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A multistage method to measure efficiency and its application to Japanese banking industry

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Abstract

When measuring technical efficiency with existing data envelopment analysis (DEA) techniques, mean efficiency scores generally exhibit volatile patterns over time. This appears to be at odds with the general perception of learning-by-doing management, due to Arrow [The economic implications of learning by doing. Review of Economic Studies 1964; 154–73]. Further, this phenomenon is largely attributable to the fundamental assumption of deterministic data maintained in DEA models, and to the difficulty such models have in incorporating environmental influences. This paper proposes a three-stage method to measure DEA efficiency while controlling for the impacts of both statistical noise and environmental factors. Using panel data on Japanese banking over the period 1997–2001, we demonstrate that the proposed approach greatly mitigates these weaknesses of DEA models. We find a stable upward trend in mean measured efficiency, indicating that, on average, the bankers were learning over the sample period. Therefore, we conclude that this new method is a significant improvement relative to those DEA models currently used by researchers, corporate management, and industrial regulatory bodies to evaluate performance of their respective interests.

Keywords: Technical efficiency; DEA; Weighted slacks-based measures; Stochastic frontier analysis; Doubly heteroscedastic model; Environmental impacts; Credit risk management

1. Introduction

Since the original work of Charnes et al. [2], data envelopment analysis (DEA) has become well established and widely applied to management science. However, given the complex nature of efficiency, DEA is not yet able to measure it in a robust way. For instance, with the increasing availability of panel data, if measuring technical efficiency with current static DEA models, the mean efficiency scores generally exhibit volatile patterns over time. This appears to be at odds with the general perception of learning-by-doing, due to Arrow [1].

Such a puzzling situation can be traced to three key phenomena: First, existing static DEA models ignore the linkage of technologies over time. Second, DEA assumes away statistical noise in data, thus allowing for biased estimates in the presence of statistical noise. And, third, DEA has yet to successfully control for environmental impacts on measured efficiency.

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1.1. Theoretical motivations

An early effort to structure the time linkage of technologies involves the Malmquist productivity index [3] (also see [4,5]). However, it is as susceptible to the impacts of statistical noise and environmental factors as are static DEA models. In response to the deterministic nature of DEA, Cooper et al. [6] advanced chance-constrained DEA in an effort to incorporate random variations into the data (but with environmental influences unaccounted for).

There have also been various innovative efforts to account for environmental influences on DEA efficiency, ranging from the single-stage non-discretionary and categorical models in Banker and Morey [7], to the two-stage approach advanced in Timmer [8]. As they reviewed such early works, however, Fried et al. [9] pointed out that statistical noise in data was generally absent.

Fried et al. [9] thus proposed a three-stage method to tackle the statistical noise issue while incorporating environmental impacts on measured efficiency in a single framework. They argued that, instead of holding managerial incompetence completely accountable, the slacks, i.e., input overuses and/or output shortfalls, found in inefficient firms could be partly attributable to the impacts of environmental factors and statistical noise. They suggested using stochastic frontier analysis (SFA) to help decompose slacks into the three aforementioned effects.

In an empirical illustration, they used the BCC [10] input-oriented model to estimate input slacks in the first stage. In the second stage, they regressed input slacks onto a set of environmental dummies using the SFA model due to Aigner et al. [11] so as to decompose environmental effects and statistical noise from managerial inefficiency. Using the so-obtained estimates, they proceeded to adjust input data by pushing all firms to an artificial common place with maximum impacts of data noise and environmental factors. In the final stage, they ran the same BCC model with the adjusted input data, and the original output data, to measure efficiency scores. As such, they found significantly different measured efficiencies, which were thus claimed as improved estimates of managerial efficiency.

The idea is significant. However, there are two major concerns with their methodology. First, the BCC slacks are not unit invariant. Besides, they were divided into radial and non-radial slacks, giving rise to concern that some useful information could be lost. Further, the BCC model ignores the role of slacks in calibrating the efficiency score, thus allowing for upward bias in measured efficiency (see [12,13]).

Second, the conventional SFA estimates of individual inefficiency are extremely sensitive to the correction for heteroscedasticity in the composed error term (see [14,15]). While this problem was left unattended in Fried et al. [9], it is critical to correct since the success of the method depends on a robust decomposition of the error term.

The current study thus proposes a slacks-based multistage framework that is significantly different from Fried et al. [9] in three ways: First, on the DEA side, Weighted SBM, a new DEA model (see [13]) is used in place of the BCC model to obtain improved estimates of slacks with the property of unit-invariance. Further, the slacks of each cross section are pooled to take advantage of econometric techniques for panel data, such that systematic features are accounted for over the sample period. As such, an intertemporal linkage of technologies is constructed.

Second, on the SFA side, the proposed framework is the first to apply the doubly heteroscedastic SFA model [16] to secure estimates robust to heteroscedasticity in both the inefficiency and statistical noise terms. A new data adjustment method is also devised to filter out undesirable effects from the data.

Third, in light of the above, we hypothesize the following: Assuming that managerial efficiency is impacted by selected environmental factors and statistical noise, controlling for the latter two effects will allow efficiency to exhibit a pattern of learning-by-doing, as popularized by Arrow [1]. If the hypothesis is not rejected, it will lend support to our proposed method as a powerful framework for evaluating performance.

1.2. Empirical motivations

After formulating our methodological framework, we illustrate it through empirical analysis. In efficiency studies, the banking industry has long been a primary interest of research due to its socioeconomic significance and competitive structure. Berger and Humphrey [17] and Paradi et al. [18] carried out extensive surveys of the