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O.R. Applications

A study of the relationship between competitiveness and technological innovation capability based on DEA models

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Abstract

Researchers and managers have been searching for appropriate methods to explore the relationship between technological innovation capability and competitiveness in recent years. This study attempts to find a systematic quantitative methodology to tackle this problem. In a recent survey covering 182 industrial innovative firms in China, the traditional data envelopment analysis (DEA) model was employed to analyze the data collected. The research results show that only 16% of the enterprises operate on the best-practice frontier and there are some inconsistencies between organizational innovation capability and competitiveness in many enterprises. Decreasing returns to scale were found among about 70% of the inefficient enterprises and increasing returns to scale were found among the remaining 30% of the inefficient enterprises. Thus the internal innovation harmonizing process in these enterprises is considerably inefficient. Based on the restricted ranges of the input/output factors, a multi-objective DEA projection model has also been developed in this study to provide a benchmark for auditing competitiveness. Research results further indicate that there is still much room for enterprises to improve competitiveness in situations of confining score ranges of technological innovation capability and competitiveness.
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Keywords: Data envelopment analysis; Competitiveness; Organizational innovation capability; Controlling projection; Innovative firms

1. Introduction

Evaluating industrial competitiveness is vital for an enterprise in its formulation of its R&D strategy, design process flow and marketing

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strategy (Oral and Reisman, 1988; Oral, 1986, 1993; Porter, 1980, 1981; Pun et al., 2004). Earlier studies in this regard were either confined to the traditional strategy analysis framework or mainly focused on financial indicators. In general, they merely provided lists of competitive factors and did not explain the formation of internal mechanism of competitiveness. In recent years, scientific analysis tools such as resource-based and capability-based theories (Langlois, 1992; Prahalad and Hamel, 1990; Teece et al., 1990; Hamel and Heene, 1994; Barney, 1991; Dierickx and Cool, 1989; Peteraf, 1993; Sun, 1994; Sun and Gertsen, 1995; Wernerfelt, 1984) were adopted to explore the causes for the formation of competitiveness. These tools not only involve technological factors in their research field, but also bring organization management, manufacturing, marketing and industry environment into consideration. In the long run, it is technological innovation capability that forms a major source of competitive advantage (Freeman, 1994). The ability to introduce new products and adopt new processes in shorter lead time has become an imperative competitive tool (Sen and Egelhoff, 2000).

The competitiveness of an enterprise is based on a complex capability hierarchy. A conventional single performance criterion, whether it measures profitability or finance, is insufficient to determine the excellence of an enterprise. Consequently, a number of studies suggested that a multi-factor performance measurement model should be used to characterize it (see, e.g., Bagozzi and Phillips, 1982; Chakravarthy, 1986; Chin et al., 2003). The multi-factor competitiveness measurement model can help a company to identify performance targets and to acquire a stronger competitive edge using the least possible resources. Traditional cost–benefit analyses (e.g., Oral and Reisman, 1988; Li, 2000) have been used to deal with competitiveness of a firm. This is a parametric approach in which the single optimized regression equation is assumed to apply to each decision-making unit (DMU) i.e., each firm in a study. The major weakness of this approach is that it requires the imposition of a specific function form with specific assumptions about the distribution of the error terms and many other restrictions, such as factors earning the value of their marginal product.

Data envelopment analysis (DEA) uses a mathematical programming model to estimate best-practice frontiers without a priori underlying functional form assumption through computing multi-input/multi-output values. Since the first CCR DEA model was put forward by Charnes et al. (1978), a number of different DEA models and their corresponding real-world applications have appeared in literatures (Seiford, 1996; Cooper et al., 2000; Zhu, 2002). Joro et al. (1998) studied the relationship between DEA and multiple criteria decision making. The MCDM tools can be used to perform the projections to the efficient frontier. DEA can be used to optimize the performance measure of each DMU. DEA calculates a maximal performance measure for each DMU relative to all DMUs in the firms under observation. In other words, the focus of DEA is on the individual observations as represented by n optimizations (where n is the number of DMUs), in contrast to the focus on the averages and estimation of parameters that are associated with a single-optimization statistical parametric approach. The major advantage of the DEA approach is that DEA does not require any assumptions about the function form. That means that DEA does not need any priori information on the underlying functional forms and weights among various input and output factors. The performance measure of a multiple inputs and multiple outputs production system can hardly be described by a concrete function form. Therefore, DEA is particularly suitable for analyzing multiple inputs and multiple outputs production systems (Charnes et al., 1985; Zhu, 2000, 2002).

DEA has been widely used in different industrial sectors in the area of industrial management for performance evaluation and benchmarking studies (Zhu, 2000, 2002). For example, Zhu (2000) employed DEA to explore the multi-dimensional financial performance of Fortune 500 companies. Thus there is a high potential for DEA applications to examine the multi-factor competitiveness performance of a company if a similar analysis framework is adopted. In this case, innovation capability indicators and competitiveness

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