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Decision Support

Decomposing technical inefficiency using the principle of least action

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ABSTRACT

In for-profit organizations, profit efficiency decomposition is considered important since estimates on profit drivers are of practical use to managers in their decision making. Profit efficiency is traditionally due to two sources – technical efficiency and allocative efficiency. The contribution of this paper is a novel decomposition of technical efficiency that could be more practical to use if the firm under evaluation really wants to achieve technical efficiency as soon as possible. For this purpose, we show how a new version of the Measure of Inefficiency Proportions (MIP), which seeks the minimization of the total technical effort by the assessed firm, is a lower bound of the value of technical inefficiency associated with the directional distance function. The targets provided by the new MIP could be beneficial for firms since it specifies how firms may become technically efficient simply by decreasing one input or increasing one output, suggesting that each firm should focus its effort on a specific dimension (input or output). This approach is operationalized in a data envelopment analysis framework and applied to a dataset of airlines.

1. Introduction

Profit inefficiency (i.e., overall inefficiency) is usually defined as the amount by which a firm's observed profit deviates from its maximum possible profit. In production economics literature, since Farrell (1957), profit (in)efficiency has usually been decomposed into two components, technical (in)efficiency and allocative (in)efficiency. While technical efficiency can be interpreted as 'to do things right', allocative efficiency can be seen as 'to do the right things' (Bogetoft, Färe, & Borge, 2006).

Most existing measures of technical efficiency often generate demanding targets that are not easily achievable by firms. Therefore, research needs to be directed at developing measures of technical efficiency capable of yielding achievable targets. In this paper, we propose a method of technical inefficiency decomposition in order to evaluate whether inefficient firms need to make an extra effort to reach the efficient frontier. To do that, we specifically show that a new measure linked to the application of the principle of least action (PLA[1]), which minimizes the total technical effort of the assessed firm and allows a lower bound of the value of technical inefficiency related to the directional distance function (DDF) to be determined.

Total technical effort reflects here a change in the inputs and outputs required by a firm to become technically efficient[2]; and the application of the PLA always yields the efficient targets associated with the least technical effort. The application of the PLA will allow us to decompose the DDF into two sub-components. While the first sub-component of the DDF will be related to a measure of technical inefficiency, satisfying the principle of least action, the second sub-component will allow us to identify whether the projection suggested by the DDF requires an extra effort to be made in order to reach the frontier. Indeed, the second component may be of interest for situations in which a central manager supervises the performance of a set of departments or divisions within an organization (e.g., branches of a bank) and has to incentivize the inefficient units into exerting effort in order to achieve efficiency in a subsequent

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[1] The PLA, a well-known law in physics, states that nature always finds the most efficient course of action. The historical origin of this concept can be traced back at least to Pierre Louis Maupertuis and Leonhard Euler in the XVIII century.

[2] We use the directional distance function for measuring technical inefficiency as a component of profit inefficiency. It is well known that the directional distance function neglects slacks (see Ray, 2004) and that it yields projections belonging to the weakly efficient frontier. For this reason, the notion of technical efficiency used in this paper coincides with that originally proposed by Debreu (1951) and Farrell (1957), in contrast to the Pareto-Koopmans definition of technical efficiency (see Cooper, Seiford, & Tone, 2000).

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period of time. For example, for two firms with the same or similar values of technical inefficiency yielded from the DDF, it seems fairer that the central manager promises more incentives to the firm with the highest second sub-component since this firm will have to make more effort to become technically efficient in the subsequent period.

In order to decompose the directional distance function, we introduce a new version of a well-known weighted additive (WA) measure of technical inefficiency,[3] i.e., the Measure of Inefficiency Proportions (MIP) by Cooper et al. (1999). In this paper, however, we define the MIP under the application of the principle of least action, and then show that this measure could be beneficial for firms, since the projection point generated by this tool specifies how firms could become technically efficient simply by decreasing one input or increasing one output. In other words, the new approach suggests how the firm should focus its effort on a specific input or output dimension in order to achieve technical efficiency. For empirical execution, this technical inefficiency decomposition is operationalized in data envelopment analysis (DEA).

In for-profit organizations, profit inefficiency measurement is important for firms in the world of changing prices since the resultant profit change has implications for their revenue growth and cost control exercises. A firm may decide to change its input and output quantities if this leads to economic gains. Obviously, the measurement of this type of inefficiency requires data not only on physical inputs and outputs, but also on their market prices. From a managerial perspective, analyzing the sources of such inefficiency is very much relevant so that necessary policy actions can be taken to improve profit in subsequent production periods.

To the best of our knowledge, the most famous decomposition of profit inefficiency is by Chambers, Chung, and Färe (1998). In their decomposition method, the technical inefficiency component is derived from the directional distance function (DDF) using duality theory.[4] Specifically, they show that the DDF is the lower bound of profit inefficiency, establishing a Mahler inequality. In this way, and following Farrell's tradition, the allocative inefficiency component could be retrieved as a residual. Note that although a number of alternative methods of profit inefficiency decomposition exist in the literature (see, e.g., Cooper et al., 1999; Portela & Thanassoulis, 2007; and Cooper, Pastor, Aparicio, & Borras, 2011a; among others), so far none of these have exploited the duality relationship between the DDF and the profit function.

In this contribution, we apply the principle of least action for the decomposition of technical inefficiency. According to this principle, the path a firm follows to achieve the efficient frontier should be the one that minimizes its total technical effort. In other words, the coordinates of the projected input-output vector of the assessed firm should be as similar as possible to its observed one. In this sense, determining the efficient projection using the principle of least action can provide key information as to how technical efficiency can be achieved in the easiest possible way.

Note that the concept of the principle of least action is very much related to the notions of 'closest projection' and 'least distances' in DEA literature. In particular, the problem of deriving the closest projection has been one of the relevant issues in recent DEA literature (see, e.g., Briec, 1998; Coelli, 1998; Gonzalez & Alvarez, 2001; Portela, Castro, & Thanassoulis, 2003; Aparicio, Ruiz, & Sirvent, 2007; Cook & Seiford, 2009; Ando, Kai, Maeda, & Sekitani, 2012[5]; and Aparicio & Pastor, 2013; among others). The general argument underlying these approaches is that by moving towards the frontier suggested by a particular approach, an inefficient firm could achieve technical efficiency with a minimum amount of effort.

Accordingly, decomposing the DDF into two new sub-components using the principle of least action is a way of relating the DDF to the models based on the closest projection in DEA literature. To the best of our knowledge, there is only one paper, by Jahanshahloo, Mehdiloozad, and Roshdi (2013), that has attempted to relate the DDF to the closest targets. In their paper, a new family of Hölder norms is defined, based on the directional distance function, with the aim of determining the closest projection. Consequently, we believe the new linkage between the DDF and the model based on the closest targets, as shown in the following section, could be viewed as an additional contribution to this study.

Note that the contribution of our study is more practical than theoretical in nature, showing how the new MIP is able to provide closer (achievable) targets in comparison to the targets yielded from other existing measures such as the directional distance function. Indeed, in order to demonstrate the ready applicability of our proposed approach in empirical works, we conduct an empirical analysis based on a real-life dataset of 28 international airlines from North America, Europe, and Asia/Oceania, one which was used earlier in Coelli, Grifell-Tatje, and Perelman (2002). In our application, we find that some airlines may reach the efficient frontier by simply changing one input or output by a reasonable amount, determined by the optimization model associated with the new MIP, instead of decreasing all inputs and increasing all outputs simultaneously through the directional distance function. From a managerial point of view, it can be considered more interesting to focus exclusively on increasing the number of passengers by 5.8% (using marketing techniques) instead of decreasing all inputs (laying off employees, conserving fuel, etc.) by 2.9% and increasing all outputs (passengers and freight) by 2.9%.

The remainder of the paper unfolds as follows: In Section 2, we briefly present the concept of the directional distance function along with its main characteristics. In Section 3, we first introduce a new weighted additive measure based on the principle of least action; second, we show that it is the lower bound of the technical effort associated with the directional distance function. Then, we show how to decompose the directional distance function into two sub-components followed by a numerical illustration; third, we discuss various properties of the new weighted additive measure followed by a detailed discussion on the steps involved in its implementation. We present an illustrative empirical application of airlines in Section 4. Finally, we conclude with some remarks in Section 5.

2. The directional distance function

The economic behavior of firms is usually modeled in three ways: (1) cost minimization, (2) revenue maximization and (3) profit maximization. The selection of a particular modeling approach depends precisely on the availability of data on market prices of inputs and outputs, and the underlying objective of firms. Given that input prices are available, and the underlying objective is cost minimization, by using the duality theory, Shephard's input distance function can be related to the cost function (Shephard, 1970). Using this relationship, cost efficiency, defined as the ratio

[3] For the related weighted additive measure of technical inefficiency, see, e.g., Cooper, Park, and Pastor (1999) and Cooper, Pastor, Borras, Aparicio, and Pastor (2011b), among others.

[4] The directional distance function allows completing duality theory in microeconomics. As Färe and Primont (2006, p. 243) showed, the different functional representations of technology can be displayed in a diamond-shaped figure in which the relationship between the directional distance function and the profit function involves the bottom and top of the diamond.

[5] In this paper, we work in the same framework as Briec (1998), where the shortest distance (the minimum effort) is measured with respect to the weakly efficient frontier. This point contrasts with the Hölder measures used by Ando et al. (2012), where the shortest distance is searched over the strongly efficient frontier, a subset of the weakly efficient frontier.