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Title: A Hierarchical Bayesian Methodology for Treating Heterogeneity in Structural Equation Models

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A Hierarchical Bayesian Methodology for Treating Heterogeneity in Structural Equation Models

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Abstract

Structural equation models are widely used in marketing and psychometric literature to model relationships between unobserved constructs and manifest variables and to control for measurement error. Most applications of structural equation models assume that data come from a homogeneous population. This assumption may be unrealistic, as individuals are likely to be heterogeneous in their perceptions and evaluations of unobserved constructs. In addition, individuals may exhibit different measurement reliabilities. It is well-known in statistical literature that failure to account for unobserved sources of individual differences can result in misleading inferences and incorrect conclusions.

We develop a hierarchical Bayesian framework for modeling general forms of heterogeneity in partially recursive structural equation models. Our framework elucidates the motivations for accommodating heterogeneity and illustrates theoretically the types of misleading inferences that can result when unobserved heterogeneity is ignored. We describe in detail the choices that researchers can make in incorporating different forms of measurement and structural heterogeneity. Current random-coefficient models in psychometric literature can accommodate heterogeneity solely in mean structures. We extend these models by allowing for heterogeneity both in mean and covariance structures. Specifically, in addition to heterogeneity in measurement intercepts and factor means, we account for heterogeneity in factor covariance structure, measurement error, and structural parameters. Models such as random-coefficient factor analysis, random-coefficient second-order factor analysis, and random-coefficient, partially recursive simultaneous equation models are special cases of our proposed framework. We also develop Markov Chain Monte Carlo (MCMC) procedures to perform Bayesian inference in partially recursive, random-coefficient structural equation models. These procedures provide individual-specific estimates of the factor scores, structural coefficients, and other model parameters.

We illustrate our approach using two applications. The first application illustrates our methods on synthetic data, whereas the second application uses consumer satisfaction data involving measurements on satisfaction, expectation disconfirmation, and performance variables obtained from a panel of subjects. Our results from the synthetic data application show that our Bayesian procedures perform well in recovering the true parameters. More importantly, we find that models that ignore heterogeneity can yield a severely distorted picture of the nature of associations among variables and can therefore generate misleading inferences. Specifically, we find that ignoring heterogeneity can result in inflated estimates of measurement reliability, wrong signs of factor covariances, and can yield attenuated model fit and standard errors. The results from the consumer satisfaction study show that individuals vary both in means and covariances and indicate that conventional psychometric methods are not appropriate for our data. In addition, we find that heterogeneous models outperform the standard structural equation model in predictive ability. Managerially, we show how one can use the individual-level factor scores and structural parameter estimates from the Bayesian approach to perform quadrant analysis and refine marketing policy (e.g., develop a one-on-one marketing policy).

The framework introduced in this paper and the inference procedures we describe should be of interest to researchers in a wide range of disciplines in which measurement error and unobserved heterogeneity are problematic. In particular, our approach is suitable for studies in which panel data or multiple observations are available for a given set of respondents or objects (e.g., firms, organizations, markets). At a practical level, our procedures can be used by managers and other policymakers to customize marketing activities or policies.

Future research should extend our procedures to deal with the general nonrecursive structural equation model and to handle binary and ordinal data situations.
(*Structural Equation Models*; *Heterogeneity*; *Hierarchical Bayes*; *MCMC Procedures*; *Metropolis-Hastings Algorithm*; *Gibbs Sampling*; *Customer Satisfaction*)

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