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Comparing ANFIS and SEM in linear and nonlinear forecasting of new product development performance

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ABSTRACT

Though the hi-tech industry has focused on value innovation and improving the quality of the new product development (NPD) process to drive new product performance, new product success has not changed dramatically over the years. This study presents a novel approach based on structural equation modeling (SEM) and adaptive neuro-fuzzy inference system (ANFIS) to forecast value innovation and the effects of the quality of the NPD process on NPD performance. Results demonstrate that value innovation directly affects NPD performance as well as the nonlinear relationships between the quality of NPD processes and NPD performance, and that ANFIS achieves better forecasting performance than the SEM technique. The ANFIS model effectively explains the nonlinear relationships that SEM cannot. This paper thus offers a new perspective on forecasting and modeling useful to both researchers and practitioners.

1. Introduction

Rapidly changing technologies, intense competition, and dynamic customer needs and wants are rendering existing products obsolete, resulting in shorter product life cycles. The dilemma faced by management in high technology firms is that while the need for successful NPD is stronger than ever, new products success has not changed dramatically over the years (Joshi & Sharma, 2004).

Studies have suggested a wide range of factors that drive new product performance (Cooper, 1996; Cooper & Kleinschmidt, 2007). Most managers will agree that value innovation enables continuous growth and profits, and plays a vital role in new product development (NPD) in hi-tech industry (Dillon, Lee, & Matheson, 2005). In recent decades, the technology management literature has emphasized the importance of value innovation in creating and sustaining competitive advantage and in rejuvenating the enterprise (Aiman-Smith, Goodrich, Roberts, & Scinta, 2005; Aragón-Correa, García-Morales, & Cordón-Pozo, 2007; Dikmen, Birgonul, & Artuk, 2005; Dillon et al., 2005). Further, the quality of NPD processes is also a major factor in new product performance (Cooper, 1996; Cooper & Kleinschmidt, 2007). But the mere existence of a formal product development process has little apparent effect on performance (Cooper & Kleinschmidt, 2007). Firms often engage in new product development processes under strict quality management, but without correspondingly strong performance results.

Structural equation modeling (SEM) is widely applied in the business and social sciences to predict endogenous latent variables and to estimate as well as test relationships between latent variables (causal analysis). In SEM, the key variables of interest are usually 'latent constructs'–abstract psychological concepts. We can observe the behavior of latent variables only indirectly, and imperfectly, through their effects on manifest variables. SEM requires a set of assumptions such as independent observations, random sampling of respondents, and the linearity of all relationships which are not achieved most frequently in practice (Hair, Anderson, Tatham, & Black, 1998; Şen & Altunkaynak, 2009).

Scholars generally use questionnaire surveys to measure NPD context. In such surveys the questions involve the concepts, opinions, habits, attitudes, and behaviors of individuals. They often appear to be abstract and subjective. The commonly used 5- or 7-point Likert scales may lead to vague answer as respondents see-saw between answers which do not accurately portray their perception of the situation (Deng & Pei, 2007). Since psychological concepts may have nonlinear relationships to each other, they cannot be directly estimated in SEM (Hair et al., 1998). By contrast, adaptive neuro-fuzzy inference systems (ANFIS) can deal with nonlinear relationships. ANFIS adopts the FIS implement, a useful computing framework based on the concepts of fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning, in the framework of a neural network (Jang, 1993). It can deal with complex, nonlinear relations between the input and output data through hybrid learning to determine the optimal distribution of membership functions. Thus,

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the ANFIS is a very powerful approach for dealing with nonlinear relationships.

ANFIS techniques have been successfully applied to many domain problems in recent years (e.g. Azadeh, Saberi, Gitiforouz, & Saberi, 2009; Şen & Altunkaynak, 2009). Tortum, Yayla, and Gökdağ (2009) use artificial neural networks (ANN) and ANFIS techniques to test models of intercity freight transport. Akdemir, Kara, Polat, Güven, and Günes (2008) proposed combining principal component analysis (PCA) and ANFIS to diagnose optic nerve disease. Radulović and Ranković (2009) used a feedforward neural network (FNN) and ANFIS to estimate electric and magnetic fields around overhead power transmission lines. Chen, Ying, and Pan (2009) proposed forecasting tourist arrivals using ANFIS. Wua, Hsu, and Chen (2009) used ANN and ANFIS technique for used car price forecasting. Chien, Wangb, and Lin (2009) also used ANN and ANFIS techniques to forecast innovation performance. The research has demonstrated that the ANFIS model offers increased accuracy and reduced forecasting error across a variety of estimate and forecasting situations. Although many studies have compared ANFIS with other techniques, comparative analysis of ANFIS and SEM is rare. To the best of our knowledge, only Kim, Han, Kim, and Park (2009) have used regression, ANN, and SEM, with the results showing that SEM is the most accurate.

It is the main purpose of this paper to compare SEM and ANFIS in the forecasting of value innovation models using vague data such as questionnaire surveys, whose questions are sometimes difficult to answer and require a long time to respond. The purpose of this study is to establish a relationship between latent variables with this imprecise survey information.

The remainder of this paper is organized as follows. First, Section 2 presents the literature review. Section 3 then describes the conceptual features of the SEM and the ANFIS used in this study. In Section 4, the research methodology is described. Section 5 then presents our empirical analysis using a questionnaire survey and comparative analysis. Finally, Section 6 offers a discussion and conclusions.

2. Literature review

Market orientation and subsequent firm innovation are widely recognized to be essential for the survival and growth of organizations (Aiman-Smith et al., 2005; Aragón-Correa et al., 2007). Value innovations require an organizational commitment to create a strong momentum for inside-in changes and advances in bringing inside-out value creating outcomes and attaining superior positions in the competition race (Mohanty, 1999). Continuing success in delighting the customer, in turn, drives sustained increase in enterprise value.

Aiman-Smith et al. (2005) defined value innovation as that innovation which occurs when organizational members are working on identifying better ways to serve their current customers, and on identifying new markets. Dikmen et al. (2005) pointed out that value innovation is not a competition-based view of the firm, but instead is an endogenous growth theory and a resource-based view, where growth and innovation come from within the organization itself. Thus, innovations emerge from knowledge accumulated within the organization and resource recombinations chosen by the firm to produce a service/product (Dikmen et al., 2005).

Many organizations believing that technology innovation alone can create new wealth (Dillon et al., 2005). Irwin, Hoffman, and Lamont (1998) used a resource-based view to demonstrate the positive relationship between technological innovations and organizational performance. Hurley and Hult (1998) showed that positive relationships between organizational innovations influenced the potential for good performance. Aragón-Correa et al. (2007) showed the positive effect of firm innovation on performance. In view of the positive relationships seen in previous research, we thus hypothesize:

Hypothesis 1. More intense value innovation will positively affect NPD performance.

The "NPD process" means those steps, activities and decision-points that new product projects follow from idea to launch and beyond. Cooper (1996) argued that a high quality new product process to guide product innovations from idea to launch is a critical success factor. New product processes have been found to fail for a number of reasons. First, inadequate up-front homework has been found to be a major cause of failure in product development (Cooper & Kleinschmidt, 2007). Second, failure to define the product before development begins can cause both new product failure and serious delays in the development cycle. Third, many failed projects were moved too far into development without serious scrutiny. The lack of tough Go/Kill decision points meant too many product failures, resources wasted on the wrong projects, and a lack of focus. Fourth, an emphasis on quality-of-execution in many firms came about after internal studies revealed that too many projects suffered from weak, inconsistent work, with some of the most deficient areas being the market-related processes and routines at improving quality of execution of key tasks and activities throughout the process. Fifth, many companies discovered that not only was the quality of work unacceptable, but needed work such as market analysis, business assessment, and customer research, were simply not done or displayed hasty corner cutting. Finally, the new product process was inflexible or overly formalized, with stages and decision points that could be not skipped or combined, becoming a straightjacket for the project (Cooper & Kleinschmidt, 2007).

Cooper and Kleinschmidt (2007) demonstrated that the strongest driver of profitability is the existence of a high-quality and rigorous new product process that emphasizes up-front homework, tough Go/Kill decision points, sharp early product definition, and flexibility. By contrast, merely having a formal new product process has no impact at all on performance. Cooper (1996) demonstrated that a high quality new product process had the strongest impact on new product performance. Hence, since high quality new product processes appear to yield positive NPD performance, we construct the following hypothesis:

Hypothesis 2. A high quality NPD process will positively affect NPD performance.

3. Conceptual features of SEM and ANFIS

3.1. SEM

SEM is a comprehensive statistical approach to testing hypotheses about relations among observed and latent variables (variables which are not measured directly, but are estimated in the model from measured variables). It has received widespread attention from social science researchers (e.g., Hair et al., 1998; Jöreskog & Sörbom, 1979; Kline, 2005).

SEM is combination of multiple regression analysis, confirmatory factor analysis, and path analysis. SEM models have a measurement model and a structural model. In the measurement model, each latent construct is modeled as a common factor underlying the associated measures. The structural model includes the relationships among the latent constructs. In essence, SEM assumes that the causal relationships are linear (Hair et al., 1998; Jöreskog & Sörbom, 1979).

The research hypotheses explore how value innovation and quality of new product process affect NPD performance. As Fig. 1