Available online at www.sciencedirect.com
ScienceDirect
Int. J. Production Economics 112 (2008) 367–379
international journal of production economics
www.elsevier.com/locate/ijpe

DEA Malmquist productivity measure: Taiwanese semiconductor companies

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Received 16 November 2005; accepted 20 March 2007

Abstract

In this research we employ data envelopment analysis (DEA) to measure the Malmquist productivity of semiconductor packaging and testing firms in Taiwan from 2000 to 2003. Malmquist productivity has three components: the measurement of technical change, the measurement of the frontier forward shift, and the measurement of the frontier backward shift of a company over two consecutive periods. This approach not only reveals patterns of productivity change and presents a new interpretation along with the managerial implication of each Malmquist component, but also identifies the strategy shifts of individual companies based upon isoquant changes. Therefore, one can judge with greater accuracy whether or not such strategy shifts are favorable and promising. We use slacks-based measurement (SBM) and Super-SBM models to obtain more accurate measurements. Comparison is made between the results from SBM/Super-SBM and CCR models.

Keywords: Data envelopment analysis; Malmquist productivity; Super-SBM

1. Introduction

DEA is a multiple input–output efficient technique that measures the relative efficiency of decision-making units (*DMUs*) using a linear programming based model. The technique is non-parametric because it requires no assumption about the weights of the underlying production function. DEA was originally proposed by Charnes et al. (1978) and this model is commonly referred to as a CCR model. The DEA frontier *DMUs* are those with maximum output levels for given input levels or with minimum input levels for given output levels. DEA provides efficiency scores for individual units as their technical efficiency measure, with a score of one assigned to the frontier (efficient) units.

Färe et al. (1992, 1994a) developed the DEA-based Malmquist productivity index by CCR model. The DEA-based Malmquist productivity is a combined index that can be extended to measure the productivity change of *DMUs* over time. It has been applied in many ways, as described in Färe et al. (1994b), Grifell-Tatjé and Lovell (1996), Fulginiti and Perrin (1997), Löthgren and Tambour (1999), Herrero and Pascoe (2004), Wei (2006) and others. The two components embedded in Malmquist productivity, measuring the changes in technology frontier and technical efficiency, are also further examined in this research. By the technology frontier shift (*FS*), the development or decline of all *DMUs* is able to measure. Technical efficiency

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0925-5273/$ - see front matter
doi:10.1016/j.ijpe.2007.03.015

change (*TEC*) is used to measure the change in technical efficiency. It is also a measure of how much closer to the frontier the company (*DMU*) is when crossing the two consecutive times. We define *TEC* and Malmquist productivity as R_3 and R_4, respectively, in Section 4.1 for the performance measurement.

Chen and Ali (2004) applied the DEA Malmquist productivity measure to the computer industries by the CCR model to assess the four distance functions of Malmquist productivity. Moreover, they discovered more information about the two components that obscure in the Malmquist productivity index. We define them as R_1 and R_2 in Section 3 for the performance measurement in this research and account for the attributes. Their approach not only reveals patterns of productivity change and presents a new interpretation along with the managerial implication of each component, but also identifies the strategy shifts of individual *DMU*s in a particular time period. They determined whether such strategy shifts were favorable and improving.

However, the ratio efficiency θ_0^* by the CCR model is not able to take account of slacks. For instance, the optimal solution $\theta_0^* = 1$ might be with positive slacks. In the DEA Malmquist productivity, the DMU_0 is regarded as efficient but actually, it should be regarded as inefficient. Therefore, it is important to observe both the ratio efficiency and the slacks. Some attempts have been made to unify θ_0^* and slacks into a scalar measure.

Charnes et al. (1985) developed the additive model of DEA, which deals directly with input excess and output shortfalls. But this model has no scalar measure (ratio efficiency) per se. Thus, although this model can discriminate between efficient and inefficient *DMU*s by the existence of slacks, it has no means of gauging the depth of inefficiency, similar to θ_0^* in the CCR model.

Tone (2001) developed a slacks-based measure (SBM) of efficiency in DEA, which takes account of scalar measure and slacks. Further, Tone (2002) developed a SBM of super efficiency (Super-SBM) in DEA for discriminating between efficient *DMU*s. Super efficiency measures the degree of superiority that efficient DMU_0 possesses against other *DMU*s.

To extend the investigation on influence from slacks to Malmquist productivity index, Chen (2003) proposed a non-radial Malmquist productivity index, which is able to eliminate possible inefficiency represented by the non-zero slacks to measure the productivity change of three Chinese major industries. Instead, we employ the SBM and Super-SBM models in this research. In addition to *TEC* (R_3) and Malmquist productivity (R_4) which existed in the traditional Malmquist productivity measurement, we also investigate the two components—R_1 and R_2 proposed by Chen and Ali (2004) to interpret a more detailed management implication. The next section reviews how the DEA-based Malmquist productivity index works. We also present the Malmquist productivity approach.

2. DEA Malmquist productivity index

Färe et al. (1992) construct the DEA-based Malmquist productivity index as the geometric mean of the two Malmquist productivity indices of Caves et al. (1982): one measures the change in efficiency and the other measures the change in the frontier technology. The frontier technology, determined by the efficient frontier, is estimated using DEA for a set of *DMU*s.

There are n *DMU*s under comparison for their performance. Let x_{ij} and y_{rj} denote the value of the ith input $(i = 1,\ldots,m)$ and the rth output $(r = 1,\ldots,s)$ of DMU_j $(j = 1,\ldots,n)$, respectively. The slack variables for the ith input and the rth output are, respectively, represented by s_i^- and s_r^+, which indicate the *input excess* and *output shortfall*, respectively. The variable λ_j denotes the weight of DMU_j while assessing the performance θ_0 of the object DMU_0.

Instead of a radial-based model, we now use the SBM model and explain the reason for the substitution. A notation with '*' in superscript indicates it is the optimal solution. We must first know two proved theorems: (I) The optimal SBM ρ_0^* is not greater than the optimal CCR θ_0^*, and (II) A DMU (x_{i0},y_{r0}) is CCR-efficient, if only if DMU_0 is SBM-efficient. Moreover, because the CCR score is a radical measure and takes no account of slacks, the particular DMU_0 may have an efficiency score $\theta_0^* = 1$ although it has a shortfall $s_r^{+*} \geqslant 0$, but an inefficiency score $\rho_0^* \leqslant 1$ for SBM measure when the factor is taken into account. In this case, we can reduce the misleading result with the SBM measure. On the other hand, the SBM score $\rho_0^* = 1$ guarantees the particular *DMU* has the more precise efficiency score. Tone (2004) discusses the differences between the slack-based and radial-based approaches in depth.