Performance Review of Taiwanese IC Design Industry: DEA-based Malmquist Productivity Measure

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Abstract: - The total revenue of Taiwan's IC design industry is now the second in the world, only behind the United States. To keep pace with abroad leaders, continually innovating by the IC design companies to maintain and enhance their performance is the most import for obtaining the sustainable competitive advantage. This paper is concerned with a study on exploring the performance of Taiwan's IC design industry, including the managerial and productive technical efficiencies and their change over time. Data envelopment analysis (DEA)-based Malmquist method was employed to analyze the financial and non-financial data of 72 companies, from the financial panel listed in Taiwan Stock Exchange market, and examine the performance of these companies over the period from 2003 to 2005. Accordingly, IC design companies can recognize which function is important to their performance and which function can be further improved to achieve competitive advantage in the industry.

Key-Words: - Data envelopment analysis, Malmquist productivity, Efficiency, IC design industry

1 Introduction

The resource-based view has been offering an important perspective in explaining the variation of firm performance. Wernerfelt (1984), Dierickx and Cool (1989), and Prahalad and Hamel (1990) made their contributions to resource-based theory by building around the internal competencies of firms, and thus suggested that competitive advantage is rooted inside a firm, in assets that are valuable and inimitable. In this view, a firm's capabilities and management's abilities to apply these assets to gain superior firm performance determine their competitive advantage (Grant, 1996). As a result, scholars in this stream argued that firms should give more attentions to its resources than to its competitive environment.

After evolution for tens of years, Taiwan's semiconductor industry has established a mature and unique vertical disintegration system. Among the sub-industries of the whole semiconductor industry, the IC design industry is a kind of knowledge-intensive service business sector. IC design industry creates its innovative competencies and high added-value through continuous endeavor to develop intellectual property which is also named silicon intellectual property (SIP). From the perspective of the resource-based theory, intellectual capital assets offer a unique source of advantage that facilitates entrepreneurship by reducing the risk, and increasing the returns from investments, and also provide the ability to manage this scarce resource controlled by a company (Hayton, 2005).

As a result of market grown to maturity, short product life cycle, and price war in IC design industry today, a firm's efficiency has become a key factor of success for sustainable competitive advantage. Efficiency can be defined as a comparison between observed and optimal values of its output and input. In terms of an organization's behavioural goal, efficiency is measured by comparing observed and optimum costs, revenue, or whatever the organization is assumed to pursue, subject to the appropriate constraints on quantities and prices (Lovell, 1993).

The issue of efficiency may need to be addresses and measured for various reasons (Teague and Eilon, 1973). In terms of strategic reasons, efficiency measurement can compare the global performance of an organization with competitors or similar firms. In terms of tactical reasons, efficiency measurement enables the performance control of an organization. In terms of planning purposes, efficiency measurement can compare the relative benefits accruing from the use of different inputs or varying proportion of the same inputs. Despite of the importance of efficiency, however, there are relatively few studies in the IC design industry. Efficiency measures can provide IC design companies managers with benchmarking information and further insight on the improvement of resource's deployment and utilization and the efficiency of resources be deployed and utilized will determine the organization's performance.

This paper aims at evaluating the performance of Taiwan's IC design industry during the time periods of 2003-2004 and 2004-2005, according to DEA-based Malmquist productivity index. Instead of adopting the traditional, accounting based performance measurements of efficiency, this study reviews the performance of Taiwan's IC design industry from the resource-based view of management (Barney et al., 2001). This view holds the sustained competitive advantage can be obtained if "the firm effectively deploys these resources in its product-markets" (Fahy and Smithee, 1999). From this view, this study takes four financial/operational inputs into account, including (i) the fixed assets, (ii) the number of employees, (iii) selling and operational expense, and (iv) R&D expense. Furthermore, the annual revenue of each company over time is taken as the output.

2 Literature Review

2.1 Resource-based theory

A firm's performance is determined by the interaction of its context, both internal and external, and by the actions its managers pursue. The basic concept of competition employed in industrial organization economics is fundamentally unchanged since this model was initially developed by Mason (1939) and Bain (1968). In this model, returns to firms are determined by the structure of the industry within which a firm exists. The key attributes of an industry's structure have an impact on firm returns. Industries with large barriers to entry, with a small number of firms, with a large degree of product differentiation, or low demand elasticity are characterized by firms earning higher returns than firms in industries without these attributes (Barney, 2001).

Yet empirical investigation has failed to support the link between industry structure and profitability. Most studies show that differences in profitability within industry's companies are much more important than differences between industries. The finding that firms' competitive advantage rather than external environments is the primary source of firm's profit between firms focuses attention upon the sources of competitive advantage (Panrose, 1959; Grant, 1991). It turns out that resources perspective provides an important basis for addressing some key issues in the formulation of strategy (Wernerfelt, 1984). What a firm wants is to create a situation where its own resource position directly or indirectly makes it more difficult for others to catch up. Since Wernerfelt (1984) articulated this view to strategy, later contributions (Barney, 1986; Rumelt, 1982; Dierickx and Cool, 1989; Prahalad and Hamel, 1990; Conner, 1991; Amit and Schoemaker, 1993; Teece et al., 1997) agreed that firm-specific resources play the key role in influencing superior performance.

Barney (1991) classified firm resources into physical capital resources, human capital resources, and organizational capital resources. Chatterjee and Wernerfelt (1991) classified firm resources into physical resources, intangible assets, and financial resources. Amit and Schoemaker (1993) classified firm resources into knowhow that can be traded (e.g., patents and licenses), financial or physical assets (e.g., property, plant and equipment), human capital, etc. Markides and Williamson (1994) focused on the strategic assets and suggested that these types of assets may be divided into customer, channel, input, process, and market-knowledge assets.

Resources are converted into final products or services by using a wide range of bonding mechanisms such as technology, management information systems, incentive systems, trust between management and labor, and more. Later, knowledge-based view of the firm suggests that intellectual resources are key organizational assets that enable sustainable competitive advantage (Winter, 1987; Kogut and Zander, 1992; Grant, 1996). Those firms able to effectively manage those knowledge resources can expect to reap benefits such as improved customer service, reduced costs of production, better decision making, improved innovation performance, improved corporate agility, rapid development of new product lines, and efficient transfer of best practices.

Performance differences between firms are a result of their different knowledge bases and differing capabilities in developing and deploying knowledge. The management of knowledge can be considered the pre-eminent dynamic capability of the firm and the principal driver of all other competencies and capabilities(Lei, et al., 1996; Demsetz, 1991). Firms can be inefficient from a failure to allocate resources in the most efficient (i.e., allocate inefficiency) and from a failure to utilize their resources given their allocation (i.e., technical inefficiency) (Anderson et al., 2000).

2.2 Performance measures

Organizational performance is a complex and critically important multidimensional construct. In thinking about organizational performance, however, it is important to keep in mind what the concept 'performance' entails and what it means with respect to measurement. Recognizing that organizations are systems of productive assets (including individuals and tangible and intangible assets) that come together for, among other things, obtaining economic advantage, the relevant performance measures should then compare the value of the organization's output using the productive input assets with the value that the asset owners expect to receive (Barney, 1996).

Traditional single-value performance measures (such as financial indicators) are popular as they are easy to observe and to know. However, they have problems that make them incomplete and thus unreliable as an only basis for evaluation. These problems include the insensitivity of financial measures to intangible assets such as reputation and the fact that they do not address the fundamental value-creating activities upon which the firm relies to create value.

Productivity is defined as the ratio of outputs over inputs. The ratio yields a relative measurement of performance, applying to any factor of production. The ratio can be calculated for a single input and output or aggregating multiple inputs and outputs. Since it is a relative measurement, it is usually necessary to refer to external benchmarks to interpret the productivity ratio. The limitation is overcome by the efficiency concept. The competitiveness of a company derives from the performance of the company itself (Krugman, 1996). Competitiveness is reflected in the size of market share the enterprise secures. The performance of a company is measured either by productivity or efficiency.

Efficiency of an organization can be defined as relative productivity over time. It includes a benchmark in its definition, i.e., the production possibility frontier, and thus an external benchmark is not required. The efficiency of a company is a comparative measure of how well it actually processes inputs to achieve its outputs, as compared to its maximum potential for doing so, as represented by its production possibility frontier.

Frontiers have been estimated using many different methods in various empirical studies in the literature. The two principal methods that have been used are stochastic frontiers approach (SFA) and data envelopment analysis (DEA), involving econometric methods and mathematical programming, respectively. DEA assumes that there are no random fluctuations from the efficient frontier, i.e. all deviations are considered inefficiency. Due to no need to assume the functional form, the DEA is easy to apply but tends to over-estimate inefficiencies (Anderson et al., 1999).

The methodologies applied in this article addresses the issue of performance review for Taiwanese IC design industry. Using linear programming techniques, data envelopment analysis (DEA) (Charnes et al., 1978) provides a suitable way to measure the relative efficiency of a production unit (Farrel, 1957). DEA allows for the identification of appropriate benchmarks which are potentially important for the companies, and, above all, those companies which are performing poorly. Färe et al. (1992, 1994) develop a DEA-based Malmquist productivity index which measures the productivity change over time. The Malmquist productivity index was first suggested by Malmquist (1953) as a quantity index for use in the analysis of consumption of inputs. Färe et al. (1992) combined ideas on the measurement of efficiency from Farrell (1957) and the measurement of Caves et al. (1982) to construct a Malmquist productivity index directly from input and output data using DEA.

DEA-based Malmquist productivity index has been widely applied in a lot of empirical cases. For example, productivity development Swedish hospitals (Färe et al., 1994) and the Swedish eye-care service provision (Löthgren and Tambour, 1999), the deregulation on Spanish saving banks(Grifell-Tatjé and Lovell, 1996; Tortosa-Ausina, et al., 2008), changes in agricultural productivity in 18 developing countries(Fulginiti and Perrin, 1997), telecommunications productivities, technology catch-up and innovation in 74 countries (Madden and Savage, 1999), and productivities of 6 high-tech industries currently developed at Taiwan's Hsinchu Science Park (Chen, et al., 2006). Moreover, Shen and Hsieh (2006), Chiang et al. (2004), Hwang and Chang (2003), and Tsaur (2001) have adopted DEA to measure hotel efficiencies in Taiwan.

3 Methodology

This section briefly introduces the concept of DEA-based Malmquist productivity index, which was employed in this study to review the performance of Taiwan's IC design industry between 2003 and 2005.

The idea DEA-based Malmquist productivity index can be shown graphically by a simplified case (that is, one-input and one-output with constant returns to scale (CRS) technology.) As shown in Figure 1, Points D and E represent the input-output combinations of a production unit in period s and t respectively. In both cases, it is operating below the production possibility frontier. The production unit in period s (correspondingly, period t) produces output y^s (y^t), given input x^s (x^t). Then its technical efficiency in period s (t) is measured by the output distance y^s/y^a (y^t/y^c), where y^a (y^c) is the possible output if it has full technical efficiency in period s (t).

Productivity change can be measured by the part of output growth that is not contributed by input growth. In Figure 1, we can calculate a productivity index by $(y^t/y^s)/(y^b/y^a)$, where (y^t/y^s) is the output growth and (y^b/y^a) represents a movement along the production frontier in period s. This can be rewritten as $(y^t/y^b)/(y^s/y^a)$, where the numerator is a distance for output in period t (y^t) with reference to the technology of period s and the denumerator is the distance function representing technical efficiency in period s. This is the exactly Malmquist Productivity Index defined by Caves et al. (1982; hereafter CCD), with reference to the technology of the initial period. Similarly, we can also choose the technology in period t as the reference in defining a productivity index. The Malmquist Productivity Index in relation to the technology of the final period can be defined as $(y^t/y^c)/(y^s/y^b)$.

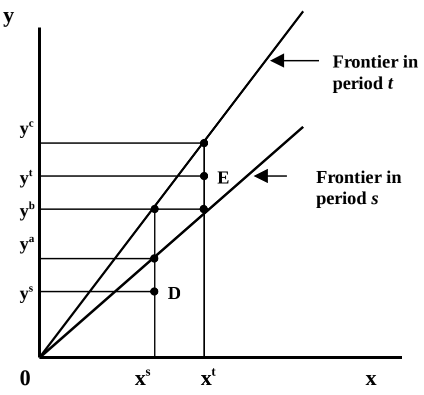

Figure 1 Decomposition of the Malmquist Productivity Index

Färe et al. (1992 and 1994) specify the Malmquist Productivity Index, namely the total factor productivity change (TFPCH), as the geometric mean of the above two indexes:

$$\text{TFPCH} = \left[\frac{(y^t/y^b)}{(y^s/y^a)} \times \frac{(y^t/y^c)}{(y^s/y^b)}\right]^{1/2} \tag{1}$$

Färe et al. (1992) define TFPCH>1 indicates productivity gain; TFPCH<1 indicates productivity loss; and TFPCH=1 means no change in productivity from s to t. They also further showed this index is equivalent to the

$$\frac{(y^t/y^c)}{(y^s/y^a)} \times \left[\frac{(y^t/y^b)}{(y^t/y^c)} \times \frac{(y^t/y^b)}{(y^s/y^a)}\right]^{1/2} \tag{2}$$

where the ratio outside the brackets measures the change in technical efficiency (EFFCH) between the years s and t:

$$\text{EFFCH} = \frac{y^t/y^c}{y^s/y^a}; \tag{3}$$

The geometric mean of the two ratios inside the square brackets captures the shift in technology (TECH) between the two periods evaluated at x^s and x^t:

$$\text{TECH} = \left[\frac{y^t/y^b}{y^t/y^c} \times \frac{y^s/y^a}{y^s/y^b}\right]^{1/2} \tag{4}$$

All of above indexes can be extended to the general case (multiple inputs and outputs with constant returns to scale technology). Let $D^s(x_0^s, y_0^s)$ and $D^t(x_0^t, y_0^t)$ represent the measure of output distance in period s and t respectively. Then the two period measures can be estimated by using the CCR DEA model (Charnes et al., 1978; Ali and Seiford, 1993)

$$\left[D^s(x_0^s, y_0^s)\right]^{-1} = \max\theta \tag{5}$$

subject to

$$\textstyle\sum_{j=1}^{n} \lambda_j y_{rj}^s \geq \theta y_{r0}^s,\ r = 1,2,\ldots,s, \tag{6}$$

$$\textstyle\sum_{j=1}^{n} \lambda_j x_{ij}^s \leq x_{i0}^s,\ i = 1,2,\ldots,m; \tag{7}$$

$$\lambda_j \geq 0,\ j = 1,2,\ldots,n. \tag{8}$$

where x_{i0}^s is the i-th input and y_{r0}^s is the r-th output for prodcution unit $0 \in \{1,2,...,n\}$ in time period s. T he efficiency (θ^*) determines the amount by which observed outputs can be proportionally increased gi ven the same input level. Using t instead of s for above model, we get $D^t(x_0^t, y_0^t)$.

As for the estimation of measure of output distance in period s(t) in relation to the technology of period t(s), denoted by $D^t(x_0^s, y_0^s)$ ($D^s(x_0^t, y_0^t)$), the DEA model can be uded again as follows.

$$\left[D^t(x_0^s, y_0^s)\right]^{-1} = \max \theta \quad (9)$$

subject to

$$\textstyle\sum_{j=1}^{n} \lambda_j y_{rj}^t \geq \theta y_{r0}^s \text{, r = 1,2,…,s,} \quad (10)$$

$$\textstyle\sum_{j=1}^{n} \lambda_j x_{ij}^t \leq x_{i0}^s \text{, i = 1,2,…,m;} \quad (11)$$

$$\lambda_j \geq 0 \text{, j = 1,2,…,n.} \quad (12)$$

Färe et al. (1994) also estimate the production frontier for variable returns to scale (VRS) technology and separate the scale effect (SE) from productivity changes.

4 Industry Context: IC Design

Taiwan is well known of owning very strong and competitive position in global IC industry, because of the uniquely successful business model in professional manufacturing wafer and semiconductor. Moreover, the IC testing and IC packaging industries are also quite successful and stable. For these superior conditions, the very superior foundation is made for succeeding Taiwan IC design industry being the leading position. It takes decades for Taiwan's semi-conductor industry to develop into a complete industrial cluster, and at the same time it has also taken on an important role not only in the Semiconductor Industry of the world but also in the economic growth of Taiwan.

Among the sub-industries of the whole semiconductor industry, IC design industry is a kind of knowledge-intensive business service sector. Taiwan's IC design industry comprises four types of designers: the independent professional designing house, the design department in an integrated device manufacture (IDM), the IC design center in a system vendor and the design unit of an overseas company. These IC design companies are capable of designing four scopes of products, in which are information (computer peripheral), communication, computer (memory) and consumer's electronics.

IC design is part of a complete semi-conductor product development cycle. For most electronic products nowadays, major product functions are incorporated into the IC chips. ICs are the core technology of these electronics products, and IC design is the most important portion of the value chain of electronics manufacturing. In 2005, Taiwan's contract chip-making industry seized a 69.2 percent share of the world market, while the IC packaging industry garnered 44.8 percent and the IC testing industry gained 60 percent, the officials said

The global market share of Taiwan 's IC design industry expanded to 21.5 percent in 2005, and the production value of Taiwan 's IC design industry was nearly US$9.8 billion in 2006, with most business focusing on information application and consumer products, making the country the world's second-largest IC designer.

As we know, Taiwan's software and system application industries are facing severe challenge and great impact under current worldwide crisis and depression. However, the know-how IC design companies became main supporters of Taiwan IC industry. In view of this, those high-tech IC design companies must surpass others in their organization and management.

5 Data Analysis

5.1 Data

A set of Taiwan Stock Exchange and the Over-the-Counter Securities Exchange companies from 2003 to 2005 was collected for analysis. In this category, there are 72 IC design companies. (Three of these companies does not show up in the list, because of the incomplete of their data), and all panel data were retrieved from Taiwan Economics News Service (http://tej.com.tw) and Market Observation Post System (http://newmops.tse.com.tw).

This research used DEAP computer program to evaluate production-oriented production efficiency index (CRS, VRS, SE) estimation. Table 1 lists production-input-oriented production efficiency average values for the Taiwan IC design companies. We take four production-oriented inputs: (i) fixed assets (ii) the number of employees (iii) selling and operational expense and (iv) R&D expense into account in building the DEA-based Malmquist productivity index. The only output, namely performance, is annual revenue.

5.2 Results

We first look at the Table 1, which shows the efficiencies of the 72 companies in Taiwan's IC design industry from 2003 to 2005. The whole industry's average productive efficiency of Constant Returns to Scale (CRS) equal to 0.3454 means IC design industry is very ineffective and still has 65% productive technical efficiency to be improved. Only VIA, ELITE, SQ, and COASIA these four companies obtained the optimal value (one) in productive technical efficiency. In addition, the whole industry's average managerial efficiency of Variable Returns to Scale (VRS) is 0.3975, means IC design industry is very ineffective and still has 65% managerial efficiency capacity to be improved, and only VIA, MTK, ELITE, NOVATEK, SQ, HERMOSA, COASIA, and APEC these eight companies obtained the optimal value (one) in management efficiency.

It reveals that the whole Taiwan's IC design industry is both technical inefficient and managerial inefficient. As aforementioned, IC design industry is a kind of knowledge-intensive business, they creates its competitive advantage and high added-value through continuous endeavour on developing intellectual property, but most of companies faces the problem of shortage in human resources, especially lack of R&D engineers, and financial resources (lack of capital), that would be the reason of technical inefficiency and managerial inefficiency.

In terms of Scale Efficiency (SE), we noted that the average value is 0.8690, and only VIA, ELITE, SQ, and COASIA these four companies obtained the optimal value (one) in scale efficiency. It meansmost IC design companies are medium and small company, they can't reach the economics of scale in R&D activities and productions, that should be the reasons of scale inefficiency.

Then we look at the Table 2, which shows the Malmquist productive index (EFFCH, TECH, TPFCH) estimation for the 72 IC design companies from 2003 to 2005.

There are totally 39 companies with values of TFPCH productive index greater than one and even three. But, the whole IC design industry's TFPCH productive index is 0.9944. It implies the production-oriented productivity of IC design industry, from 2003 to 2005, did not have outstanding improvement.

The technical change index TECH equal to 1.0263, indicates IC design industry has a little improvement in technology during 2003-2005; and the technical efficiency change index EFFCH of the whole IC design industry equal to 0.969, means the technical efficiency of the IC design industry, from 2003 to 2005, is slightly declined. Overall, the improvement on production-oriented productivity for Taiwan's IC design industry is tiny as the technical inefficiency of IC design industry nibbled the minor improvement in technology.

Table 1 DEA efficiency from 2003 to 2005

DMU	Abbr. of company name	CRS	VRS	SE
1	SiS	0.3419	0.5958	0.5738
2	RT	0.2192	0.4411	0.4969
3	VIA	1.0000	1.0000	1.0000
4	SUNPLUS	0.3941	0.6439	0.6120
5	WELTREND	0.2114	0.2287	0.9245
6	MTK	0.8458	1.0000	0.8458
7	ELAN	0.2502	0.3985	0.6280
8	SPRINTSOFT	0.1305	0.1790	0.7291
9	ELITE	1.0000	1.0000	1.0000
10	ITE	0.2726	0.3100	0.8791
11	NOVATEK	0.8257	1.0000	0.8257
12	FARADAY	0.3142	0.4274	0.7350
13	ALI	0.3883	0.4817	0.8061
14	KB	0.1475	0.1527	0.9659
15	PRESCOPE	0.5594	0.5840	0.9580
16	DAVICOM	0.1539	0.1677	0.9173
17	ACARD	0.1240	0.1306	0.9491
18	ULTRA	0.7353	0.7592	0.9684
19	ASIX	0.2301	0.3674	0.6263
20	AMIC	0.3903	0.4120	0.9473
21	AAME	0.3817	0.3840	0.9939
22	SQ	1.0000	1.0000	1.0000
23	PIXART	0.7021	0.7202	0.9748
24	RDC	0.1439	0.1465	0.9820
25	3S	0.7032	0.7151	0.9834
26	Higher Way	0.9221	0.9810	0.9400
27	CTK	0.4160	0.4314	0.9642
28	SILICON TOUCH	0.2139	0.2173	0.9843
29	IST	0.5686	0.6114	0.9301
30	FEELING TEK	0.2273	0.2473	0.9190
31	AIMTRON	0.7653	0.8213	0.9318
32	OURS	0.3561	0.3581	0.9942
33	NIKO	0.4950	0.5023	0.9856
34	EON	0.5648	0.8118	0.6958
35	AAT	0.7042	0.9561	0.7365
36	GLOBAL UNICHIP	0.1873	0.1919	0.9760
37	RALINK	0.4347	0.4605	0.9440
38	SYNTEK	0.0479	0.0497	0.9632
39	MYSON	0.2776	0.3020	0.9191
40	ETRON	0.5591	0.7644	0.7315
41	HERMOSA	0.3222	1.0000	0.3222
42	TTM	0.4430	0.5683	0.7795
43	SONIX	0.2526	0.2680	0.9426
44	TONTEX	0.1907	0.2012	0.9478
45	AVID	0.3256	0.3375	0.9650
46	GENESYS	0.1660	0.1926	0.8617
47	PRINCETON	0.2741	0.3730	0.7350
48	HIMARK	0.0720	0.0760	0.9476
49	ANPEC	0.3070	0.3411	0.9000
50	SMARTASIC	0.4854	0.4932	0.9840
51	TOPSHINE	0.3570	0.4207	0.8485
52	AVERLOGIC	0.1803	0.2714	0.6641
53	HOLTEK	0.3756	0.4969	0.7560
54	V-TECH	0.9197	0.9432	0.9751
55	PROLIFIC	0.3701	0.3811	0.9709
56	TOPPRO	0.2814	0.2846	0.9888
57	C-MEDIR	0.1671	0.1731	0.9653
58	ENE TEC	0.3169	0.3251	0.9748
59	ATEN	0.2561	0.3922	0.6529
60	SYSTEM-GENERAL	0.2524	0.2680	0.9419
61	RICHTEK	0.3295	0.3773	0.8734
62	ANALOG	0.2910	0.3029	0.9605
63	SITRONIX	0.5173	0.5379	0.9618
64	ALPHA	0.2103	0.2120	0.9923
65	IC PLUS	0.1559	0.1584	0.9842
66	ALCOR	0.4802	0.5139	0.9344
67	GMMT	0.3528	0.3579	0.9858
68	CHIP HOPE	0.7895	0.8317	0.9493
69	COASIA	1.0000	1.0000	1.0000
70	MOSART	0.2874	0.3053	0.9411
71	PROGATE	0.2365	0.2441	0.9690
72	APEC	0.9865	1.0000	0.9865
	Average	0.3454	0.3975	0.8690

Table 2 Malmquist Productivity (2003-2005)

DMU	Abbr. of company name	EFFCH	TECH	TFPCH
1	SiS	0.8323	1.1341	0.9434
2	RT	0.7982	1.0629	0.8487
3	VIA	1.0000	0.9625	0.9625
4	SUNPLUS	0.9709	1.0099	0.9800
5	WELTREND	0.8868	0.9892	0.8770
6	MTK	0.9225	0.8367	0.7719
7	ELAN	0.9641	0.9619	0.9270
8	SPRINTSOFT	0.8513	1.2398	1.0557
9	ELITE	1.0000	0.9312	0.9312
10	ITE	1.1363	1.0640	1.2087
11	NOVATEK	1.0668	1.1469	1.2234
12	FARADAY	1.1060	0.8582	0.9491
13	ALI	1.3843	0.9302	1.2870
14	KB	0.8359	0.9684	0.8095
15	PRESCOPE	0.6159	0.8514	0.5240
16	DAVICOM	1.2732	0.8590	1.0936
17	ACARD	1.1782	0.9898	1.1662
18	ULTRA	0.7576	1.1519	0.8729
19	ASIX	1.0234	0.9285	0.9505
20	AMIC	0.8276	0.8796	0.7278
21	AAME	0.9810	0.9412	0.9234
22	SQ	1.0000	0.7866	0.7866
23	PIXART	1.0457	0.9118	0.9539
24	RDC	0.9408	1.0042	0.9447
25	3S	1.1690	1.0554	1.2334
26	Higher Way	0.8854	1.3372	1.1839
27	CTK	0.7317	0.8703	0.6363
28	SILICON TOUCH	0.9110	1.0917	0.9941
29	IST	0.6416	1.2152	0.7793
30	FEELING TEK	1.1637	0.9705	1.1297
31	AIMTRON	0.7431	1.1813	0.8778
32	OURS	0.7955	1.2974	1.0318
33	NIKO	0.8685	0.9460	0.8216
34	EON	1.1640	1.1457	1.3342
35	AAT	1.2724	0.9196	1.1697
36	GLOBAL UNICHIP	1.0125	0.9842	0.9961
37	RALINK	2.1865	1.0436	2.2824
38	SYNTEK	1.1059	1.0196	1.1277
39	MYSON	0.9591	1.0246	0.9826
40	ETRON	1.0085	1.0291	1.0382
41	HERMOSA	2.4319	1.5225	3.7032
42	TTM	0.6750	1.1884	0.8026
43	SONIX	1.0104	0.9556	0.9651
44	TONTEX	0.9084	0.9792	0.8886
45	AVID	0.6480	1.0197	0.6606
46	GENESYS	1.0837	0.9397	1.0184
47	PRINCETON	0.9603	0.9783	0.9400
48	HIMARK	0.9384	0.9466	0.8887
49	ANPEC	0.8351	1.0609	0.8859
50	SMARTASIC	0.5322	1.0556	0.5613
51	TOPSHINE	0.8627	1.2812	1.1049
52	AVERLOGIC	0.4850	0.9049	0.4390
53	HOLTEK	1.1194	1.0008	1.1205
54	V-TECH	0.9048	1.1655	1.0550
55	PROLIFIC	0.8681	0.8131	0.7061
56	TOPPRO	0.7888	0.9744	0.7687
57	C-MEDIR	1.1340	0.9996	1.1336
58	ENE TEC	0.8591	1.3240	1.1373
59	ATEN	0.9010	1.2240	1.1031
60	SYSTEM-GENERAL	1.3641	0.9868	1.3465
61	RICHTEK	0.8396	0.9725	0.8163
62	ANALOG	0.9824	1.1524	1.1320
63	SITRONIX	1.2568	0.9139	1.1487
64	ALPHA	0.9338	1.0243	0.9569
65	IC PLUS	1.4726	0.9380	1.3804
66	ALCOR	0.8807	1.2202	1.0744
67	GMMT	1.3570	0.9963	1.3514
68	CHIP HOPE	0.8068	1.1167	0.9009
69	COASIA	1.0000	1.3823	1.3823
70	MOSART	1.2860	0.8860	1.1393
71	PROGATE	1.1146	1.0258	1.1436
72	APEC	1.0002	1.0746	1.0745
	Average	0.9690	1.0263	0.9944

6 Concluding Remarks

Facing strong growing competition, the efficiency of IC design industry operations and management plays a crucial role to determine a firm's performance and even its survival. Efficiency measures can provide IC design companies managers with benchmarking information and further insight on the improvement of resource's deployment and utilization and the efficiency of resources be deployed and utilized will determine the organization 's performance.

DEA and stochastict frontier approach are the two main methods to estimate the efficiency in terms of the frontier concept based on production theory. In the study, we employed the DEA-based Malmquist productivity approach to measure operational efficiency of 72 Taiwanese IC design companies.

The whole industry's average productive efficiency of Constant Returns to Scale (CRS) equal to 0.3454 means IC design industry is very ineffective and still has 65% productive technical efficiency to be improved. the whole industry's average managerial efficiency of Variable Returns to Scale (VRS) is 0.3975, means IC design industry is very ineffective and still has 60% managerial efficiency capacity to be improved. In terms of Scale Efficiency (SE), we noted that the average value is 0.8690, and only VIA, ELITE, SQ, and COASIA these four companies obtained the optimal value (one) in scale efficiency.

The whole IC design industry's TFPCH productive index is 0.9944. It implies the production-oriented productivity of IC design industry, from 2003 to 2005, did not have outstanding improvement. The technical change index TECH equal to 1.0263, indicates IC design industry has a little improvement in technology during 2003-2005; and the technical efficiency change index EFFCH of the whole IC design industry equal to 0.969, means the technical efficiency of the IC design industry, from 2003 to 2005, is slightly declined.

The whole Results show that most companies confront the dilemma of managerial, technical, and scale inefficiency, because most of companies face the problem of shortage in human resources, especially lack of R&D engineers. In addition, most IC design companies are medium and small enterprises such that they can't reach the economics of scale in R&D activities and productions, and this is the reason of scale inefficiency.

Unfortunately, IC design industry is a kind of knowledge-intensive business; they usually create its competitive advantage and high added-value through continuous efforts on developing intellectual assets. Facing the shortage of resources, the medium and small IC design companies had better cooperate with external companies, to coordination with other companies in R&D and /or production, to decrease the disadvantage of scale and resources. For large companies, the best long-run strategy is to devote to R&D activities, to create their own intellectual property (patents) to maintain competitive advantage.

Besides, through an analysis of components of the DEA based Malmquist productivity index, we reveals that the improvement on production-oriented productivity for the whole Taiwan's IC design industry is little as the technical inefficiency of IC design industry nibbled the minor improvement in technology.

Moreover, in the future the stochastic frontier approach will be conducted to examine the IC design industry, because SFA method have advantages such as well-developed statistical tests to investigate the validity of the model specification, and ability to decompose the deviations from efficient levels between noise and pure inefficiency (Barros, 2004). In the context of Taiwanese IC design industry, there is still no studies have adopted SFA to measure industry efficiency. Furthermore, it would be also interesting in the future to conduct the research on the performance comparison of IC design industry between Taiwan with other (leading) countries.

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