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Improper use of endogenous formative variables

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ABSTRACT

Researchers often develop and test conceptual models containing formative variables. In many cases, these formative variables are specified as being endogenous. This article provides a clarification of formative variable theory, distinguishing between the formative latent variable and the formative composite variable. When an endogenous latent variable relies on formative indicators for measurement, empirical studies can say nothing about the relationship between exogenous variables and the endogenous formative latent variable: conclusions can only be drawn regarding the exogenous variables' relationships with a composite variable. The authors also show the dangers associated with developing theory about antecedents to endogenous formative variables at the (aggregate) formative latent variable level. Modeling relationships with endogenous formative variables at the (disaggregate) indicator level informs richer theory development, and encourages more precise empirical testing. When antecedents' relationships with endogenous formative variables are modeled at the formative latent variable level rather than the formative indicator level, theory construction can verge on the superficial, and empirical findings can be ambiguous in substantive meaning.

1. Introduction

Formative variables are receiving increasing attention in business research (Diamantopoulos, 2008), as the *Journal of Business Research* 2008 special issue on formative indicators demonstrates. Formative indicators are used in different ways in the literature. For instance, Cadogan, Souchon, and Procter (2008, p. 1263) model each of the three dimensions underpinning market-oriented behavior in a formative way, to create a toolkit with "diagnostic capabilities which can help managers understand how to improve the quality of market orientation within the firm". Diamantopoulos and Siguaw (2006) and Ruiz, Gremler, Washburn, and Carrión (2008) compare the performance of scale development procedures adopting reflective and formative assumptions. Diamantopoulos and Siguaw (2006, p. 263) conclude, "the choice of measurement perspective impacts on the content, parsimony and criterion validity" of the measures they develop, while Ruiz et al. (2008, 1287) contend, "the formative index significantly outperforms a reflective measure in terms of criterion validity". These studies, and others like them, demonstrate the potential utility of modeling variables using formative indicators.

Studies also model formative measures as endogenous latent variables in structural models: these models attempt to explain variance of the formative latent variable, and test hypotheses about the causes of the explained variance. Two problematic issues are apparent in many such studies. First, as the next section demonstrates, researchers relying on formative indicators can never know how a formative latent variable varies, and can say little with confidence about the amount of variance explained in a formative latent variable. As a result, unless a census of formative indicators is used (in which case, and as discussed subsequently, the researcher is using a formative composite variable rather than a formative latent variable), one never knows how a potential antecedent variable is related to a formative latent variable. Without such a census of formative indicators, all one can do is comment on how the proposed antecedent covaries with the subset of formative indicators used: one cannot necessarily generalize the observed covariances to the full population of defining formative indicators.

Second, researchers interested in identifying exogenous causes of endogenous formative variables often make the mistake of modeling the endogenous variable at the aggregated formative variable level. Given that a "variable's formative indicators may have different antecedent factors, and those antecedents may not influence all indicators the same way" (Cadogan et al., 2008), failure to model antecedents at the disaggregated formative item level can obscure true relationships in the population, either hiding existing relationships, or suggesting the presence of non-existent relationships. As such, when antecedents to endogenous formative variables are modeled with causal paths affecting the formative variable, rather than affecting the formative indicators, the empirical findings have uncertain interpretation.

The purpose of the current note is to demonstrate the reasoning behind the conclusions presented above, and to make recommendations regarding the appropriate use of endogenous formative variables.

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In order to set the context, the next section outlines the assumptions of the formative indicator model, contrasting them with the more traditional reflective measurement model. The authors then explain why researchers can never know how a formative *latent* variable varies, and examine the potential problems arising from researchers erroneously modeling antecedents to endogenous formative variables at the endogenous variable level. Finally, recommendations for future research practice are provided, and the conditions under which antecedents to formative variables can appropriately be modeled at the endogenous variable level (as opposed to the indicator level) are discussed.

2. Reflective and formative indicators

Bollen and Lennox (1991) distinguish between two sets of measurement assumptions. The first is based on classical test theory, utilizing what are known as reflective items. Reflective items are dependent on the value of a latent variable, with the latent variable determining the item scores. On the other hand, the formative perspective treats items as being determinants of the latent variable: formative variables are defined by their items (Bagozzi & Fornell, 1982). Fig. 1a shows a path diagram for a reflective measurement model, with the direction of causality flowing from the latent variable (ξ_1) to the reflective measurement items (x_i), while Fig. 1b shows the formative model where the formative indicators (x_i) determine a latent variable (η_1). Importantly, there is a difference in the meaning of the error terms in Fig. 1a and b.

In Fig. 1a, the error terms (the δs) are random errors which can be estimated based on information provided by the covariance matrix of the xs. In Fig. 1b, the error term (ζ_1) "is a term that includes all other determinants of [η_1] that are not included in the [xs]" (Bollen, 2007, p. 220). The error term in the formative latent variable model recognizes that, operationally, a researcher may capture only a subset of the formative indicators that conceptually define the formative variable. Fig. 1c provides an example of a formative model in which all the defining formative indicators of η_1 are included. As Diamantopoulos (2006, p. 11) explains, in such cases, "the best way of dealing with the error term would be to simply exclude it from the model," in which case, the formative indicators define a type of formative variable which Grace and Bollen (2008, 194) label as the "composite variable" model (C_1), which is represented by an octagon. Formative variable models can also be higher-order in nature (Grace & Bollen, 2008; Jarvis, MacKenzie, & Podsakoff, 2003). Fig. 2a, for example, shows a higher-order formative latent variable containing reflective first-order constructs as indicators, while Fig. 2b shows a composite variable model containing reflective first-order constructs as indicators (cf. Jarvis et al., 2003).

The assumptions underpinning the reflective and formative models are widely discussed in the literature (e.g., Bollen & Lennox, 1991; Diamantopoulos, 2006; Diamantopoulos, Riefler, & Roth, 2008; Diamantopoulos & Winklhofer, 2001; Jarvis et al., 2003). Likewise, the conceptual and methodological challenges inherent in the formative modeling approach are also highlighted: for instance, Wilcox, Howell, and Breivik (2008) question the usefulness of formative variables for theory testing, Franke, Preacher, and Rigdon (2008) raise the issue of the proportionality of formative indicators' structural effects, and Howell, Breivik, and Wilcox (2007) and Bollen (2007) discuss the issue of interpretational confounding and formative model misspecification.

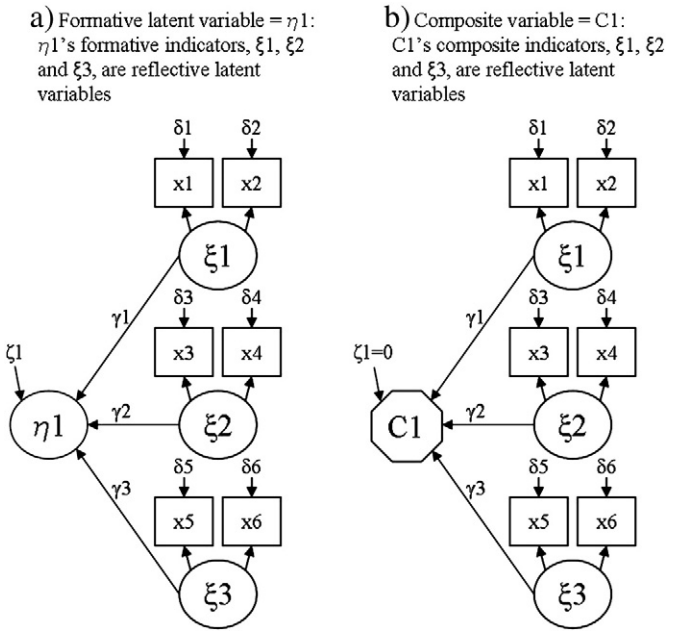

Fig. 2. Second-order formative indicator and composite variable models.

On the other hand, although composite variables are long established in the literature (see MacCorquodale & Meehl, 1948), according to Grace and Bollen (2008, p. 191) they "have received very limited use [in structural equation models], in part because of a lack of theoretical consideration, but also because of difficulties that arise in parameter estimation when using conventional solution procedures". The work presented here extends these debates by examining the issue of the modeling of endogenous formative variables in conceptual and empirical models.

3. The problem of endogenous formative latent variables in substantive empirical analyses

Importantly, since a formative latent variable is defined by its indicators (Jarvis et al., 2003), a change in the value of a formative

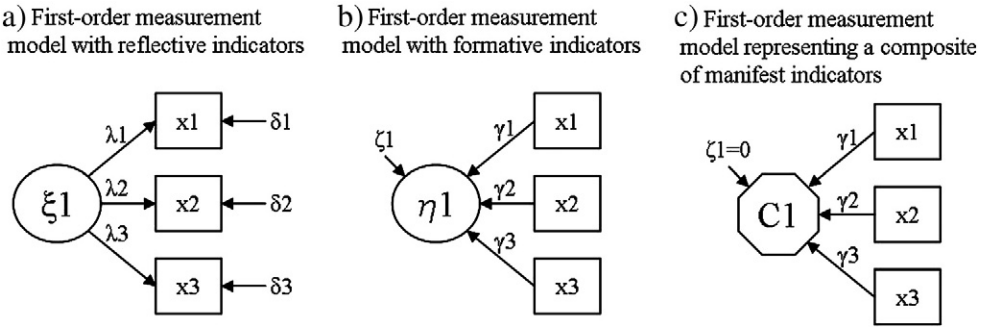

Fig. 1. First-order reflective, formative, and composite variable indicator models.