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Invited Contribution

Product development practices and performance: A structural equation modeling-based multi-group analysis

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Abstract

This paper provides an illustration of the strategies associated with conducting tests of model invariance that are uncommonly applied and reported in the Operations Management literature. The illustration uses a theoretical model that describes the relationships between key product development practices (i.e., *heavy-weight product development managers, information technology use* and *concurrent engineering*) and performance as measured through product innovation and quality. Based on a sample of 214 manufacturing executives and managers, the study considers a priori proposed measurement and structural models and further examines the extent to which these models are invariant across two different cellular manufacturing environments.

Keywords: New product development; Structural equation models; Multi-group analysis and model invariance

1. Introduction

The overwhelming majority of recent empirical research in the field of Operations Management employs some type of structural equation modeling (SEM) analysis. More often than not, however, there is little consideration that the given sample examined in the research study may be comprised of multiple groups. This is particularly important as the components of a proposed model (e.g., the so-called measurement and/or structural components of a model) may not always be invariant across the different groups. For example, certain manufacturing practices may only improve performance in large firms but not in small firms. While running separate models for large and small firms may provide some insight into potential differences between employed manufacturing practices, a more sophisticated statistical testing approach within SEM must be undertaken in order to pinpoint specific similarities and discrepancies.

In the SEM methodological literature, general statistical tests dealing with hypotheses about potential group differences are commonly referred to as tests of model invariance (Heck and Marcoulides, 1989; Marcoulides and Heck, 1993). The terms interaction modeling or multi-sampling are also often used to refer to data analyses that aim to compare the similarities of proposed models across different samples or subgroups of samples

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(Schumacker and Marcoulides, 1998). Of course, all these modeling techniques are really just part of the more general class of approaches encompassed by SEM (Raykov and Marcoulides, 2000).

The analysis basically begins by fitting a model to the data for each sample considered separately with none of the parameters constrained to be equal across groups. This unconstrained model serves as the baseline model. Subsequently, in a stepwise fashion, more stringent constraints are placed on the model by specifying the parameters of interest to be constrained across groups. The model is then examined using a chi-square (χ^2) difference test between the less restrictive and more restrictive models to determine whether the model and the individual parameter estimates (e.g., factor loadings, factor inter-correlations, error variance, structural relations) are invariant across the samples. A significant difference in χ^2 represents a deterioration of the model and the null hypothesis that the parameters are equal is rejected. A non-significant χ^2 difference is consistent with model invariance; that is, the parameters examined are equal across groups.

The above tests of model invariance also represent an approach to construct validation, which essentially demands that if the field of Operations Management is to advance as an academic discipline, greater attention must be paid to ensure that models developed for a given environment are also examined in other environments. Consequently, the crucial and decisive question is ultimately whether constructs developed to measure certain operations management principles and practices are invariant across different environments of interest. According to Horn and McArdle (1992), measurement invariance basically refers to "whether or not, under different conditions of observing and studying phenomena, measurement operations yield measures of the same attribute (p. 117)". Obviously the consequences of not establishing invariance can be detrimental to the integrity of any research findings. For example, differences in scale means for levels of JIT practices might be due to true differences between small and large firms or due to systematic biases in the way people from large and small firms respond to certain items. Differences in relationships between constructs as exhibited among large and small firms could indicate real disparities in structural relations between constructs as scaling artifacts, disparities in scale reliability, or even non-equivalence of the constructs involved.

The purpose of this paper is to provide a non-technical overview of strategies associated with conducting tests of model invariance that are uncommonly applied and reported in the Operations Management literature. The paper is written more from a didactic perspective so as to serve as a guide for researchers interested in applying this methodology but who may be uncertain of the strategies involved. To accomplish this purpose, we focus on examining the invariance of a model across only two types of firms: (i) those that have a high cellular manufacturing presence, and (ii) those that have a low cellular manufacturing presence.

Case and industry studies focusing primarily on large, highly visible firms have substantially improved our understanding of key product development practices (e.g., heavy-weight product development managers and concurrent engineering) and describe how these practices impact product innovation and quality (Donnellon, 1993; Millson et al., 1992; Koufteros et al., 2001, 2002b, 2005). An essential question is whether these practices actually contribute equally in different environments. While firms have adopted new and innovative product development practices, many have also adopted innovative manufacturing practices such as cellular manufacturing. Cellular practices are purported to improve operational efficiencies by producing one family of parts within each cell. Because parts produced in each cell are "similar," setup times are reduced. Because similar products are made within each cell, quality may improve as well. Beyond operational efficiencies, however, it is conceivable that the relationships among product development practices and performance would be different under varying levels of cellular manufacturing. Perhaps firms with heavier presence of cellular manufacturing would be more accommodating to product development efforts and thus boost the ability of firms to introduce new products and features.

This research study describes a multivariate model for examining relationships among key product development practices (i.e., heavy-weight product development managers, information technology use, concurrent engineering), and performance such as product innovation and quality. Beyond the prototypical strictly confirmatory testing of an a priori proposed model, multi-group analyses are carried out both on the measurement and structural parts of the model. The two groups are formed based on specified levels of cellular manufacturing. The hypotheses are tested with