Multifactor performance measure model with an application to Semiconductor industry Performance

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Abstract : - The research described in this paper contains four parts. The first part is to present an empirical investigation where financial index is considered to measure the semiconductor industry performance. The second part is to examine the effects of financial index on outputs. The technique of Data Envelopment Analysis is utilized to derive the efficiency. The serve part utilized the referral of clustering analysis to view the relatively efficient enterprises, and then they are used to be the references and frequencies of improving the efficiencies of the relatively inefficient enterprises. Finally, The Slack Variable Analysis was used to find out the improper resources allocation and utilization of the enterprise.

With regards to the existence of the enterprise, the effectiveness of operating performance possesses a critical factor. The quantifying formula analysis of DEA can obtain a more impartial and objective result of the performance evaluation, and then this result are used to analyze the competitiveness of the enterprise, so as to adjust its operating strategies, strengthen its internal management; as a result the continuously operating objective can be reached.

Keywords: - Semiconductor industry, DEA, performance

1 Introduction

The development of Taiwan's semiconductor industry began in the packaging section. In 1966, General Instruments (GI) established a factory in Kaohsiung which was responsible for the transistor packaging, and this has opened the milestone of the package technology. After that, the research and development of the new technology are carried out in Electronics Research & Service Organization of Industrial Technology Research Institute; also Science Park provides a faultless environment for the establishment of factories, with these two conditions many manufacturing factories of semiconductor's wafers are formed one after another domestically. Consequently, these conditions established the foundation of

Taiwan's IC industry, also Taiwan's semiconductor industry has been brought to the world's competitive stage. After the long period of development, the current market size of Taiwan's semiconductor industry ranks the fourth worldwide, which is one of the high technology industries that has the highest developing potential, it also possesses considerable weight in the industrial structure [1].

Because of that, this study uses the DEA model to find out if every enterprise has effectively made use of the costs in order to reach the highest efficiency or not. Through the quantifying formula analysis of DEA, a more impartial and objective result of the performance evaluation can be obtained, and then this result is used to analyze the competitiveness of the enterprise and improve the index, so as to provide the enterprises with the references of strategically adjustments.

The ten study samples are selected from the database of Taiwan Institute of Economic Research's semi-conductor industry, including Taiwan Semiconductor Manufacturing Company Limited, United Microelectronics Corporation, Powerchip Semiconductor Corporation, Nanya Technology Corporation, Winbond Electronics Corporation, Inotera Memories, Unimicron Technology Corporation, Lite-on Semiconductor Corporation, Faraday Technology Corporation, and Arima Optoelectronics Corporation, they are numbered as A1, A2, A3 to A10 respectively.

2. Data Envelopment Analysis, DEA

The CCR model that was addressed by Charnes, Cooper and Rhodes in 1978 was the origin of data envelopment analysis[1]. The DEA method first uses a formula to get the "Product Frontier", then the product frontier is compared with the actual information of the decision making unit (DMU), as a result the decision making unit's relative efficiency and inefficiency can be measured; thus, the recommended objective can be modified effectively[4].

The BCC model that was addressed by Banker, Charnes, and Cooper in 1984[8], revoked the constant returns to scale assumption of the CCR model, the assumption of variable returns to scale was used in the BCC model. These two models had been recognized as the most influential models in the DEA field [5]. Therefore, this study adopts CCR and BCC as the major efficiency measuring model.
The followings are the brief introductions of the CCR and BCC models:

2.1 The CCR Model

DEA was formerly developed by Charnes, Cooper and Rhodes in 1978[7], it is an efficiency measuring model that can evaluate the inputs and outputs, and was formally named as "Data Envelopment Analysis" [2] [6]; the name of "CCR" was named by the three writers' initials. The CCR model is based on the constant returns to scale assumption to evaluate the efficiency of DMU. The formula is：

$$Max\ h_{j0} = \frac{\sum_{r=1}^{s} U_r Y_{rj0}}{\sum_{i=1}^{m} V_i X_{ij0}} \quad (1)$$

$$Subject\ to\ \frac{\sum_{r=1}^{s} U_r Y_{rj}}{\sum_{i=1}^{m} V_i X_{ij}}$$

$U_r, V_i \geq \varepsilon > 0$; $i = 1, \ldots, m$; $r = 1, \ldots, s$; $j = 1, \ldots, n$

Where：

j is the DMU, with n^{th} terms；

i is the input, with m^{th} terms;

r is the output, with s^{th} terms;

U_r is the r^{th} weighed sum of output;

V_i is the i^{th} weighed sum of input;

h_{j0} is the relative efficiency value;

ε is the non-Archimedean quantity.

2.2 The BCC Model

In 1984, Banker, Charnes and Cooper developed a model[8], compared to the constant returns to scale assumption of the CCR model, this model is based on the variable returns to scale assumption to address a new and revised model called the "BCC" model [2]; and the name of "BCC" was named by the three writers' initials. The formula is：

$$Min\ Z_0 = H_0 - \varepsilon\{\sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} S_r^+\} \quad (3)$$

$$Subject\ to\ H_0 X_{i0} - \sum_{j=1}^{n} X_{ij}\lambda_j - S_r^+ = 0 \quad (4)$$

$$\sum_{j=1}^{n} Y_{ij}\lambda_j - S_i^- = Y_{r0} \quad (5)$$

$$\sum_{j=1}^{n} \lambda_j = 1 \quad (6)$$

$\lambda_j, S_i^-, S_r^+ \geq 0$; $i = 1, \ldots, m$; $r = 1, \ldots, s$; $j = 1, \ldots, n$

where:

0 is the evaluated DMU;

Z_0 is the efficiency value;

Y_{r0} is the r^{th} output in 0^{th} unit;

X_{i0} is the i^{th} input in 0^{th} unit;

S^+ is the difference variable of the input;

S^- is the difference variable of the output;

λ is the weighed value;

ε is the non-Archimedean quantity.

3. The study Method

In this keen competitive era, the effectiveness of operating performance possesses a critical factor with regards to the existence of the enterprise. The final goal of the enterprise's operation simply wants to use the least amount of inputs to acquire the most amount of outputs, therefore the owners are urging to know how to reach this final goal. This study uses the quantifying formula analysis of DEA to obtain a more impartial and objective result of the performance evaluation, and this result is used to analyze the competitiveness of the enterprise, so as to adjust its operating strategies, strengthen its internal management; as a result the continuously operating objective can be reached. The analyzing process of this study is divided into five sections:

1. The determination of Decision Making Unit, DMU;
2. The determination of outputs and inputs;
3. The analysis of operating performance;
4. The referral of clustering analysis;
5. The analysis of difference variables.

In this section, the determination of Decision Making Unit (DMU) and the determination of outputs and inputs are introduced, while the rest will be conferred in Section 4 – The actual analysis of operating efficiency.

3.1 The Determination of Decision Making Unit (DMU)

The major studying object in this study is Taiwan's semiconductor industry, and the study data is mainly from 2005 [9]; this study selects Taiwan Semiconductor Manufacturing Company Limited, United Microelectronics Corporation, Powerchip Semiconductor Corporation, Nanya Technology Corporation, Winbond Electronics Corporation, Inotera Memories, Inc., Unimicron Technology Corporation, Lite-on Semiconductor Corporation, Faraday Technology Corporation, and Arima Optoelectronics Corporation after sifting as the studying objects, they are numbered as A1, A2, A3 to A10 respectively.

3.2 The Determination of the Outputs and Inputs

This study uses the costs as the major consideration, therefore the operating costs, operating expenses, fixed assets, and total assets are selected and considered as the inputs, while the operating net income is considered as the output. The data source is from the database of Taiwan Institute of Economic Research [9], for more details please refer to Table 1.

Table 1 – The Basic Information of The Enterprises

Company number	The Operating Net Income	The Operating Costs	The Operating Expense	The Fixed Assets	The Total Assets
A1	264,588,364.00	149,344,315.00	22,230,225.00	214,145,633.00	507,539,815.00
A2	90,775,439.00	79,614,153.00	13,864,269.00	149,809,616.00	326,221,237.00
A3	51,611,653.00	42,588,396.00	3,512,381.00	88,197,809.00	153,445,521.00
A4	49,771,582.00	42,321,027.00	6,875,721.00	34,382,643.00	100,726,528.00
A5	27,815,070.00	22,943,672.00	7,077,146.00	45,154,792.00	80,770,937.00
A6	23,032,203.00	16,350,746.00	941,987.00	66,162,814.00	87,358,089.00
A7	20,817,313.00	16,350,802.00	1,396,238.00	11,023,971.00	29,556,932.00
A8	9,777,065.00	9,172,998.00	772,855.00	2,420,174.00	12,067,064.00
A9	5,744,675.00	3,249,009.00	1,117,333.00	1,104,500.00	6,373,771.00
A10	2,633,727.00	2,223,965.00	286,963.00	1,689,620.00	3,748,815.00

The data source: the database of TIER, after this study's arrangement. Unit: NT$1,000

4. The Actual Analysis of Operating Efficiency

The analyzing process of the operating efficiency is divided into three parts:

1. The analysis of operating performance: The four evaluating items include the overall efficiency, the technical efficiency, the scale efficiency, and the returns to scale. The overall efficiency can be obtained from the CCR model, and the BCC model can obtain the technical efficiency, then the technical efficiency is divided by the overall efficiency in order to get the scale efficiency, then the obtained efficiency values are used to analyze the operating performance of every enterprise.
2. The referral of clustering analysis: The purpose of the referral of clustering analysis is to view the

relatively efficient enterprises, and then they are used to be the references and frequencies of improving the efficiencies of the relatively inefficient enterprises [4]. The more the enterprise is being referred, the more efficient is the enterprise in DMU, therefore, the improvement of operating flow of the inefficient enterprises can be more reachable.

3. The Slack Variable Analysis: The Slack Variable Analysis can find out the improper resources allocation and utilization of the enterprise, hence, the relatively low efficient enterprises can understand how to adjust their inputs in order to increase the outputs. The Slack Variable Analysis is separated into the CCR model and the BCC model, the analyzing result of CCR model represents the long term striving direction of the enterprise, and the analyzing result of the BCC model is the short term improving direction of the enterprise [3].

4.1 The Analysis of Operating Performance

The four evaluating items of the analysis of operating performance include the overall efficiency, the pure technical efficiency, the scale efficiency, and the returns to scale. This study uses Frontier Analyst to proceed with the analysis, first uses the CCR model to get the overall efficiency, and the BCC model can obtain the technical efficiency, then the pure technical efficiency is divided by the overall efficiency in order to get the scale efficiency, and the efficiency value of every enterprise is shown in Table 2.

Table 2 - The Analysis of Operating Performance

Company number	The Overall Efficiency	The Pure Technical Efficiency	The Scale Efficiency	The Returns to Scale
A1	1	1	1	CRS
A2	0.6436	0.6436	1	DRS
A3	0.8738	0.9853	0.8868	IRS
A4	0.7700	1	0.7700	CRS
A5	0.6843	0.6845	0.9997	DRS
A6	1	1	1	CRS
A7	1	1	1	CRS
A8	1	1	1	CRS
A9	1	1	1	CRS
A10	0.9145	1	0.9145	CRS
AVG	0.8886	0.9313	0.9571	

The Data Source: The analysis of this study

Note: IRS – Increasing Returns to Scale, CRS – Constant Returns to Scale, DRS – Decreasing Returns to Scale

In the overall efficiency, when the overall efficiency value is 1, represents that enterprise has reached the relative efficiency. From Table 2 one can find that A1, A6, A7, A8, and A9 these five enterprises' overall efficiencies equal to 1, which represents these five enterprises have reached the

relative efficiencies. For the other five enterprises A2, A3, A4, A5, A10, their overall efficiencies are less than 1, representing these enterprises are relatively inefficient.

In the pure technical efficiency, if purely the technical efficiency is equaled to 1, representing that enterprise uses a more efficient method to produce under the evaluation of DMU, the qualified enterprises include A1, A4, A6, A7, A8, A9, and A10; if pure the technical efficiency is less than 1, representing that enterprise cannot use a more efficient method to produce, the enterprises include A2, A3, and A5.

In the scale efficiency, when the scale efficiency is 1, which represents that enterprise lies in the most suitable scale condition, the enterprises that lie in the most suitable scale are A1, A2, A6, A7, A8, and A9. When the scale efficiency is less than 1, which represents that enterprise does not lie in the most suitable scale condition, the enterprises that do not lie in the most suitable scale are A3, A4, A5, and A10.

In the returns to scale, A1, A4, A6, A7, A8, A9, and A10 present constant returns to scale, only A3 presents increasing returns to scale which means that A3 needs to increase its scale in order to promote the efficiency, A2 and A5 present decreasing returns to scale which means that they need to decrease their scales in order to promote the efficiency.

4.2 The Referral of Clustering Analysis

The purpose of the referral of clustering analysis is to view the relatively efficient enterprises, then they are used to be the references and frequencies of improving the efficiencies of the relatively inefficient enterprises [4]. The more the enterprise is being referred, the more efficient the enterprise is in DMU, and therefore, the improvement of operating flow of the inefficient enterprises can be more reachable. Table 3 shows every enterprise's referral frequency and have been referred by which enterprises respectively.

Table 3 – The Referral of Clustering Analysis

Company number	The Referral Clustering	The Referral Frequency
A1	1	3
A2	1、9	0
A3	1、6	0
A4	4	0
A5	1、9	0
A6	6	1
A7	7	0
A8	8	0
A9	9	2
A10	10	0

The Data Source: The analysis of this study

From the analyzing result, A1 has the highest referral frequency, which is 3, the enterprises that

referred to A1 are A2, A3 and A5. A9 has the second highest referral frequency, which is 2, the enterprises that referred to A9 are A2, and A5. The lowest one is A6, its referral frequency is 1, the enterprise that referred to A6 is A3; the result indicates that these three enterprises are more efficient in DMU, the improvement of operating flow of the inefficient enterprises can be more reachable.

4.3 The Slack Variable Analysis

The Slack Variable Analysis can find out the improper resources allocation and utilization of the enterprise, hence, the relatively low efficient enterprises can find out how to adjust their inputs in order to increase the outputs. The analysis of difference variables is separated into the CCR model and the BCC model, the CCR model (the slack variable analysis of overall efficiency) represents the long term striving direction of the enterprise, and the BCC model (the slack variable analysis of the pure technical efficiency) is the short term improving direction of the enterprise [3]. Two of the following models are based on A2 to proceed with the illustration.

Table 4 - The Slack Variable Analysis of Overall Efficiency

Company number	The Slack Variable Analysis of Overall Efficiency				
	The Operating Net Income	The Operating Costs	The Operating Expenses	The Fixed Assets	The Total Assets
A1	0	0	0	0	0
A2	0	28376844.03	6237484.50	76340157.44	152093588.98
A3	0	5375039.64	443294.16	11131358.88	28048603.21
A4	0	9732525.88	1581202.95	7906943.34	26018568.34
A5	0	7243727.71	4740175.26	22642555.70	27415395.32
A6	0	0	0	0	0
A7	0	0	0	0	0
A8	0	0	0	0	0
A9	0	0	0	0	0
A10	0	190100.29	24529.05	685429.38	320441.56
Average	0	5091823.76	1302668.59	11870644.47	23389659.74

The Data resource: The analysis of this study **Unit: NT$1,000**

In the analysis of difference variables of overall efficiency (as shown in Table 4), A2 should reduce its operating costs by 28376844.03 ($1,000), reduce its operating expenses by 6237484.50 ($1,000), reduce its fixed assets by 76340157.44 ($1,000), reduce its total assets by 152093588.98 ($1,000) in order to reach the efficient output.

Table 5 - The Slack Variable Analysis of The Pure Technical Efficiency

Company	The Slack Variable Analysis of The Pure Technical Efficiency

number	The Operating Net Income	The Operating Costs	The Operating Expenses	The Fixed Assets	The Total Assets
A2	0	28372490.46	5811301.05	78720599.97	155213235.3
A3	0	10502662.99	51699.67	4526571.46	16374095.86
A4	0	0	0	0	0
A5	0	7237797.15	4159615.1	25885267.48	31665073.15
A6	0	0	0	0	0
A7	0	0	0	0	0
A8	0	0	0	0	0
A9	0	0	0	0	0
A10	0	0	0	0	0
Average	0	4611295.06	1002261.582	10913243.89	20325240.43

The Data resource: The analysis of this study **Unit: NT$1,000**

In the analysis of difference variables of technical efficiency (as shown in Table 5), A2 should reduce its operating costs by 28372490.46 ($1,000), reduce its operating expenses by 5811301.05 ($1,000), reduce its fixed assets by 78720599.9 ($1,000), reduce its total assets by 155213235.3 ($1,000) in order to reach the efficient output.

5. Conclusion

According to the study results, we found that among the ten enterprises, the overall efficiencies of five enterprises are equaled to 1 which means that these five enterprises are relatively efficient. Seven enterprises have reached the purely technical efficiency which means that these seven enterprises use more efficient methods to produce. Six enterprises have reached the scale efficiencies which means that these six enterprises lie in their most suitable scale conditions. For the returns to scale, among the ten enterprises, seven of them lie in the constant returns to scale, one of them lies in the increasing returns to scale, and two of them lie in the decreasing returns to scale. The enterprises can base on the result of the analysis of the difference variables to adjust the allocation and utilization of the resources, so that the resources can be utilized in the most suitable way in order to elaborate the resources' maximum efficiency, so as to help the enterprise to produce the maximum outputs. Hence, the enterprise can reach its relatively efficient operating method, this not only can reduce the costs and expenses, but also help the enterprise to create the maximum profits.

With regards to the existence of the enterprise, the effectiveness of operating performance possesses a critical factor. The quantifying formula analysis of DEA can obtain a more impartial and objective result of the performance evaluation, and then this result are used to analyze the competitiveness of the enterprise, so as to adjust its operating strategies, strengthen its internal management; as a result the continuously operating objective can be reached.

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