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How, when and why integrated choice and latent variable models are latently useful

Akshay Vij[a,*], Joan L. Walker[b,1]

[a] Institute for Choice, University of South Australia, Level 13, 140 Arthur Street, North Sydney, NSW 2060, Australia
[b] University of California at Berkeley, 111 McLaughlin Hall, Berkeley, CA 94720-1720, United States

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ABSTRACT

Integrated Choice and Latent Variable (ICLV) models are an increasingly popular extension to discrete choice models that attempt explicitly to model the cognitive process underlying the formation of any choice. This study was born from the discovery that an ICLV model can in many cases be reduced to a choice model without latent variables that fits the choice data at least as well as the original ICLV model from which it was obtained. The failure of past studies to recognize this fact raised concerns about other benefits that have been claimed with regards to the framework. With the objective of addressing these concerns, this study undertakes a systematic comparison between the ICLV model and an appropriately specified reduced form choice model. We derive analytical proofs regarding the benefits of the framework and use synthetic datasets to corroborate any conclusions drawn from the analytical proofs. We find that the ICLV model can under certain conditions lead to an improvement in the analyst's ability to predict outcomes to the choice data, allow for the identification of structural relationships between observable and latent variables, correct for bias arising from omitted variables and measurement error, reduce the variance of parameter estimates, and abet practice and policy, all in ways that would not be possible using the reduced form choice model. We synthesize these findings into a general process of evaluation that can be used to assess what gains, if any, might be had from developing an ICLV model in a particular empirical context.

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1. Introduction

Traditional models of disaggregate decision-making have long ignored the question of why we want what we want. Human needs have been treated as given, and attention has largely centered on the expression of these needs in terms of behavior in the marketplace. As a consequence, traditional models of disaggregate decision-making have focused on observable variables, such as product attributes, socioeconomic characteristics, market information and past experience, as determinants of choice, at the expense of the biological, psychological and sociological reasons underlying the formation of individual preferences (McFadden, 1986). This idealized representation of consumers as optimizing black boxes with predetermined wants and needs is at odds with findings from studies in the social sciences that have attempted explicitly to map the cognitive path that leads consumers from observable inputs to their observed choices in the marketplace. These studies

* Corresponding author. Tel.: +61 8 8302 0817.
E-mail addresses: vij.akshay@gmail.com (A. Vij), joanwalker@berkeley.edu (J.L. Walker).
[1] Tel.: + 1 510 642 6897.

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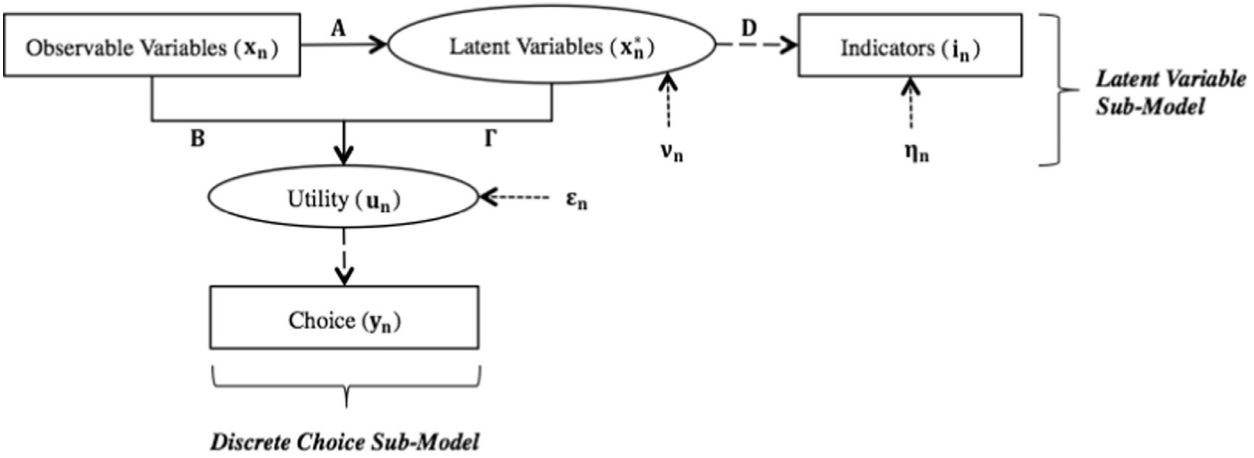

Fig. 1. The ICLV model framework (adapted from Ben-Akiva et al., 2002).

have consistently shown that latent constructs such as attitudes, norms, perceptions, affects and beliefs can often override the influence of observable variables on disaggregate behavior (see, for example, Bamberg and Schmidt, 2001; Gärling et al., 2003; Anable, 2005).

Integrated Choice and Latent Variable (ICLV) models overcome these deficiencies by allowing for the incorporation of latent behavioral constructs within the framework employed by traditional models of disaggregate decision-making. ICLV models were first proposed two-and-a-half decades ago by McFadden (1986) and Train et al. (1987) and popularized by later studies such as Ashok et al. (2002) and Ben-Akiva et al. (2002). Rapid strides in optimization techniques and computational power and the ready availability of estimation software such as Python Biogeme (Bierlaire, 2003) and Mplus (Muthén and Muthén, 2011) have since contributed to a veritable explosion in the number of studies estimating ICLV models. In the context of transportation and logistics, ICLV models have been applied to the study of travel mode choice (Paulssen et al., 2014), route choice (Bhat et al., 2015), car ownership (Daziano and Bolduc, 2013a), departure time (Thorhauge et al., 2015), freight (Bergantino et al., 2013), etc.

Much progress has been made in terms of model development and estimation (see, for example, Bhat and Dubey, 2014; Daziano, 2015 for recent methodological advances on the subject), but concerns remain regarding the value of the framework to econometricians, practitioners and policy-makers. On one hand, ICLV models appear to be powerful methods with which to enhance existing representations of decision-making. They allow for the proper integration of psychometric data within extant model frameworks and provide statistical tools with which to test complex theories of behavior, such as the Theory of Interpersonal Behavior (Triandis, 1977) and the Theory of Planned Behavior (Azjen, 1991). On the other, questions have been raised regarding the practical benefits of the framework (see, for example, Chorus and Kroesen, 2014). Does an ICLV model fit the choice data better than a simpler choice model without latent variables? Can findings from an ICLV model be used for policy analysis in ways that are not already possible using choice models without latent variables? Both sides of the debate have their proponents, but a clear verdict remains elusive.

The objective of this study is to systematically evaluate the benefits of the ICLV model framework in comparison with a more traditional choice model without latent variables, using a set of criteria based on statistical considerations and relevance to practice and policy. The study derives analytical proofs regarding the benefits, or lack thereof, of ICLV models over choice models without latent variables for each criterion and uses synthetic datasets to corroborate any conclusions drawn from the analytical proofs. Through most of the paper, we limit our attention to the form of the model that has most commonly been employed in the literature, but wherever possible, we outline how findings from the paper might be extrapolated to other variations. Our process of evaluation is general, and can be used to assess the benefits of any ICLV model framework over an appropriately specified reduced form model.

The paper is structured as follows: Section 2 describes the ICLV model framework in greater detail; Section 3 compares the framework with a choice model without latent variables in terms of its ability to predict outcomes to the choice data; Section 4 explores the usefulness of additional parameters identified by the framework; Sections 5 and 6 compare the bias and variance of parameter estimates obtained by the two model forms, respectively; Section 7 discusses the benefits of ICLV models to practice and policy; and Section 8 concludes the paper with a summary of key findings and directions for future research.

2. The ICLV model framework

Fig. 1 illustrates the ICLV model framework. In the general formulation, two components can be distinguished: a multinomial discrete choice model and a latent variable model. Each of these sub-models consists of a structural and a measurement

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