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Modeling leakage in two-stage DEA models: An application to US mutual fund families ☆

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ABSTRACT

This paper proposes a two-stage DEA model with leakage variables at stage 1 for assessing relative performance of decision making units. We refer to the output variables at the first stage that leave the two-stage system without entering the second stage as leakage variables. In addition to the leakage variables, the proposed model can handle multiple input and output variables at both stages and multiple intermediate variables. The concept of leakage variable adds a new dimension to two-stage DEA modeling. The applicability of the proposed model is demonstrated by assessing the performance of a sample of the US mutual fund families over the period 1999–2008 with operational management and portfolio management processes as the two stages of mutual fund operation. We consider total cash flow to investors (TCF) as the leakage variable. The results reveal that, over the sample period, modeling TCF increases discriminatory power of overall performance considerably. Moreover, we find consistent evidence over the sample period that small fund families are more likely to perform better than large fund families. This is not observed when TCF is not modeled as a leakage variable.

1. Introduction

Measurement of mutual fund performance has attracted intense scrutiny over the past 50 years and the body of literature on mutual fund performance appraisal is rich and vast. The literature documents that underperformance of mutual funds relative to their passive benchmarks approximately equals management fees [1–3] highlighting the value of good mutual fund performance. The ability of fund managers as a collective to balance the portfolio of funds within a fund family and generate high risk-adjusted returns plays a vital role in achieving superior fund performance. In order to reward fund managers for attaining superior performance relative to their counterparts, performance should be assessed through credible methods. Hence, the search for credible methods that enable both fund managers and investors to distinguish superior performance continues [4,5].

Traditional performance measures such as the Sharpe [6] and Treynor [7] ratios are developed under the risk-adjusted return framework. The risk-adjusted return based performance appraisal may be interpreted under the production frontier concept. In that case risk may be considered as the input and return may be considered as the output with performance appraised with respect to a production frontier. Under the production frontier concept, the aim of fund managers is to optimize controllable efforts (inputs) in order to achieve a desired level of return (output) as defined by a production frontier [8]. In other words, fund managers would prefer their funds to lie on the outer extremities of the production frontier to show themselves as efficient performers. However, in reality, they may fall short of achieving efficient performance due to reasons within and sometimes beyond their control. This notion of shortfall that aligns with the concept of production inefficiency led to the development of relative performance measures.

Kapur and Timmermann [9] argue that evaluating fund managers with traditional performance measures during periods of prosperity is inappropriate and suggest relative performance measures based on frontier analysis in the spirit of Koopmans [10] and Farrell [11] as a better alternative. When assessing the

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performance of a sample of mutual funds, Murthi et al. [12] highlight that cost is an important consideration of investors and therefore cost should also be incorporated in performance appraisal. However, when cost is taken together with risk and return, performance measurement becomes a multidimensional problem.

A technique that allows multiple metrics (or multiple inputs and multiple outputs) in performance appraisal is data envelopment analysis (DEA). DEA is a linear programming based approach for performance evaluation and benchmarking. While DEA has a strong link with the production theory in estimating production frontiers (refer [13]), Cook et al. in 2014 point out that DEA is also used for benchmarking in operations management. When using DEA for performance appraisal it is not necessary to specify a production frontier. Not having to nominate a benchmark in performance appraisal is considered as an advantage of the DEA methodology.

A number of studies [14,15] link mutual fund performance to its ability to attract new money. However, an important factor and yet often overlooked when assessing mutual fund performance is total cash flow to investors (TCF). Examples of cash flows to mutual fund investors include payments such as pension and annuity. The main focus of this paper is to investigate the effect of this new factor TCF on mutual fund performance when the mutual fund management process is conceptualized as a two-stage process. We interpret TCF as reward to investors and treat it as a desirable output variable at the first stage of the two-stage process. We find that TCF of mutual funds vary considerably across mutual fund families and therefore we argue that TCF may have a significant impact on the relative performance of mutual fund families. Because the cash flown to investors (TCF) is not available to be fed into the second stage of the two-stage process, we refer to it as a leakage from the mutual fund management perspective. Leakage variables add a new dimension to two-stage DEA modeling of mutual fund management. We refer to our new modeling framework as a two stage DEA model with leakage.

This paper contributes to the existing literature in several ways. First, we generalize the two-stage DEA model developed in Premachandra et al. [16] by including leakage variables. Second, the greatest share of investment company assets is held by households. As households have come to rely more on investment funds such as mutual funds over the past decade, their demand for directly held equities has fallen. Hence, given this significant reliance by individual investors on the performance of such investment products, it is important to analyze the performance of mutual funds in a comprehensive way and provide consumer-friendly performance measures on different aspects of mutual fund management. We devise an analytical procedure to decompose overall efficiency of the general case depicted in Fig. 1 into stage 1 (operational management) efficiency and stage 2 (portfolio management) efficiency components. Third, we use the technique in Chen et al. [17] and Cook et al. [18] to adopt an additive decomposition approach. Additive models however use user specified weights and therefore choice of weights may influence efficiency decomposition. We investigate this issue empirically. In our empirical investigation, we use the proposed model to assess the relative performance of a comprehensive sample of 66 large US mutual fund families over the period 1999–2008.

2. Two-stage networks with stage-based independent inputs and outputs

Early applications of two-stage DEA models treat the underlying process as comprising of two independent sub-processes or stages with no independent outputs at stage 1 and no independent inputs at stage 2. For example, Seiford and Zhu [19] adopt this approach to appraise bank performance and Sexton and Lewis [20] to appraise Major League Baseball team performance. Kao and Hwang [21] assess Taiwanese non-life insurance company performance using a two-stage DEA model where the assumption of independence of the two sub-processes is relaxed. Huang et al. [22] assess tourist hotels, productive efficiency using a modified two-stage DEA model. They separate the operations associated with hotel management at the second stage into two sub-processes and evaluate the efficiency of the first stage and of the sub-process in a single implementation linear programming model.

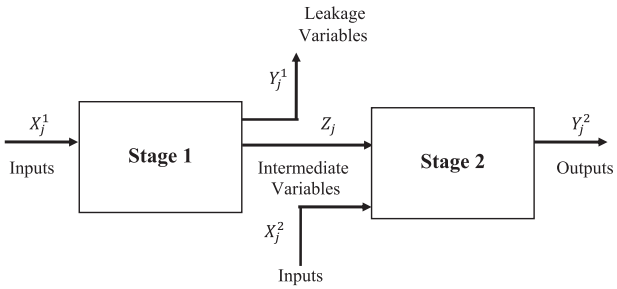

Fig. 1. General two-stage process with leakage.

Liang et al. [23] consider decision-making unit operation as a two-stage network structure and allow the second stage to have its own independent inputs in addition to intermediate measures. They adopt a cooperative structure between the two sub-processes and consider overall efficiency of the process as arithmetic average of the efficiency of the two sub-processes. Liang et al. [23] apply their DEA-based non-linear model to a supply chain management data set. Another application of two-stage network model with additional inputs to the second stage is available in Li et al. [24]. Kao and Hwang [21] derive a relationship between overall efficiency and the efficiencies of serially linked sub-processes. They define overall efficiency as a product of the efficiencies of the sub-processes. Kao and Hwang [21] derive a relationship between overall efficiency and the efficiencies of serially linked sub-processes- overall efficiency is the product of the efficiencies of the sub-processes. Cook et al. [18] develop general DEA models for variants of series and parallel multistage processes where each stage is allowed to have its own independent inputs and/or outputs. In their models, overall efficiency is captured through additive weighted average of individual stage efficiencies and thereby is able to decompose overall efficiency under the variable returns to scale and constant returns to scale assumptions. Kao [25] builds a relational network model to decompose overall efficiency of different network systems. Tone and Tsutsui [26] introduce a network DEA model that assesses performance using the slacks-based measure (SBM) approach. SBM is a non-radial approach. Another extension of application of two-stage DEA models is performance appraisal across multiple periods. Dynamic DEA models evaluate performance from a long-term perspective. In dynamic DEA, multiple periods are modeled through carry-over variables. Performance in network structures over multiple periods may be assessed using the SBM approach, refer Tone and Tsutsui [27]. When measuring performance thorough the radial approach as for example in Cook et al. [18], it assumed that inputs and output may undergo proportional change.

Fukuyama and Weber [28] develop a two-stage network DEA model when undesirable factors are present. Wang et al. [29] consider a case with undesirable output in the second stage of a two-stage process. A discussion on how to deal with undesirable factors in two-stage DEA models is available in Liu et al. [30]. For recent developments on modeling network DMUs using DEA refer to Cook and Zhu [31]. In a recent study, Aviles-Sacoto et al. [32]