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Association of DEA super-efficiency estimates with financial ratios: Investigating the case for Chinese banks

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ABSTRACT

The great majority of applications of the popular frontier technique data envelopment analysis (DEA) do not test for the association of efficiency estimates with key performance indicators used by industry observers. Nevertheless, identifying efficiency estimates' associations with commonly accepted financial measures of performance could guide benchmarking activities, pricing decisions, and regulatory monitoring. Thus, the current paper investigates to what extent bank DEA super-efficiency estimates are associated with key financial ratios. A low correlation may present an opportunity to address inefficiencies that were not obvious in financial ratio analysis, thus enabling an update of inferences drawn from ratios. Regressing ratios on efficiency estimates may also help predict financial ratios. Where an input–output specification is comprised of key financial ratios, DEA can also be used to objectively identify benchmarks for ratio analysis based on actual observed data collected from peers. Nine super-efficiency DEA formulations across two profitability models are systematically tested. The slacks-based measure of DEA with a parsimonious profitability efficiency model emerges as the most significant combination explaining the variation in the two industry ratios, *post-tax profit/average total assets* and *return on average equity*.

1. Introduction

According to Ahmad et al. [1, p. 8], "The most commonly used indicators of bank performance or efficiency are the accounting ratios and efficiency scores obtained from various frontier efficiency approaches". Some of the earliest applications of data envelopment analysis (DEA), arguably the most widely used frontier efficiency technique first popularized by Charnes et al. [2], are in the banking sector (e.g., see [3–5]). According to the Web of Science database,[1] there are more than one-hundred and seventy articles that combine DEA and banking. As a result, DEA is a well-established relative efficiency analysis technique in banking. Yet, the great majority of applications of DEA in banking literature do not test for the association of computed efficiency estimates with key performance indicators widely used by industry observers. The current paper investigates to what extent estimates from bank efficiency models, that is, from a selection of input–output specifications based on recent literature are associated with key performance indicators such as financial ratios when tested through various DEA formulations. While efficiency analyses can be used together with key performance indicators in a complementary manner [6], to the best of the author's knowledge, no one has *systematically* tested the association between efficiency and key financial ratios.[2]

Insights gained from the current study can bridge efficiency and financial ratio analyses of bank performance, where various industry observers including regulators are more familiar with ratios, thus better informing decision-makers and future researchers alike. For example, a low correlation may present an opportunity to address production inefficiencies that were not obvious in financial ratio analysis, thus enabling an update of inferences drawn from ratios. Significant regression coefficients may also help predict financial ratios through efficiency estimates. Equally important, where an input–output specification in DEA is based on key financial ratios, such an analysis can be used to objectively identify benchmarks for ratios based on actual observed data collected from peers. Benchmarks thus identified can contribute to within-industry ratio analysis.

The empirical analysis in the current study focuses on China, where the Chinese banking sector is a newcomer to the field of DEA publications. Notwithstanding Chinese journals, there are only a handful of DEA studies based on Chinese banks published in

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[1] http://thomsonreuters.com/products_services/science/science_products/scholarly_research_analysis/research_discovery/web_of_science

[2] Elyasiani et al. [22] report a limited study using only one input–output specification and price data.

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international journals (see [7–11]). Furthermore, as a result of the ongoing deregulation which gained momentum since China joined the World Trade Organization in 2001, Chinese banks are currently offering a wider range of products and services.[3] There is also a substantial effort by foreign banks locally incorporating, as well as major domestic banks listing on stock exchanges. As a result, the ongoing liberalization of the Chinese banking sector is attracting the interest of researchers in what may well be recorded in history as the main economy to have led the world out of the recent global financial crisis (GFC). According to Laurenceson and Qin [10, p. 59], "The need for China's banks to improve their efficiency is mounting now that they are operating in an increasingly competitive and liberalized banking environment."

Therefore, this is a particularly appropriate point in time to pause and critically reflect on existing multivariate relative efficiency modeling that uses the popular frontier technique of DEA. As Chinese banks come under increasing scrutiny by the international banking and investment community, as well as their domestic capital markets, identifying efficiency estimates' associations with commonly accepted financial measures of performance could guide benchmarking activities, pricing decisions and regulatory monitoring. Findings of the current study indicate mostly low correlations, suggesting an inadequacy in ratios' ability to represent multivariate production inefficiencies. Nevertheless, the ratios of *post-tax profits to average total assets* and *return on average equity* are significantly associated with efficiency estimates, where the former ratio has the stronger relationship. Findings also indicate poor credit quality with Chinese banks. The non-radial DEA formulation that has gained popularity in recent times, namely, super-efficiency slacks-based measure, dominates all other formulations in terms of generating estimates that are correlated with ratios. The paper also illustrates how DEA can be used to address the long-recognized problem of objectively selecting financial ratio benchmarks.

The remainder of the paper is organized as follows. Section 2 begins with an introduction to DEA, followed by an exposition of the conceptual framework built around the paper's motivation and anticipated associations between ratios and relative profit efficiency. Methodology is detailed in Section 3 with explanations of input–output specifications and data used. Section 4 discusses the findings from various empirical tests, while Section 5 offers some concluding remarks.

2. Conceptual framework

2.1. Data envelopment analysis (DEA)

DEA is an efficient frontier technique that computes a comparative ratio of weighted outputs to weighted inputs for each decision-making unit (DMU) using linear programming. The linear program scales the relative efficiency estimate between 0 and 1, thus enabling easy comparison, where 1 represents an efficient operation relative to others in the sample, and a DMU with a score less than 1 is defined as inefficient. At the heart of this concept lies the condition of Pareto optimality for efficient production. Pareto optimality states that a DMU is not efficient if it is possible to raise an output without raising any of the inputs and without lowering any other output; similarly, a DMU is not efficient if it is possible to lower an input without decreasing any of the outputs and without increasing any other input [12].

In linear programs without weight restrictions, a DMU has complete freedom to select weights that are most favorable for its assessment, thus maximizing its efficiency score. Under input-orientation, the objective is to estimate how much the inputs can fall while maintaining existing levels of outputs. Alternatively, under output-orientation, the objective is to expand outputs for given levels of inputs. Basic principles of DEA formulation dictate that for any input, the reference unit must consume proportionately no more of the resource than does the unit under consideration. Similarly, for any output, the reference unit must produce no less than the unit evaluated.

DEA's ability to capture the interaction among multiple inputs and multiple outputs in a scalar value, that is, in a single number, is its distinct advantage over traditional ratio analysis. DEA also has the advantage of not assuming a particular distribution for data. That is, DEA does not pre-specify a production technology. The importance of the latter is that a DMU's efficiency is based on actual observed performance within the sample. The key limitation of DEA is the assumption of data being free of measurement error. Thus, DEA is more sensitive to the presence of measurement error than parametric techniques. The reader not familiar with DEA can refer to Cooper et al. [13] for a more in-depth exposition. Avkiran and Rowlands [14] provide a comparison of DEA against its main parametric counterpart, stochastic frontier analysis, and show how to address measurement error if its presence is suspected.

Traditional DEA suffers from tied ranks because the efficient DMUs in a sample share the same score of 1. Where the sample size is small, discrimination can become problematic. Andersen and Peterson [15] solved this problem under the name of super-efficiency, where their approach removes censoring of scores above 1. That is, the researcher is able to distinguish among the efficient units in the sample and rank them. While in some cases it is possible to encounter identical super-efficiency scores, a separate stream of DEA literature has addressed this under the heading of *infeasibility* (see [16], and the relevant literature therein). Super-efficiency also helps in generating more meaningful correlations and measures of central tendency in an empirical application with multiple efficient units where such units would otherwise share the same score of 1. The current study uses a set of super-efficiency DEA formulations as part of systematically testing for associations between efficiency estimates and financial ratios.

All else the same, the author's preferred DEA formulation among widely available and accepted formulations is variable returns-to-scale, non-oriented, non-radial super-efficiency slacks-based measure (see SBM by Tone [17,18]). In literature reporting DEA applications, SBM has slowly become the preferred non-radial model in the first decade of the twenty-first century. Assuming variable-returns-to-scale acknowledges the often different scale of operations found in business units and permits translation invariance. The choice of non-orientation and non-radial modeling further enhances the relevance of frontier efficiency studies to the world of business. For example, non-orientation ensures the analysis simultaneously captures slacks on the cost and revenue sides of the profitability equation as the linear program minimizes inputs (such as expenses), and maximizes outputs (such as revenues). Similarly, use of non-radial modeling acknowledges the generally non-proportional nature of slacks in organizations where production relationships call for different proportions of reduction in inputs and rise in outputs.

2.2. To associate or not to associate?

DEA studies that neglect an exploration of associations between efficiency and financial ratios do so for a number of

[3] Ironically, the historically slow adoption in China of sophisticated investment securities, such as collateralized debt obligations, insulated Chinese banks from the full impact of the recent global financial crisis.