Productivity and Efficiency Analysis of Taiwan's Integrated Circuit Industry

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ABSTRACT This paper is an analysis of productivity and efficiency in some Taiwan's Integrated Circuit (IC) companies. We chose 36 companies covering three years for our analysis. The Malmquist index (MI) is appropriate for measuring the productivity change because it does not require the assumption of a possibly unwarranted functional form on the structure of production technology, as required by the econometric method. In this paper, Relationships between efficiency and insurer size are also explored. Results indicate that as the asset size class become larger and larger, the associated companies become more and more inefficient.

Keywords: *Productivity change, Malmquist index, Data envelopment analysis (DEA), Efficiency, Taiwan's Integrated Circuit Industry*

1. INTRODUCTION

Data Envelopment Analysis (DEA) is perhaps the most popular method for efficiency measures. It is a mathematical programming approach for characterizing the relationships among multiple inputs and multiple outputs and has been a proven way to measure bank performance (Seiford and Zhu, 1999). There is a wealth of literature on both basic and applied research in DEA. Since the DEA model was proposed by Charnes, Cooper and Rhodes (1978), it has been widely used in profit organizations, such as the banking industry (Sherman and Gold, 1985; Oral and Yolalan, 1990; Chen and Yeh, 1998), securities (Lin, 1998), insurance (Mahajan, 1991), medical services (Grosskopf and Valdmanis, 1987), stock markets (Meric and Meric, 2001), the mutual fund industry (Tarim and Karan, 2001; McMullen and Strong, 1998), and the airline industry (Huang and Huang, 2000; Schefczyk, 1993). Subsequently, applications have also appeared in non-profit organizations like educational institutions (Sarrico and Dyson, 2000), hospitals (Harris, Ozgen and Ozcan, 2000), and police force (Thanassoulis, 1995).

Recently, there are plenty of literatures that attempt to study the productivity and efficiency of a particular industry. A commonly used framework is described as follows. Efficiency measures are calculated by DEA that has particular applicability in the service sector.Productivity is measured by the Malmquist index and defined as ratio between efficiency, as calculated by DEA. This kind of methodology is previously been applied in several industries to study productivity and efficiency at the same time, but the study that is aimed at Taiwan’s IC industry of recent year is rare. As a result, the Malmquist indexes of 36 listed corporations of the IC industry in Taiwan are calculated based on the information of Taiwan’s stock market collected from 2002 to 2004. The result provides integrated and objective consultative information for investors to make a correct investment.

The rest of the paper is organized as follows. Section 2 provides the background for this study. Section 3 is literature review of DEA application in IC industry. Section 4 is the calculation of the Malmquist productivity indexes by DEA. Section 5 describes the result of the empirical study and discussion. The last section presents our conclusions.

2. THE BACKGROUND FOR THE RESEARCH

Taiwan's semiconductor industry has very important contribution to Taiwan's economics, and also brings the reputation for "Information technology (IT) empire" to Taiwan. IC is major output of the semiconductor industry, so when people refer to semiconductor industry, they use the term "IC industry" regardless of the larger scope of semiconductor industry. According to a survey done by TSIA (Taiwan Semiconductor Industry Association), the production value of IC industry excesses one trillion in 2004, up to 1 trillion 990 hundred million, especially, no industry's production value has ever reached to that high before in Taiwan. For more detail of the performance of IC industry, the scale of IC design industry in Taiwan is ranked secondly in the whole world, next to the U.S; the production value of semiconductor wafer fabrication occupies 70% share, which is the top of the world; the production value of IC packaging and testing occupies 40%~50% share of the world, which is also the top one; the production value of DRAM occupies 22% share, which is the third of the world. Each illustration of the performance proves that Taiwan's IC industry stands on a critical position globally. Further investigation done by TSIA, IC industry has constant growth of "production value", "operational value-added", "income of foreign exchange creation", "investment", "government investment return ","margin revenue", and so on, as an powerful evidence that IC industry is deeply competitive industry in Taiwan.

3. LITERATURE REVIEW

The choice of inputs and outputs is influenced by literature on DEA applications in IC related industry. The inputs and outputs used in earlier DEA applications are listed in Table 1. Through the survey, it reveals that the application of DEA in measuring efficiency or performance is practical and valid. All the inputs and outputs selected in the study are important variables for measuring productivity and efficiency, because those variables chosen below define important dimensions of productivity or efficiency of a revenue-producing organization.

Table 1. Survey of DEA application in the IC-related industry

Author	Research topic	Input variable	Output variable
Sengupta (2005)	Nonparametric efficiency analysis under uncertainty using DEA□an empirical application to computer industry	R & D expenditure Net plant and equipment Total manufacturing and marketing costs	Net sales
Chen and Ali (2004)	DEA Malmquist productivity measure :Application to computer industry	Assets Shareholder's equity Employees	Revenue
Ho(2003)	Study of the operational efficiency and stock marketability of Taiwan's listed electronic companies	Employees Assets Capital stock	Revenue Operating profit Net income
Shao and Lin (2002)	Technical efficiency analysis of information technology investments: a two-stage empirical investigation	Capital Labour (employees)	Value-added output (gross sales deflated by the industry output price deflators, minus its non-labor expenses deflated by the producer price index for intermediate materials, supplies and components)
Lien and Peng (2001)	Study of competition and production efficiency of telecommunications in OECD countries	The number of telephone main lines installed Employees Operator investment	Revenue
Kozmetsky and Yue (1998)	Comparative performance of global semiconductor companies (apply DEA to measure cost efficiency)	Cost of good sold Selling, general, and administrative expenses Total assets	Net sales
Thore, Phillips, Ruefli and Yue (1996)	Application of DEA to rank the efficiency of U.S computer companies	Cost of goods sold Selling, general, and administrative expenditure Employees Capital expenditure Research and development (R & D) expenditure	Gross sales revenues Income before taxes Market capitalization

In this study, three variables are chosen as inputs, which are *assets, employees, shareholder's equity*, because they are the most important resources to be used to generate business output for IC industry. It is also supported by literature review in Table 1, that is, the three variables are the most commonly used input variables when applying DEA to measure productivity or efficiency .The other seven variables are chosen as outputs, which are *net sales, earning before tax (EBT), return on asset (ROA), gross margin rate, total asset turnover, operating profit, net income*. A company generates its sales in terms of its capital stock, assets, and employees, and then operating profit, earning before tax, net income will be generated as a result. The ROA, gross margin rate, total asset turnover can be calculated as well. Consequently, the seven variables can be chosen to reflect efficiency or productivity of a company after it uses the three inputs to run business.

4. MALMQUIST PRODUCTIVITY INDEX BY DEA

4.1 The Malmquist Productivity Index

Malmquist index is a total factor productivity index based on distance functions, calculated relative to previous year. For simplicity, $\mathbf{z}^{t1} = (\mathbf{x}^{t1}, \mathbf{y}^{t1}) \in Z(t1)$ and $\mathbf{z}^{t2} = (\mathbf{x}^{t2}, \mathbf{y}^{t2}) \in Z(t2)$, where $\mathbf{x}^s$ (s= t_1 and t_2) is the vector of inputs used in production and $\mathbf{y}^t$ is the vector of outputs. Now, for each time period $s = 1, \ldots, T$, using $P^s(\mathbf{x})$ denotes the output possibility set at time s, the output distance function[1] is defined as follows:

$$D^s(\mathbf{z^s}) = \inf_{\theta} \{\theta: \mathbf{y}^s/\theta \in P^s(\mathbf{x})\}$$

$$= [\sup_{\theta} \{\theta: \theta\mathbf{y^s} \in P^s(\mathbf{x})\}]^{-1} \quad (1)$$

where superscript s on D^s denotes that technology in period s is used as the reference technology. θ is a scalar, and its value is the efficiency score for each production activity. It satisfies $0 < \theta \leq 1$ for a non-negative output level, with a value of 1 indicating a point on the frontier and hence a technically efficient production activity. This output distance function is defined as the reciprocal of the maximal proportional expansion of output vector $\mathbf{y^s}$ with given input vector $\mathbf{x^s}$ in relation to the technology at s.

4.2 DEA-based Estimation Method

The calculation of Malmquist index implicates to measure production frontier or efficiency frontier by the most used non-parametric method DEA method. It consists to use linear programming methods to construct a non-parametric piecewise frontier over the data, in order to be able to calculate efficiencies relative to this surface, with hypotheses relative to convex and monotony of all production possibilities. Consequently, with DEA method, we can build an empirical production frontier that are constituted by the most efficient DMUs and measure the distance of each DMU to this frontier as efficiency. Either the orientation-based (input-oriented or output-oriented) DEA model or the non-oriented DEA model can be used to develop the MI. Here we demonstrate envelopment DEA fundamentals by means of the

[1] the Farrell (1957) input distance function $D_I^{\,s}(\mathbf{z}^s) = \inf_\alpha \{\alpha: \alpha > 0, (\alpha\mathbf{x}^s) \in P^s(\mathbf{y})\}$, or the Shephard (1953) input distance function $SD_I^{\,s}(\mathbf{z^s}) = = \sup_\alpha \{\alpha: \alpha > 0, (\mathbf{x}^s/\alpha) \in P^s(\mathbf{y})\} = 1/D_I^{\,s}(\mathbf{z^s})$, where $P^s(\mathbf{y})$ denotes the corresponding input requirement set

input-oriented DEA model, processes leading to MI by other techniques are similar to that by the input-oriented DEA model. One may refer to Cooper et. al. (2004).

5. RESULTS AND DISCUSSIONS

5.1 Raw Data Analysis

Statistic results of three years' Taiwan's Integrated Circuit Industry data are presented in Table 2 where the Mean, standard deviation, Median, sum, minimum and maximum of each measure are calculated respectively. For example, the Mean, standard deviation, Median, sum, minimum and maximum of total assets, an input measure, are 40345938.5, 87978437.9, 8736651.5, 1452453785, 589949 and 439826848 respectively as indicated in the 2nd column of Table 2. Other similar information for each of the measures can also be found in Table 2.

As presented in the 1st column of Table 2 and 3, we have 36 compannies for each of three years respectively, which means that number of DMUs in our DEA models 36 for each year. Each company has three variables as inputs, which are *assets, employees, shareholder's equity*; the other seven as outputs, which are *net sales, earning before tax (EBT), return on asset (ROA), gross margin rate, total asset turnover, operating profit, net income.*

To consider the sum for each measure over the time horizon, we cannot find whole consistence of varying trend. Generally, there is a relatively great decrease for total sum of outputs with value from 325 million in the 2002 year to 337 million in the 2003 year. However, a dramatic increase is viewed from 2003 to 2004 achieving an output of 653 million, which accounts 9.4 percent increase comparing to that of 2003.

Corresponding to the inconsistent trend of output aspect, the input aspect also behaves similar trend, which indicates a positive correlation between trend of investment change and that of production change. To sum up the value for each of the input measures in Table 3, we obtain a total value of 2.22 billion for the 2002 year. A decrease of 1.41 percent is generated due to a total input value 2.19 billion in 2003. In 2004, along with the increase of dramatic output, input is improved with a relative value of 1.2%. Although there is no comprehensive monotone trend for both input and output, some indicators do keep constant increase over three years. For example, for output aspects, total asset turnover keeps increase from 67200 in 2002 to 82733 in 2004. Evidently, an initial analysis of the raw data helps us a lot to extract intuitive information, which will benefit our hereby results.

Table 2. Summary statistics of raw data

	Static	**Assets (input)**	**Net sales (output)**	**Earning before tax(EBT) (output)**	**ROA (output)**	**Gross margin rate (output)**	**Total asset turnover (output)**	**Employees (input)**	**Share-holder's equity (input)**	**Operating profit (output)**	**Net income (output)**
year 2004 (36)	Mean	40345938.5	10714288	2551314	8.041389	27.66139	0.806944	2298.139	3E+07	2292840	2569913
	Median	8736651.5	4543511	433504	8.265	29.99	0.62	769	6E+06	426152.5	427969.5
	Standard Deviation	87978437.9	21571373	7567952	6.853195	12.75225	0.460824	3694.66	7E+07	6891995	7654661
	Minimum	589949	180642	-1681249	-5.46	-2.79	0.34	96	334079	-1085264	-1623511
	Maximum	439826848	1.22E+08	4.2E+07	27.29	49.97	2.44	16529	4E+08	39674150	42198802
	Sum	1452453785	3.86E+08	9.2E+07	289.49	995.81	29.05	82733	1E+09	82542254	92516882
year 2003 (36)	Mean	35830275.1	7957813	415695	6.591944	22.06167	0.759444	2070.694	2E+07	614969.9	378603.7
	Median	6617823	3025494	117505	5.935	20.645	0.58	693.5	5E+06	141920	129119.5
	Standard Deviation	76571032.9	15745959	3547159	6.78658	19.82718	0.552878	3281.8	6E+07	3702849	3418485
	Minimum	655948	213282	-6280670	-14.01	-39.34	0.23	88	366740	-5324956	-6281248
	Maximum	362852489	89247465	1.7E+07	22.7	53.11	3.09	14938	3E+08	19534718	16087834
	Sum	1289889903	2.86E+08	1.5E+07	237.31	794.22	27.34	74545	9E+08	22138918	13629734
year 2002 (36)	Mean	36701360.6	7105441	645302	7.504722	24.43639	0.741389	1866.667	2E+07	745183.4	541294.3
	Median	5707576.5	2736290	177031	6.505	27.17	0.565	552.5	4E+06	191855.5	195872.5
	Standard Deviation	78772259.4	13964025	3558609	7.124539	18.12118	0.595292	2912.24	6E+07	3676832	3277931
	Minimum	469251	169665	-7184356	-5.12	-18.62	0.19	82	320654	-4229957	-7184356
	Maximum	374980380	79972169	1.8E+07	29.98	51.93	3.5	13676	3E+08	20157484	15897351
	Sum	1321248981	2.56E+08	2.3E+07	270.17	879.71	26.69	67200	9E+08	26826603	19486595

To pre-process the raw data, correlation analysis among the output variables is carried out as well as input variables. Although there's heavy correlation among some variables, they are all employed in our calculation so that information can be completely used. Moreover, some negative values are changed to positive ones by adding a constant across the whole units over the associated measures so that DEA calculation can be easily performed.

5.2 Efficiency and Insurer Size

Efficiency issue is important because it is related to management of input factors. This section investigates the relationship between technical efficiency and company size. The average technical efficiency measures classified by asset size are presented in Table 3, as well as the *t*-statistic value between the efficiency scores and assets for both production and investment models. It is noted that the values of assets and their corresponding efficiencies are based on the year 2004.

Table 3. Efficiency Measures by Asset Size Class

Year			2004			2003			2002
Asset Size Class	**Efficiency**	**Efficiencient %**	**No. of DMUs**	**Efficiency**	**Efficiencient %**	**No. of DMUs**	**Efficiency**	**Efficiencient %**	**No. of DMUs**
0.55M-5M	0.974	5	11	0.977	5	12	0.979	6	13
5M-20 M	0.955	4	12	0.948	3	9	0.912	2	9
20 M-50M	0.914	2	7	0.92	2	8	0.855	1	6
50M-440 M	0.893	1	6	0.871	1	7	0.846	1	8

Using *t*-statistics, the null hypothesis that the asset size is independent of the efficiency score is rejected in both cases at the 5% level or better. In other words, the evidence shows that firms' size as measured by total assets is significantly related to efficiency.

From Table 3, it could be easily find that as the Asset Size Class become larger and larger, the associated companies become more and more inefficient. Most of the companies are small entities with total assets no more than 20 millions.

5.3 Productivity Analysis

Four distances are calculated for each firm in each year. These are relative to : 1 the previous periods CRS DEA frontier; 2 the current periods CRS DEA frontier; 3 the next periods CRS DEA frontier; 4 the current periods VRS frontier. The BCC scores are also documented in the last three columns in the following Table 4.

Table 4. DEA scores

Company	Code*	$d_o^{04}(Y_{04}, X_{04})$	$d_o^{03}(Y_{04}, X_{04})$	$d_o^{04}(Y_{03}, X_{03})$	$d_o^{03}(Y_{03}, X_{03})$	$d_o^{02}(Y_{03}, X_{03})$	$d_o^{03}(Y_{02}, X_{02})$	$d_o^{02}(Y_{02}, X_{02})$	VRS02	VRS03	VRS04
UMC	2303	0.237	0.273	0.184	0.214	0.176	0.167	0.138	0.851	0.895	0.878
ASE	2311	0.194	0.149	0.183	0.125	0.115	0.14	0.117	0.841	0.862	0.841
SPIL	2325	0.27	0.19	0.265	0.179	0.164	0.156	0.143	0.838	0.875	0.947
OSE	2329	0.518	0.365	0.423	0.244	0.166	0.186	0.127	0.787	0.82	0.917
TSMC	2330	0.356	0.392	0.305	0.329	0.272	0.307	0.254	1	1	1
MXIC	2337	0.21	0.207	0.15	0.144	0.114	0.117	0.093	0.765	0.79	0.836
TMC	2338	0.429	0.419	1.352	0.439	0.421	0.469	0.381	0.886	0.906	0.88
MVI	2342	0.888	1.034	0.821	0.853	0.678	0.314	0.251	0.763	1	1
WEC	2344	0.266	0.274	0.209	0.216	0.178	0.222	0.184	0.843	0.844	0.864
SDI	2351	0.514	0.335	0.853	0.308	0.305	0.316	0.241	0.915	0.931	0.954
SiS	2363	0.314	0.356	0.398	0.343	0.279	0.257	0.207	0.86	0.9	0.838
LPI	2369	0.416	0.288	0.771	0.323	0.32	0.272	0.223	0.835	0.902	0.929
RT	2379	0.296	0.297	0.673	0.401	0.353	0.49	0.415	0.96	0.978	0.904
VIA	2388	0.359	0.371	0.391	0.382	0.317	0.421	0.349	0.918	0.896	0.935
SUN-PLUS	2401	0.526	0.552	0.6	0.388	0.342	0.445	0.375	0.918	0.923	0.938
NTC	2408	0.283	0.328	0.208	0.218	0.173	0.296	0.236	0.863	0.831	0.888
Wel-trend	2436	0.759	0.53	2.542	0.679	0.703	0.777	0.671	0.958	0.95	0.903
GTK	2441	0.43	0.286	0.698	0.311	0.308	0.308	0.266	0.898	0.919	0.949
PPt	2446	0.29	0.2	0.415	0.163	0.15	0.172	0.138	0.797	0.863	0.928
KYEC	2449	0.196	0.121	0.27	0.123	0.114	0.123	0.085	0.785	0.844	0.88
Tran-Scend	2451	0.894	0.813	1.441	0.791	0.673	0.851	0.721	1	1	1
MTK	2454	0.701	0.867	1.074	1	0.829	1.275	1	1	1	1
ELAN	2458	0.563	0.458	1.238	0.52	0.476	0.573	0.482	0.943	0.952	0.962
I-CHIUN	2486	0.556	0.351	1.674	0.409	0.482	0.589	0.497	0.974	0.965	0.912
ESMT	3006	1	1.513	2.512	1	1.027	1.291	1	1	1	1
ITE	3014	0.762	0.666	2.57	0.749	0.753	0.771	0.646	0.98	0.984	0.99
PRECISION	3016	1	0.935	5.3	1	1.201	1.236	1	1	1	1
NOVA TEK	3034	1	1.173	1.425	0.951	0.828	1.008	0.813	0.935	1	1
Fara-day	3035	0.573	0.412	1.2	0.486	0.464	0.538	0.482	0.99	0.994	0.985
ALi	3041	0.705	0.562	0.871	0.411	0.368	0.5	0.421	1	0.987	0.943
KB	3056	1	1.139	5.133	1	1.415	1.599	1	1	1	1
IST	3063	0.655	0.405	1.016	0.414	0.42	0.381	0.345	0.947	0.928	0.946
SONIX	5471	0.939	0.622	2.917	0.865	0.854	1.141	1	1	1	1
PQI	6145	1	0.936	2.129	1	0.953	1.532	1	1	1	1
SI-GURD	6257	0.445	0.304	1.095	0.387	0.422	0.364	0.325	0.957	0.976	0.979
Richtek	6286	1	0.701	3.174	1	1.213	1.341	1	1	1	1

*:Note: The numbers stand for the stock-number code of the company in Taiwan Stock Exchange Corporation (TSEC).

Following presents four indices over time horizon including the Malmquist index for each company. All indices are relative to the previous year. Four indices are presented in each year: 1 technological change; 2 pure technical efficiency change calculated relative to the VRS technology; 3 scale efficiency change and 4 total factor productivity (TFP) change. Note that all Malmquist index averages are geometric means.

Table 5. Malmquist index scores for each company

Company	Code	Year 03-04				Year 02-03			
		Tech-ch	Pe-ch	Se-ch	TFP(MI)	Tech-ch	Pe-ch	Se-ch	TFP(MI)
UMC	2303	0.824	1.052	1.477	1.28	1.157	0.981	1.131	1.285
ASE	2311	0.873	1.026	1.047	0.937	0.724	0.976	1.592	1.124
SPIL	2325	0.917	1.044	1.196	1.146	0.69	1.082	1.391	1.038
OSE	2329	0.682	1.042	1.845	1.312	0.638	1.119	1.894	1.351
TSMC	2330	0.826	1	1.299	1.073	1.092	1	1.081	1.179
MXIC	2337	0.793	1.032	1.499	1.227	0.971	1.059	1.377	1.416
TMC	2338	0.883	1.023	1.126	1.016	0.563	0.971	1.007	0.55
MVI	2342	0.796	1.311	2.597	2.71	1.1	1	1.041	1.144
WEC	2344	0.828	1.001	1.17	0.969	1.03	1.025	1.206	1.272
SDI	2351	0.869	1.017	1.258	1.111	0.485	1.025	1.626	0.81
SiS	2363	0.809	1.047	1.585	1.342	0.988	0.931	0.983	0.905
LPI	2369	0.902	1.081	1.339	1.306	0.539	1.03	1.252	0.694
RT	2379	0.863	1.019	0.948	0.834	0.773	0.924	0.799	0.571
VIA	2388	0.829	0.977	1.121	0.907	1.003	1.043	0.903	0.944
SUNPLUS	2401	0.861	1.005	1.031	0.893	0.824	1.016	1.332	1.116
NTC	2408	0.795	0.963	0.962	0.736	1.101	1.068	1.217	1.431
Weltrend	2436	0.946	0.992	1.019	0.957	0.432	0.951	1.177	0.483
GTK	2441	0.924	1.024	1.14	1.08	0.545	1.032	1.339	0.752
PPt	2446	0.86	1.082	1.091	1.015	0.52	1.075	1.653	0.925
KYEC	2449	0.8	1.075	1.344	1.157	0.529	1.042	1.531	0.845
Transcend	2451	0.85	1	1.097	0.931	0.706	1	1.131	0.799
MTK	2454	0.806	1	1	0.806	1.073	1	0.701	0.752
ELAN	2458	0.878	1.009	1.068	0.947	0.584	1.01	1.073	0.633
I-CHIUN	2486	0.997	0.991	0.83	0.82	0.393	0.945	1.439	0.534
ESMT	3006	0.892	1	1	0.892	0.776	1	1	0.776
ITE	3014	0.918	1.004	1.155	1.065	0.505	1.006	1.011	0.514
PRECISION	3016	0.985	1	1	0.985	0.42	1	1	0.42
NOVATEK	3034	0.838	1.07	1.094	0.98	0.885	1	1.052	0.93
Fara-day	3035	0.924	1.003	1.006	0.933	0.54	0.991	1.191	0.637
ALi	3041	0.869	0.987	0.988	0.847	0.614	0.955	1.795	1.053
KB	3056	0.941	1	1	0.941	0.471	1	1	0.471
IST	3063	0.959	0.979	1.226	1.151	0.502	1.019	1.553	0.794
SONIX	5471	0.93	1	0.864	0.805	0.443	1	1.086	0.481
PQI	6145	0.789	1	1	0.789	0.663	1	1	0.663
SIGURD	6257	0.985	1.019	1.171	1.177	0.491	1.004	1.144	0.564
Richtek	6286	0.951	1	1	0.951	0.47	1	1	0.47
Geo. mean		0.664	1.007	1.185	1.025	0.869	1.023	1.152	0.792

A relatively large shortfall in productivity is viewed from the 2002 year to the 2003 year in Taiwan's Integrated Circuit Industry as indicated by the geometric mean value 0.792 at the last cell of Table 5. However, productivity is slightly improved from June, 2003 to June, 2004 reflected by the MI value 1.025, the last row and 6th column of Table 5.

From June, 2003 to June, 2004, across the whole industry, 21 out of 36 companies yield a shortfall in productivity with minimum 0.736 and maximum 0.985. Conversely, the rest 15 companies demonstrate an improved productivity with minimum 1.015 and maximum 2.71. From June, 2002 to June, 2003, 25 out of 36 companies yield a shortfall in productivity with minimum 0.42 and maximum 0.944 and the rest 11 companies perform well with minimum 1.038 and maximum 1.431. Results in Table 5 indicate that most companies in this industry suffer from shortfall in productivity. The total MI from 02-04 is the geometric mean of MI02-03 and MI03-04, i.e., 0.901, indicating that the productivity of Taiwan's Integrated Circuit Industry is decreasing from June, 2002 to June, 2004.

6. CONCLUSION

This paper presents a DEA study to investigate the productivity and efficiency in IC industry. This performance analysis is important because Taiwan's IC industry stands on a critical global position as indicated by the top two ranking scale of IC design industry, top one ranking of the production value of semiconductor wafer fabrication and the production value of IC packaging and testing, and such an analysis will definitely help provide valuable managerial insights so that huge revenue might be yielded.

Malmquist index, as a total factor productivity index based on distance functions, is estimated using DEA in this study. Three years data, i.e., the year 2002, 2003 and 2004 are employed for calculating Malmquist indices, each calculated relative to previous year. From the results, we can sense a relatively large shortfall in productivity from the 2002 year to the 2003 year in Taiwan's IC Industry and a slightly improvement from June, 2003 to June, 2004. Generally, the productivity of Taiwan's IC industry is suffering from a decreasing from June, 2002 to June, 2004.

Relationships between efficiency and insurer size are explored. Results indicate that as the asset size class become larger and larger, the associated companies become more and more inefficient. Most of the companies are small entities with total assets no more than 20 millions.

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