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Interfaces with Other Disciplines

Pro-efficiency: Data speak more than technical efficiency

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ABSTRACT

In this study, we demonstrate a new method of addressing efficiency in situations in which only the input and output data are available, while evaluating efficiency more accurately than is possible via the ordinary data envelopment analysis (DEA). Technical efficiency is important, but management always desires information regarding the profit aspects of performance. In practice, however, the precise price data are frequently unavailable. Is it possible to approximate profit efficiency in the absence of price information? We develop a simple and usable approach, a linear programming model, for the evaluation of profit efficiency. Our approach implies technical efficiency in DEA and gives rise to the upper bound of profit efficiency, referred to as pro-efficiency. We also report a successful application of our method to a securities company, in which a comparison of the actual profit data and the pro-efficiency measures of the company's branches demonstrates a significant correlation.

1. Introduction

Productivity (or efficiency) is a common measure of how well a country, industry, or business unit utilizes its resources to produce outputs. Research into efficiency valuations has generally employed two distinct approaches. The first of these is the parametric approach based on regression analysis, and the other is the nonparametric approach. In this study, we focus on the latter nonparametric approach. Data envelopment analysis (DEA), a nonparametric and linear programming approach, has been suggested as a possible application for the evaluation of efficiency of a host of distinct entities engaged in a variety of different activities in many different contexts (Cooper et al., 2006; Färe et al., 1985). DEA allows for the description of the efficiency of an entire organization or even a nation through a total factor measure of productivity, the ratio of all outputs to all inputs of interest, each of which will be composed of incommensurable units.

While the ordinary DEA has primarily measured technical efficiency, in which no price information is involved, there have been several attempts to measure profit efficiency in ways of extending the DEA and requiring price information (Banker and Maindiratta, 1988; Färe and Grosskopf, 2000, 2006; Tone, 2002; Portela and Thanassoulis, 2007). Although the algorithms are different, they all necessitate exact price data. For a review of profit efficiency, see Cooper et al. (2006, Chapter 8) and Portela and Thanassoulis (2007). Profit efficiency is important. In practice, however, the precise price data are frequently unavailable or difficult to estimate, for several reasons. Many companies are unwilling to disclose their unit costs, and prices are often subject to variation over very short periods, such that additional choices and assumptions concerning their pertinence are involved (Cooper et al., 2006, Chapter 8). Many of the key outputs and inputs in public entities, including schools and hospitals, have no prices or costs that can be readily ascertained (Cooper et al., 1996).

The assurance region approach of Thompson et al. (1990, 1995) and Charnes et al. (1990) allows for the use of partial or imprecise price information in the ordinary DEA framework, and generates a different concept of efficiency, referred to as assurance-region efficiency. Owing to the merit that obviates the need for exact price data, many extensions and applications of this approach have been made (Thanassoulis and Allen, 1998; Camanho and Dyson, 2005; Cooper et al., 2006, Chapter 6). However, it might be onerous to estimate sensible ranges of permissible prices (i.e., assurance regions), and difficult to verify the estimated assurance regions rigorously, owing to the dynamic nature of prices and the varying motives of buyers and sellers, among others.

In this article, we develop a new method for measuring the profit aspect of efficiency, "pro-efficiency" for short, under the condition of no prior price information. The pro-efficiency is the upper bound or the highest possible measure on profit efficiency. In other words, a firm cannot be profit-efficient unless it is pro-efficient. Therefore, we can identify the profit-efficient candidate without any price data. The economic underpinnings and interpretations of pro-efficiency are provided in detail. We also demonstrate an application of our method to the evaluation of branches of a securities company. We then find a considerable correlation between the actual profit data and the pro-efficiency measures of the branches. The correlation between the profit data and the technical efficiency measures is found to be insignificant.

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In fact, how to measure the profit aspect of efficiency in the absence of price data has never before been taken into account. In practice, the precise price data are frequently unavailable and management is always desirous of the profit aspects of performance. We therefore propose pro-efficiency to address the practical needs. The measurement model developed herein seeks to increase both inputs and outputs to improve pro-efficiency, and hence profit efficiency. We are not aware of any efficiency measurement model that increases input to improve efficiency. For a technically efficient firm, an increase in output while input stays the same is unrealistic, and profit efficiency cannot therefore be achieved unless inputs and outputs increase together. Note that a larger firm generally enjoys a greater profit margin in practice, on which the concept of economies of scale is based, on which our approach is based. The possible applications of our method are numerous.

This paper is organized as follows: The next section contains the key to the measurement of pro-efficiency without any price information. To implement this concept, we construct the pro-efficiency measurement model, which is followed by the model characterizations, a numerical example, and some discussions. Following that, we demonstrate an application and finally conclude the paper.

2. Key concept

We employ the profit concept of dominance as our starting point. Profit refers to the difference between the revenue received from outputs and the cost incurred by inputs. Throughout, the profit value is assumed to be positive, unless otherwise noted.

Consider two firms: Firm 1 generates 4 units of output using 2 units of input. Firm 2 produces 8 units using 4 units. The exact cost per unit of input and price per output may frequently be unavailable in practice, and thus may differ among different firms. However, the basic notion of economies of scale is that as a firm grows and its volume increases, the average cost per unit of output drops. This is partially attributable to lower operating and capital costs, as a piece of equipment with twice the capacity of another piece typically does not cost twice as much to purchase or operate. Firms also achieve efficiencies when they become sufficiently large to fully utilize dedicated resources for tasks such as material handling and administrative support personnel. From this perspective, it should be clear that Firm 2 is more profitable than Firm 1. In short order, Firm 2 dominates Firm 1 in terms of profit. Even if we use the same price-cost scheme for both firms, Firm 2 is twice as profitable as Firm 1.

This is the key to the measurement of *pro-efficiency*, under the condition of no prior price-cost information. In order to achieve pro-efficiency, Firm 1 must increase both its inputs and outputs to twice its current levels, in response to Firm 2. Particularly for a technically efficient firm, an increase in output while input stays the same is an unrealistic proposition, and pro-efficiency cannot therefore be achieved unless inputs and outputs increase together. A larger firm generally enjoys a greater profit margin in practice.

DEA does not consider increasing any input, and thus it adjudges both Firms 1 and 2 as efficient, as in the same (constant) return-to-scale case. A firm achieves DEA efficiency when it is not dominated by any other actual firms or virtual firms formed by the prescribed combination of two or more actual firms. We maintain the basic spirit of the DEA efficiency, but add to it the concept of profit dominance. This is because the business size is necessary, but by no means sufficient to achieve pro-efficiency, thus implying technical efficiency as in the DEA. In this fashion, we obtain pro-efficiency scores that are lower than those of the DEA, in addition to other useful diagnostic information, including peers and sources of inefficiency. Furthermore, the efficiency classification will tend to differ, in that we have a smaller number of efficient firms than does the DEA.

Remark 1. We have employed the concept of economies of scale as the key to the measurement of pro-efficiency, and showed an example in which the economies of scale differ from the returns-to-scale in DEA. This implies that a firm operating under the constant returns-to-scale may or may not enjoy the economies of scale. In this regard, it should be noted that Sahoo et al. (1999) and Tone and Sahoo (2003) have already discussed the history and concept of economies of scale in connection with the returns-to-scale. They describe that the term "economies of scale" is defined in the literature either in terms of physical output or cost of production. The physical output intends that a proportionate increase in all inputs used in the production process would result in a more proportionate increase in the output. The other in terms of cost of production means that the unit cost of production decreases as the level of output increases. Although the former might be related to the latter, we employ the latter concept (in terms of production cost). They also point out that the economies of scale differ conceptually from the returns-to-scale, and discuss a variety of scale aspects of performance. However, we do not pursue further the conceptual clarification and concrete distinction of scale efficiencies, because our main objective is to develop a method to measure the profit aspect of efficiency without any price-cost data.

Aside from the notion of economies of scale, there is an additional reason that a simultaneous increase in inputs and outputs must be achieved in order to attain efficiency. We see the firms in a start-up industry. Their business scales will generally be on the rise, and therefore so will their profit margins, until their market is mature. Benchmarking relatively large firms is more relevant in that industry context.

Remark 2. At some point, a firm becomes too large and diseconomies of scale become a problem. This might lead to a technical inefficiency owing to the excessive use of inputs and/or a big loss due to, for example, significant discounting of the product or output. No such problem arises in regard to technical inefficiency, because the firm cannot be pro-efficient unless it is also technically efficient. The problem arises when a loss occurs, as we are basically assuming positive profits. In this case, the size of the firm necessitates a reduction in both inputs and outputs. We elaborate on this point mathematically in the appendix of this paper.

3. Model building

Suppose that firms are evaluated on $n = g + h$ factors or criteria, where the first g criteria are outputs and the remaining h criteria are inputs. A firm can then be described by an n-dimensional vector $\mathbf{z} = (\mathbf{y}, -\mathbf{x})$ of consequences or data for every criterion, where $\mathbf{y} \in \Re^g$ and $\mathbf{x} \in \Re^h$. Similarly, let the price-cost vector be denoted by $\mathbf{w} = (\mathbf{p}, \mathbf{c})$, where $\mathbf{p}$ stands for the price vector corresponding to $\mathbf{y}$, and $\mathbf{c}$ the cost vector for $\mathbf{x}$. Then,

$$\mathbf{zw} = \mathbf{yp} - \mathbf{xc} \tag{1}$$

represents the firm's profits. Again, we assume that $\mathbf{zw} > 0$ for all firms of interest and every positive price-cost scenario. This assumption will be relaxed later in the appendix.

Let there be a finite set of firms, $Z = \{\mathbf{z}_i : i = 1, \ldots, m\}$. Consider the following ratio:

$$\gamma_o = \frac{\mathbf{z}^*\mathbf{w}_o}{\mathbf{z}_o\mathbf{w}_o}, \tag{2}$$

where $\mathbf{z}^* \in Z$ is the best firm in terms of profit at the given price-cost scenario, $\mathbf{w}_o$. The profit inefficiency $\gamma_o \geqslant 1$ of firm $\mathbf{z}_o$ is thus given by