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Performance measurement with multiple interrelated variables and threshold target levels: Evidence from retail firms in the US

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ABSTRACT

In this study, we developed a DEA–based performance measurement methodology that is consistent with performance assessment frameworks such as the Balanced Scorecard. The methodology developed in this paper takes into account the direct or inverse relationships that may exist among the dimensions of performance to construct appropriate production frontiers. The production frontiers we obtained are deemed appropriate as they consist solely of firms with desirable levels for all dimensions of performance. These levels should be at least equal to the critical values set by decision makers. The properties and advantages of our methodology against competing methodologies are presented through an application to a real-world case study from retail firms operating in the US. A comparative analysis between the new methodology and existing methodologies explains the failure of the existing approaches to define appropriate production frontiers when directly or inversely related dimensions of performance are present and to express the interrelationships between the dimensions of performance.

1. Introduction

The performance of modern organizations that operate in competitive marketplaces is based on multiple interrelated dimensions, which are both endogenous (controllable by the organizations) and exogenous (either non-controllable or partially controllable by the organizations). An important study in the area of performance management is the Balanced Scorecard (BSC) (Kaplan & Norton, 1992). The BSC goes beyond the traditional financial measures for assessing the performance of organizations as it also incorporates customers, internal processes, and learning and growth perspectives (Kaplan & Norton, 1996).

The fundamental drawback of the BSC is the ambiguity of putting the theory into practice by modeling the conceptual framework so as to yield specific and measurable results (Amado, Santos, & Marques, 2012). In addition, the link among the dimensions of performance is vague, and the impact on the performance of trade-offs that may exist among these dimensions is not explicit (Otley, 1998).

Several studies, most of which are performed within the area of Operational Research, have been published providing scientific underpinning to performance assessment frameworks. Many of these studies use Data Envelopment Analysis (DEA) for evaluating performance. DEA is a nonparametric methodology for assessing the production process of operational units. DEA provides a robust quantitative framework that enables the identification of the strengths and weaknesses of each unit under evaluation and yields measurable results that lead to the optimization of each unit's performance. Since the publication of the seminal paper by Charnes, Cooper, and Rhodes (1978), a significant number of extensions of DEA have been developed (Emrouznejad, Parker, & Tavares, 2008). A selected list of DEA-based studies related to performance assessment in a multidimensional setting is provided in Table 1.

The studies presented in Table 1 either do not deal with the mixed relationships between the dimensions of performance or omit a discussion of whether the targets decision makers set for a number of dimensions of performance are satisfied. As a result, the benchmarking either does not express reality or is not flawless. Drawing on the results presented in the studies listed in Table 1, it is questionable if the units located in the frontier are appropriate benchmarks for the remaining units of the sample as it is unknown whether these units are qualified in all dimensions of performance incorporated in the evaluation.

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Table 1
DEA-based performance measurement studies.

Study	Objectives	Applied method(s)	Outline of the methodology & comments
Lim and Zhu (2013)	Performance measurement when targeted factors are incorporated in the analysis.	DEA	Modification of the radial, slacks-based, and Nerlove-Luenberger measures to treat unequally deviations of the factors from the targets selected by decision makers. It is not discussed whether the target values are achieved by the factors of all units of the sample. In Section 3.2 of this study, we present that factors, obtained from Lim and Zhu (2013)'s method, for both benchmark and non-benchmark units deviate from the target. In the business world, any score that falls below a target level is regarded as a failure for the firm. Our methodology ensures that factors of all units are assigned scores at least equal to target values.
Amado et al. (2012)	Identification of the areas within the four perspectives of performance that need improvement.	BSC, DEA	Application of network DEA models to evaluate the four perspectives of performance according to the BSC. The relationships (i.e. direct and inverse) between the perspectives of performance are captured by network DEA. This study does not incorporate target or threshold values that the dimensions of performance need to meet.
Paradi, Rouatt, and Zhu (2011)	Performance assessment and identification of firms' inefficiency when multiple dimensions are present.	DEA	A two-stage DEA-based methodology is developed to evaluate firms' performance. In the first stage, conventional DEA is applied to measure units' performance for every single dimension (i.e. production, profitability and intermediation). In the second stage, a slacks-based measure is applied to develop a composite performance index for each unit. This study does not elaborate on either the underlying relationships between the dimensions of performance or the introduction of targets for these variables.
Asosheh, Nalchigar, and Jamporazmey (2010)	Performance measurement of IT projects using DEA both with precise and imprecise data.	BSC, DEA	A modified DEA model is developed to deal with various categories of precise and imprecise data, such as cardinal, ordinal, bounded and ratio-bounded data. The selection of the variables is based on the BSC framework. This work focuses on the measurement of performance of IT projects. However, it does not deal with the relationships between the dimensions of performance and target or threshold values for these variables.
García-Valderrama et al. (2009)	Development of a framework for the analysis of the relationships between the perspectives of performance.	BSC, DEA	DEA is applied five times to identify the relationships between the perspectives of performance in pairs: (a) financial perspective-innovation; (b) innovation- learning and growth; (c) learning and growth-internal processes; (d) internal processes - customers; and (e) customers–financial perspective. The strength and type of the relationships between the perspectives of performance defined by this study are based on a sample of 90 companies. The scope of this study is not the measurement of the performance of firms, but the application of DEA programs to define the underlying relationship between the perspectives of performance.
Chen, Chen, and Peng (2008)	Comparative analysis between conventional DEA models and BSC-DEA models for measuring the performance of a bank.	BSC, DEA	Application of conventional DEA programs (i.e. constant returns to scale DEA and variable returns to scale DEA) to measure the performance of a bank. Six scenarios are developed incorporating diverse variables. Four out of six scenarios use variables that express the perspectives of performance according to the BSC framework. The scope of this study is to present the sensitivity of the performance measurements to the selection of variables. This work neither considers the relationships between the dimensions of performance nor introduces any target or threshold value to these dimensions.
Eilat, Golany, and Shtub (2008)	Evaluation of Research & Development (R&D) projects using multiple criteria.	BSC, DEA	A modified DEA program is applied to evaluate the performance of R&D projects, which provides the option for decision makers to set priorities and bounds to the perspectives of performance. The projects with the lowest performance are excluded from the analysis in order to facilitate the identification of the best-performing projects. The methodology presented in this paper measures the performance of units using multiple dimensions with mixed relationships. However, it does not endure that the benchmark units (i.e. R&D projects) are assigned desirable scores for every dimension of performance. Similarly, the originally disqualified units are not guaranteed that will become qualified in every dimension of performance when they are projected to the frontier.
Eilat, Golany, and Shtub (2006)	Evaluation of Research & Development (R&D) projects using multiple criteria.	BSC, DEA	A seven-step DEA-based methodology is applied to evaluate alternative portfolios when multiple objectives and possible interactions among the projects are present. The methodology deals with uncertain and subjective data (i.e. inputs and outputs). It does not incorporate non-controllable variables and target or threshold values for these variables.
Sherman and Zhu (2006)	Performance measurement that incorporates quality metrics in addition to operational variables.	BSC, DEA	DEA and quality metrics are jointly used to measure performance. The units that are efficient but are assigned quality scores lower than a critical value are excluded from the evaluation process as these are not regarded as appropriate benchmarks for the remaining units. This missing information caused by the exclusion of the partially disqualified benchmark units distorts the results of the performance evaluation. This approach could be appropriate for only significantly large samples, which are not common in most real-world cases.
Banker et al. (2004)	Evaluation of trade-offs between performance measures.	DEA	Modified DEA models, which do not include constraints for inputs, are applied in conjunction with statistical analysis to define whether performance measures associated with the BSC are inversely or directly related. This study is regarded as supportive of performance measurement methodologies as it facilitates the identification of the type of the relationship between the dimensions of performance.

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