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A systematic stochastic efficiency analysis model and application to international supplier performance evaluation

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ABSTRACT

The selection of suppliers and the evaluation of their performance are challenging complex task faced by manufacturing managers in a global market. This is mainly due to three hurdles: (1) various criteria that characterize the supplier performance, (2) risk and uncertainty associated with supplier performance on multiple measures and (3) intangible attributes in cross- countries such as the political, legal, economic, socio-cultural and technological features.

The paper develops a stochastic efficiency analysis model to deal with these three hurdles. The model is a new methodological extension to data envelopment analysis (DEA) and applicable to efficiency analysis for entities from different systems with imbedded uncertainty. The application of the proposed model to the international supplier evaluation is the first attempt to model suppler performance from different sub-systems with different environment factors and uncertainty using Stochastic DEA.

1. Introduction

Supplier evaluation has been very important to operational decisions, involving decisions of selecting which vendors to employ, as well as decisions of with respect to quantities to order from each vendor. An assessment of supplier performance involves many capacities such as the following: (1) it helps managers to focus on the priority areas and make objective realization more likely (2) it collects data for taking corrective action to enhance performance related to a special perspective goal. For example, the evaluation can document possible needs in additional resources such as personnel or information technology (3) it helps to explore and maintain better internal relationships by isolating problem areas (4) it provides information to senior management with supplier's contribution (5) people performing at a better-than-normal level can be identified and rewarded, which would improve motivation in the organization. In today's competitive global business environment, the selection of suppliers and the evaluation of their performance remain to a complex task faced by manufacturing managers in a global market. This is mainly because of the following three reasons.

Firstly, various criteria characterizing the supplier performance are required to be involved in the model (Dickson, 1966; Vijayan, 2000; Weber, Current, & Benton, 1991). These multiple measures often include important product- and service-related attributes such as price, delivery, and quality performance. Even in B2B transactions, it is important for software developing companies to consider multiple vendor related attributes other than Price (Vijayan, 2000).

Secondly, as pointed out by several researchers supply risk and uncertainty associated with supplier performance on multiple measures are critical elements in the supply chain management. Handling supply risk and uncertainty has been a significant management effort due to the increasing number of suppliers and multiple criteria on which these suppliers are evaluated.

The third reason is that most of the time it is important to categorize various suppliers of interests in the evaluation process. Talluri and Narasimhan (2005) classify the candidate suppliers into two sets: potential candidates and existing supplier. This supplier selection problem is considered by a large, multinational, telecommunications company, which is a global leader in design, production, and marketing of communication systems. The company operates production plants, research and development facilities, and distribution systems globally. Six input and five output factors are utilized to represent the supplier capabilities and the performance outcomes of the suppliers, respectively. Narasimhan, Srinivas, and David (2001) identified four supplier clusters based on the DEA efficiency: high performers and efficient (HE), high performers and inefficient (HI), low performers and efficient (LE), and low performers and inefficient (LI). With such categories, effective benchmarks from the HE cluster can be identified for improving the operations of suppliers in the HI, LE, and LI clusters. Another issue related to the assessment of multiple sub-systems is to incorporate environmental criteria into supplier selection process in green supply chain management due to increasing consumer awareness and

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concern over environmental pollution. Different locations involve different environmental criteria, and therefore a multi-system evaluation becomes necessary. In reality there is a need to compare suppliers where some candidates may have different environment and work in different sub-systems, which the others cannot adopt. Hence, the classical way to perform comparisons within one system is obviously not fair in the above. A concrete example is that managers have to understand and analyze the political, legal, economic, socio-cultural and technological features when they try to conduct business in different countries. Traditional methods may no longer applicable to real-world cases.

The above three points have an obvious effect on the international supplier selection due to the complexity and uncertainty by lack of information associated with related countries' business environment in a global market (Qu & Brocklehurst, 2003). In fact, international supplier selection has become an active area in supply chain management since many companies have begun to realize the opportunities in terms of lower production and labor costs that other countries can offer (Bowman, Farleyn, & Schmittlein, 2000; Buskens, Batenburg, & Weesie, 2003; Kaynak, 1989; Mummaleneni, Dubas, & Chao, 1996; Murray, Kotabe, & Zhou, 2005). The choosing of international suppliers may involve more intangible criteria and require more time to gather information and identify uncertainty and risk in order to effectively evaluate potential suppliers.

Various methods have been developed to deal with these problems. The readers are suggested to read the review report by Sonmez M. (2006) and the references therein. However, none of these approaches address all of the three points mentioned above.

In this paper, a method is developed to measure international supplier performance by taking into account risk and uncertainty associated with supplier performance on multiple measures in multiple categorical suppliers. This method is an extension to the classical stochastic DEA model and also the bilateral systematic DEA model in Cooper, Seiford, and Tone (2000). As an alternative to various multi-factor productivity analysis techniques, our proposed model deals with two major drawbacks of classical DEA: (i) failure to model the stochastic error in the estimated frontier and (ii) extra requirement of a consistent infrastructure and operating environment in which the entities, appropriately called Decision Making Units (DMUs), operate.

Given the paper's emphasis in this area, the contribution of our research is twofold. First, we propose an efficiency analysis approach for entities from different systems to address the risk and uncertainty imbedded in different systems of interests. This is a new methodological extension to DEA research. Second, we apply the proposed model to evaluate the performance of international suppliers from different countries. To our knowledge, it is the first one to attempt this by modeling supplier performance from different sub-system with stochastic factors and uncertainty using stochastic DEA.

We begin in the following section with a literature review. Section 3 provides the proposed model for muti-system performance evaluation and international vendor selection in this paper. Section 4 gives the numerical illustration. Finally, our conclusions and further discussions are presented in Section 5.

2. Literature review

Substantial research literature has been developed over the decades on the subject of using decision tools for supplier selection and evaluation in supply chain management. This section simply reviews the methods, with the focus on using DEA to deal with supplier performance evaluation.

Dickson (1966) appears to be the pioneer to deal with supplier assessment problem from the multiple criteria point of view. Based on a survey of 170 purchasing managers, Dickson (1966) points out that cost, quality, and delivery performance are the three most important criteria in vendor evaluation. Willis, Huston, and Pohlkamp (1993) classified supplier performance evaluation models into categorical, weighted points, and cost ratio approaches. Pearson and Ellram (1995) and Wilson (1994) argued that supplier selection and evaluation studies in the literature could be categorised as (i) prescriptive (suggesting models that should be used), (ii) descriptive (emphasising models that are in use) and (iii) research that examines the supplier selection criteria. A vast number of papers have reported a wide range of uses of mathematical programming methods such as linear programming Ghodyspour and O'Brien (1998), Ghodyspour and O'Brien (2001), integer goal (Feng, Wang, & Wang, 2001;Gupta & Krishnan, 1999), goal programming (Karpak, Kasuganti, & Kumcu, 1999; Karpak, Kumcu, & Kasuganti, 1999), total cost based approach (Degraeve, Labro, & Roodhooft, 2000; Degraeve, Labro, & Roodhooft, 2004, 1998; Degraeve & Roodhooft, 1999a, 1999b; Degraeve, Roodhooft, & van Doveren, 2005) and data envelopment analysis (Weber, 1996; Weber, Current, & Desai, 1998; Weber, Current, & Desai, 2000). Multiple criteria decision making methods approaches involves Analytical Hierarchy Process (AHP) (Bhutta & Huq, 2002; Yahya & Kingsman, 1999), Multiple Attribute Utility Theory (MAUT) (Min, 1994), Outranking methods (Dulmin & Mininno, 2003). Other approaches include computer software supported systems such as neural networks (Choy, Lee, & Lo, 2004) and case based reasoning (Choy, Lee, Lau, & Choy, 2005).

As alternatives to traditional supplier performance assessment tools, DEA has received more and more attention since it allows management to objectively identify best practices in complex operational environments and requires no prior assumption on the specification of the best practice frontier (Wu, 2006). As a non-parametric mathematical programming approach originally developed by Charnes, Cooper, and Rhodes (1978), DEA is a leading approach for the performance analysis in many areas such as financial industry in literature (Sherman and Gold (1985), Golany and Storbeck (1999), Soteriou and Zenios (1999), Athanassopoulos and Giokas (2000), etc.).

Weber (1996), Weber and Desai (1996) and Weber et al. (1998) employ DEA in supplier evaluation for an individual product and demonstrate the advantages of applying DEA to such a system. Kleinsorge, Schary, and Tanner (1992) demonstrates the applicability of DEA in a shipper-carrier setting, where Customer–Supplier Relationships are presented. Liu, Ding, and Lall (2000) argue that a supplier selection problem is inherently a multi-criterion decision problem, and thus DEA is proposed and demonstrated in evaluating the overall performances of suppliers in a manufacturing firm. Talluri and Narasimhan (2004) apply cross-efficiency DEA into a problem of strategic sourcing. This model helps manage the supply base in an effective manner by identifying and selecting suppliers for strategic long-term partnerships. The above and other DEA related literatures are summarized in Table 1.

The majority of these vast literatures ignore the stochastic considerations and uncertainty, which are a significant importance as an issue in the supplier evaluation process. Moreover, the consideration of assessing suppliers where some candidates may have different environment and work in different sub-system is very limited in the existing literatures. No rigorous model has been developed in the cross-country supplier evaluation in consideration of the political, legal, economic, socio-cultural and technological features as well as how to conduct business in different countries. Therefore it is obviously to quantify these key issues, as to be done in this paper.