illustrative model in the field of e-collaboration. A Monte Carlo experiment suggests that model parameters generated by the method are asymptotically unbiased. The method is implemented as part of the software WarpPLS, starting in version 5.0. This note provides enough details for the method’s implementation in other venues such as R and GNU Octave.

Keywords: Measurement Error, Monte Carlo Simulation, Partial Least Squares, Path Bias, Structural Equation Modeling, Variation Sharing

INTRODUCTION

The debate among proponents and detractors of the use of Wold’s partial least squares (PLS) method (Adelman & Lohmoller, 1994; Lohmöller, 1989; Wold, 1980) in the context of structural equation modeling (SEM) has been going on for a long time. So far, it shows no signs of resolution. It arises from common factor model assumptions, which form the basis on which covariance-based SEM (CB-SEM) rests (Kline, 2010; Mueller, 1996). The debate is centered around two main issues.

The first issue is that Wold’s original PLS design for “soft” SEM has a number of advantages over CB-SEM, such as minimal model identification demands, practically no data or model parameter distribution assumptions, virtually universal convergence to solutions, and estimation of “pseudo-factors”. The latter, “pseudo-factors”, provide a partial solution to the factor indeterminacy problem of CB-SEM.

The second issue fueling the debate is that, unlike CB-SEM, the original PLS design does not base its model parameter estimation methods on the estimation of true factors. Estimation is based on “composites”, which are exact linear combinations of indicators, and are referred to above as “pseudo-factors”. The composite estimates generated by the original PLS design...
can be seen as factors minus their corresponding measurement errors. Reliance on them leads to biased model parameter estimates (notably path coefficients and loadings) even as sample sizes grow to infinity (Kock, 2014b).

In this brief research note we describe what could be a solid step in the resolution of this debate, although it may open new avenues for debate on different issues. We show how researchers can implement what we refer to as “Factor-Based PLS-SEM” (PLSF-SEM). This new method generates estimates of both true composites and factors, in two stages, fully accounting for measurement error.

The PLSF-SEM method is implemented in version 5.0 of WarpPLS, which is under intensive internal testing and nearing beta release at the time of this writing. WarpPLS is an SEM software tool that is unique in that it enables nonlinear analyses where best-fitting nonlinear functions are estimated for each pair of structurally linked variables in path models, and subsequently used (i.e., the nonlinear functions) to estimate path coefficients that take into account the nonlinearity. Moreover, WarpPLS provides a comprehensive set of model fit and quality indices that are compatible with both composite-based and factor-based SEM.

ILLUSTRATIVE MODEL

Our discussion is based on the illustrative model depicted in Figure 1, which builds on an actual empirical study in the field of e-collaboration (Kock, 2005; 2008; Kock & Lynn, 2012). This illustrative model incorporates the belief that e-collaboration technology use ($F_1$) by teams of workers tasked with the development of new products in organizations (e.g., a new consulting service, a new car part) increases both team efficiency ($F_2$) and team performance ($F_3$). Team efficiency ($F_2$) is related to the speed and cost at which teams operate. Team performance ($F_3$) is related to how well the new products developed by teams perform in terms of sales and profits.

In this illustrative model $\beta_{ij}$ is the path coefficient for the link going from factor $F_j$ to factor $F_i$; $\lambda_{ij}$ is the loading for the $j$th indicator of factor $F_i$; $\theta_{ij}$ is the indicator error for the $j$th indicator of factor $F_i$; $\varepsilon_i$ is the measurement error associated with $F_i$; and $\zeta_i$ is the structural error associated with $F_i$, which exists only for endogenous factors. An endogenous factor has at least one other factor pointing at it in the model.

Note that the measurement errors $\varepsilon_i$ are not the same as the structural errors $\zeta_i$. Measurement errors exist for any factors that are measured with a certain degree of imprecision, whether the factors are exogenous or endogenous. Structural errors exist only for endogenous factors.

Figure 1. Illustrative model
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