An Analysis of the Production and Marketing Efficiency for Major TFT-LCD Manufacturers in the World

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Abstract: This paper set out to analyze the efficiency in two respects of panel manufacturers from Taiwan (AUO, CMO, CPT, Hannstar, and QDI), South Korea (Samsung and LPL), and Japan (Sharp), first using Grey Relation Analysis to determine representative indicators, then using those indicators as input and output variables (grouped into production and marketing efficiency groups) for two-stage Data Envelopment Analysis, all based on research conducted between 2002 and 2004. The results showed that Taiwanese companies were generally stronger in marketing efficiency than production efficiency, however their average marketing efficiency still lagged behind that of overseas companies. As a result, one can see that the two-stage model has clear potential for helping these companies improve their performance levels. The companies that must most urgently improve production efficiency are AUO, CMO, CPT, and QDI, while those that must most urgently improve marketing efficiency are CMO, CPT, Hannstar, and LPL.

Keywords: production efficiency, marketing efficiency, grey relation analysis, two-stage data envelopment analysis

I. General Information

Within the flat panel display industry, the LCD holds a prominent position, particularly considering the superiority of TFT-LCD (Thin Film Transistor Liquid Crystal Display) technology, its wide applications, and its economies of scale; at the same time it can satisfy the demands of the information technology and consumer electronics industries, allowing it to rapidly become the mainstream in the flat panel display market

Most of the world's TFT-LCD panels are currently supplied by Taiwan, Korea, and Japan; Japan leads in technology, while Korea has the largest production capacity and Taiwan has a competitive advantage in the form of abundant capital and numerous downstream clients [1].

According to Table I, we see that the top eight firms in the sector come from these three territories—Korea, Taiwan, and Japan—and that their collective capacity share has grown from 83.9% in 2002 to 87.8% in 2005. The five Taiwanese firms in the eight have since 2002 surpassed the capacity share of the Korean firms, standing at 38.1% as compared to 37.7%, with the difference growing annually, while Japan is steadily losing capacity share.

Table I. Capacity share in the global major large-area TFT-LCD manufacturers

Nation	Firm	2002		2003		2004		2005	
Korea	Samsung	18.6	37.7	19.4	38.7	18.8	37.1	19.0	37.6
	LPL	19.1		19.3		18.3		18.6	
Taiwan	AUO	12.7		13.2		13.9		13.6	
	CMO	10.6		12.1		14.5		15.6	
	CPT	5.7	38.1	6.6	40.8	5.9	42.2	5.5	41.8
	Hannstar	5.1		4.3		3.3		2.7	
	QDI	4.0		4.6		4.6		4.4	
Japan	Sharp	8.1	8.1	6.5	6.5	7.7	7.7	8.4	8.4
Total		83.9		86.0		87.0		87.8	

Source: DisplaySearch (2006), %

Currently the top Japanese firms in the field are Sharp, Sanyo, Hitachi, Toshiba, and NEC. The industry cluster effect in Taiwan continues to drive development in upstream materials and component industries. According to statistics from DisplaySearch [2], CMO and AUO were third and fourth respectively in terms of global capacity share, and are the leaders of the industry in Taiwan. Meanwhile in South Korea, Samsung and LG-Philips LCD (LPL) become major contributors to industry in South Korea. In 2005, these two companies placed first and second respectively in terms of global capacity share, with Taiwan quickly coming up from behind.

The TFT-LCD industry has become the natural successor to the semiconductor industry in Taiwan. It occupies a vital position in Taiwan's economic growth, and as such industrial performance and efficiency, and the improvement thereof, are issues of vital concern. However most research done in this field to date lacks useful comparisons with the major firms in Korea and Japan. As a result, this paper will focus on Taiwan's top five panel manufacturers—AUO, CMO, CPT, Hannstar, QDI—as well as Sharp of Japan, and Samsung and LPL of South Korea. First Grey Relation Analysis (GRA) will be carried out to select representative indicators, followed by Two-Stage Data Envelopment Analysis (DEA) to divide those indicators into production efficiency indicators and marketing efficiency indicators.

II. A conceptual framework

Feng and Wang [3][4][5] developed a conceptual framework to describe the cycle of operation activities of an enterprise and to help produce a set of initial indicators. In this model, the operation activities of an enterprise include three parts: factor input, product output and consumer consumption. Whether the activities of an enterprise are efficient or not has direct influence on profitability, thereby potentially threatening the survival of the enterprise. As shown in Figure I, the operational activities of a TFT-LCD company also include these three parts and constitute the two stages of the operation cycle: production and marketing.

Figure I illustrates the two types of performance categories: production efficiency and marketing efficiency. Production efficiency of factor input and product output measures the resources expended to produce output (e.g. liquidation, finance structure, or productivity). It can be represented as the efficiency of production-related departments. Marketing efficiency of product output and consumer consumption measures the extent to which output is used (e.g. debts turnover, profitability, process capability, or marketing capability). It can be represented as the efficiency of departments related to sales activities, such as the departments of sales and marketing.

Prior research, based on the use of DEA analysis, was used as a tool for measurement of improvement of business performance, while input and output variables were, after review of previous literature, were determined on the basis of relational analysis. This paper took as its subjects eight main producers of TFT-LCD around the world, and attempted to offer a means of performance evaluation appropriate to the industry through the integration of GRA and DEA, and then use these to determine performance levels of TFT-LCD firms.

As shown in Figure I, through input, output and consumption variables being evaluated in pairs, we can build a ranking of the ratios acquired. However, before producing the initial performance indicators set, two criteria were used for choosing the indicators. First, an evaluation indicator should have a preliminary explanatory meaning. Second, indicator data must be readily acquirable. If not, it is unsuitable for use in any ratio calculation. Based on the above two selection criteria and the ratios of both evaluation items in Figure I, the numbers of initial evaluation indicators were reduced to a total of 20- 10 representing production efficiency, 10 representing marketing efficiency, as shown in Tables II and III.

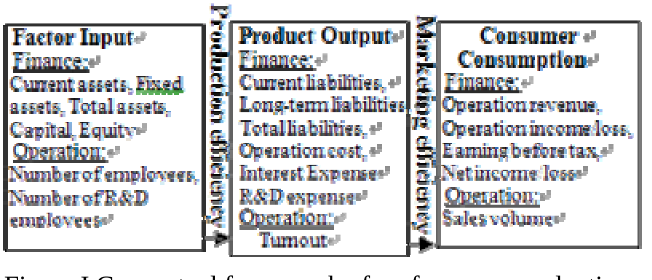

Figure I Conceptual framework of performance evaluation item set in TFT-LCD industry

Table II Performance indicators set in production efficiency

Code	Indicator	Evaluation Formula
P_1	Ratio of turnout to number of employee	Turnout/ number of employee
P_2	Ratio of turnout to number of R&D employee	Turnout/ number of R&D employee
P_3	Ratio of R&D expense to number of R&D employee	R&D expense/ number of R&D employee
P_4	Ratio of turnout to total assets	Turnout/ total assets
P_5	Current ratio	Current assets/ current liabilities
P_6	Ratio of long-term debts to fixed assets	Long-term liabilities/ fixed assets
P_7	Ratio of total debts to capital	Total liabilities/ capital
P_8	Ratio of interest expense to current assets	Interest expense/ current assets
P_9	Debt ratio	Total assets/ total liabilities
P_{10}	Debt-equity ratio	Equity/ total liabilities

Table III Performance indicators set in marketing efficiency

Code	Indicator	Evaluation Formula
M_1	Ratio of sales volume to turnout	Sales volume/ turnout
M_2	Ratio of operation revenue to turnout	Operation revenue/ turnout
M_3	Operation Ratio	Operation revenue/ operation cost
M_4	Gross profit ratio	(Operation revenue- operation cost)/ operation cost
M_5	Ratio of net income to operation cost	Net income (loss)/ operation cost
M_6	Current debts turnover ratio	Operation revenue/ current liabilities
M_7	Long-term debts turnover ratio	Operation revenue/ long-term liabilities
M_8	Total debts turnover ratio	Operation revenue/ total liabilities
M_9	Interest expense ratio	Operation revenue/ interest expense
M_{10}	Ratio of operation revenue to R&D expense	Operation revenue/ R&D expense

III Methodology

Grey relation analysis

Grey system theory was first proposed by Professor Deng in 1982 [6]. The fundamental definition of "greyness" is information being incomplete or unknown, thus an element from an incomplete message is considered to be of "grey" element. A "grey relation" refers to the measurement of changing relations between two systems or elements that occur in a system over time. The analysis method, which measures the relations between elements based on the degree of similarity or difference of development trends among these elements, is called "grey relation analysis". More precisely, during the process of system development, should the trend of change between two elements be consistent, it then enjoys a higher grade of synchronized change and can be considered as having a greater grade of relation, otherwise, the grade of relation is smaller. Grey relation analysis will be applied in the selection of representative indicators.

Data envelopment analysis

DEA was first proposed in 1978 by Charnes, Cooper, and Rhodes [7], and is based on the technical efficiency measurement theories proposed by Farrell [8], using mathematical programming methods to measure the productivity boundaries of the unit to be evaluated and calculate the relative efficiency of each individual unit. Since the formal definition of the method, several scholars have proposed revisions to the theory and expansions of its application. This paper uses the CCR and BCC methods for evaluation of overall efficiency, and uses return to scale analysis and slack variable analysis to carry out a more detailed investigation and enable a greater understanding of the factors involved in each elements productivity or non-productivity. Through this, managers will have access to greater amounts of information that may be used to determine means to improve performance.

IV Representative indicators and I/O variables

This paper takes as its subjects 8 main large-area TFT-LCD producers around the world, five companies in Taiwan are AUO, CMO, CPT QDI, Hannstar, two companies in Korea are Samsung and LPL, and Sharp is a Japanese firm. According to data from DisplaySearch [2], these eight firms had 86.0%, 87.0%, and 87.8% collectively of global capacity share in 2003, 2004, and 2005 respectively, showing their representativeness of the industry as a whole. Using the three years of data from 2002 through 2004, Grey Relation Analysis was undertaken to determine suitable efficiency indicators, after which two-stage DEA was carried out to evaluate production efficiency and marketing efficiency. The source of the data used was the public financial records of each company. However, Samsung and Sharp do not make the financial records of their TFT-LCD departments independently available, and so to account for this a percentage of operating income was used to provide the data necessary; for Samsung, panel manufacturing accounted for 7%, 12%, and 15% of their income in 2002, 2003, and 2004 respectively, while the figures for Sharp were 14%, 17%, and 18%.

Grouped indicator and representative indicators

The performance indicators can be divided into several groups according to the calculation of all indicators with regard to the grey relation coefficient. A representative indicator has to be selected from each group and the principal of selection depends on the degree of the relationship between an indicator and the other indicators in the same group. Wang [9] provided a “relative total score” method helpful for selecting a representative indicator. In this method, the selected principal depends on the how many times that an indicator leads the sequence.

A total of 20 initial indicators were selected for the performance evaluation, with 10 related to production efficiency and 10 to marketing efficiency. Based on GRA method and relative total score method, indicators were divided into four production efficiency groups and four marketing efficiency groups. As Table IV shows, eight representative indicators were selected from each group and had the DEA method applied as the basis for selecting input/output variables.

Table IV Classification of indicators groups of production and marketing efficiency

Categories	Groups	Indicators within each group	Representative indicator of each group
Indicators in production efficiency	P-I	P_3	P_3
	P-II	P_1、P_2、P_4、P_8	P_4
	P-III	P_7	P_7
	P-IV	P_5、P_6、P_9、P_{10}	P_9
Indicators in marketing efficiency	M-I	M_1	M_1
	M-II	M_2、M_3	M_2
	M-III	M_5、M_6、M_7、M_8	M_8
	M-IV	M_4、M_9、M_{10}	M_{10}

I/O variables selection for two-stage DEA

As shown in Table IV, the representative indicators selected through GRA analysis were then used as the input and output variables for DEA method, divided across first- and second-stage DEA evaluations. The first stage is the evaluation of data from the production efficiency inputs and outputs, while the second is based on the marketing efficiency of the outputs and consumer consumption, with the previous outputs becoming the inputs for this stage of analysis and consumer consumption serving as the output variable. The inputs and outputs can be seen in Figure II.

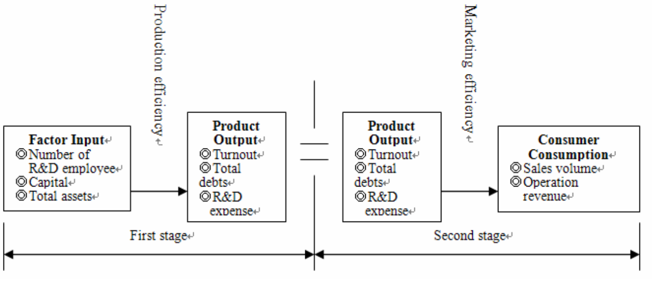

Figure II Input and output variable in two-stage DEA

V Two-stage DEA evaluation result

This paper used the DEA-Slover software written by Zhu [10], giving each DMU’s efficiency value while allowing us to see each DMU’s overall efficiency, technical efficiency, and return to scale results.

Overall efficiency analysis

Production efficiency evaluation: From Table V we see that overall efficiency values for CMO in 2002, AUO in 2004, Samsung in 2002 and 2003, LPL from 2002 through 2004, and Sharp for 2002 and 2004 are at 1, the optimal level. For geometric mean of production efficiency values for each manufacturer, LPL shows the optimal level (1.0000), with Samsung second (0.9906).

Marketing efficiency evaluation: From Table V we see that overall efficiency values for AUO from 2002 through 2004, CMO in 2003 and 2004, Hannstar in 2002, QDI in 2002 and 2004, Samsung in 2003 and 2004, LPL in 2004, and Sharp in 2003 and 2004 all sit at the optimal value, 1. The results of marketing efficiency evaluation indicate that 60% of DMUs are functioning efficiently. Table V shows the geometric mean of marketing efficiency values for each manufacturer, and of these AUO shows the optimal level (1.0000), with LPL second (0.9850).

Technical and Scale efficiency: Technical efficiency is an indicator of whether or not each manufacturer can make effective use of input factors; as its value rises, it indicates a more efficient use of inputs. Technical efficiency values of 1 indicate production activities taking place at or above the production efficiency fronter, at which level inputs are best organized. Technical inefficiency refers to the presence of errors in implementation, leading to inefficiencies. Scale efficiency is an indicator of whether or not the ratio of

Table V Two-stage DEA: value of OE, TE, and SE

No. of DMU		Production efficiency (First stage)					Marketing efficiency (second stage)				
		Overall efficiency	Technical efficiency	Scale efficiency	Σ λ	Returns to scale	Overall efficiency	Technical efficiency	Scale efficiency	Σ λ	Returns to scale
1	AUO2002	0.7985	0.8433	0.9468	0.703	ISR	1.0000	1.0000	1.0000	1.000	CSR
2	AUO2003	0.9048	0.9655	0.9370	0.721	ISR	1.0000	1.0000	1.0000	1.000	CSR
3	AUO2004	1.0000	1.0000	1.0000	1.000	CSR	1.0000	1.0000	1.0000	1.000	CSR
Geometric Mean		0.8973	0.9338	0.9609	----	----	1.0000	1.0000	1.0000	----	----
4	CMO2002	1.0000	1.0000	1.0000	1.000	CSR	0.9090	0.9474	0.9594	0.657	ISR
5	CMO2003	0.7196	0.7392	0.9735	1.086	DSR	1.0000	1.0000	1.0000	1.000	CSR
6	CMO2004	0.9234	1.0000	0.9234	1.804	DSR	1.0000	1.0000	1.0000	1.000	CSR
Geometric Mean		0.8726	0.9041	0.9651	----	----	0.9687	0.9824	0.9861	----	----
7	CPT2002	0.7470	0.7870	0.9491	0.739	ISR	0.9300	0.9724	0.9564	0.639	ISR
8	CPT2003	0.7868	0.8799	0.8941	0.678	ISR	0.8224	0.8349	0.9851	1.210	DSR
9	CPT2004	0.8515	0.9673	0.8803	1.446	DSR	0.8777	0.9131	0.9613	1.366	DSR
Geometric Mean		0.7939	0.8750	0.9073	----	----	0.8756	0.9050	0.9675	----	----
10	Hannstar2002	0.6719	1.0000	0.6719	0.286	ISR	1.0000	1.0000	1.0000	1.000	CSR
11	Hannstar2003	0.8079	0.8309	0.9723	0.527	ISR	0.8101	0.8743	0.9265	0.524	ISR
12	Hannstar2004	0.8104	0.8175	0.9914	0.710	ISR	0.8742	0.9022	0.9690	0.648	ISR
Geometric Mean		0.7605	0.8790	0.8652	----	----	0.8914	0.9240	0.9647	----	----
13	QDI2002	0.9549	1.0000	0.9549	0.577	ISR	1.0000	1.0000	1.0000	1.000	CSR
14	QDI2003	0.8839	0.8952	0.9874	0.724	ISR	0.9411	1.0000	0.9411	0.458	ISR
15	QDI2004	0.9008	0.9010	0.9999	1.006	DSR	1.0000	1.0000	1.0000	1.000	CSR
Geometric Mean		0.9127	0.9309	0.9804	----	----	0.9800	1.0000	0.9800	----	----
16	Samsung2002	1.0000	1.0000	1.0000	1.000	CSR	0.7413	1.0000	0.7413	0.512	ISR
17	Samsung2003	1.0000	1.0000	1.0000	1.000	CSR	1.0000	1.0000	1.0000	1.000	CSR
18	Samsung2004	0.9721	1.0000	0.9721	1.036	DSR	1.0000	1.0000	1.0000	1.000	CSR
Geometric Mean		0.9906	1.0000	9.9906	----	----	0.9050	1.0000	0.9050	----	----
19	LPL2002	1.0000	1.0000	1.0000	1.000	CSR	0.9817	0.9857	0.9960	1.369	DSR
20	LPL2003	1.0000	1.0000	1.0000	1.000	CSR	0.9734	0.9877	0.9855	1.039	DSR
21	LPL2004	1.0000	1.0000	1.0000	1.000	CSR	1.0000	1.0000	1.0000	1.000	CSR
Geometric Mean		1.0000	1.0000	1.0000	----	----	0.9850	0.9911	0.9938	----	----
22	Sharp2002	1.0000	1.0000	1.0000	1.000	CSR	0.8708	1.0000	0.8708	0.695	ISR

23	Sharp2003	0.9677	1.0000	0.9677	1.042	DSR	1.0000	1.0000	1.0000	1.000	CSR
24	Sharp2004	1.0000	1.0000	1.0000	1.000	CSR	1.0000	1.0000	1.0000	1.000	CSR
Geometric Mean		0.9891	1.0000	0.9891	----	----	0.9549	1.0000	0.9549	----	----

outputs to inputs is appropriate; the higher it gets, the more appropriate the ratio. A scale efficiency value of 1 indicates optimal scale. Scale inefficiency is where the company has not achieved production at an appropriate scale, leading in inefficient production. Table V shows the average overall inefficiency values, with the factors involved shown in Table VI and Table VII. The companies that must most urgently improve production efficiency are AUO, CMO, CPT, and QDI, while those that must most urgently improve marketing efficiency are CMO, CPT, Hannstar, and LPL.

Table VI Causes of inefficiency in first stage

Firms	Production efficiency (first stage)		
	Overall	Technical	Scale
AUO	0.8973	0.9338	0.9609
CMO	0.8726	0.9041	0.9651
CPT	0.7939	0.8750	0.9073
Hannstar	0.7605	0.8790	0.8652
QDI	0.9127	0.9309	0.9804
Samsung	0.9906	1.0000	0.9906
Sharp	0.9891	1.0000	0.9891

Table VII Causes of inefficiency in second stage

Firms	Marketing efficiency (second stage)		
	Overall	Technical	Scale
CMO	0.9687	0.9824	0.9861
CPT	0.8756	0.9050	0.9675
Hannstar	0.8914	0.9240	0.9647
QDI	0.9800	1.0000	0.9800
Samsung	0.9050	1.0000	0.9050
LPL	0.9850	0.9911	0.9938
Sharp	0.9549	1.0000	0.9549

VI Conclusions and future research

Conclusions

In previous studies using the DEA method for evaluations, although it was possible to determine inefficient DMUs, it was not possible to determine what was causing those inefficiencies, nor where the unproductive elements lay. If we can consider the data from the twin perspectives of production efficiency and marketing efficiency, we can obtain data more useful to management in their efforts to improve their business. In this paper we used the two-stage DEA method for efficiency evaluation, undertaking production efficiency and marketing efficiency for eight companies—AUO, CMO, CPT, Hannstar, and QDI of Taiwan; Samung and LPL of Korea; and Sharp of Japan. We then used GRA to select eight representative indicators from the 20 initial indicators, increasing the objectivity of the data used in the overall analysis. The results of this analysis show that the firms that are relatively strong in production efficiency generally do not need an equivalent level in marketing efficiency. This result indicates that simply using production efficiency to measure the efficiency of panel manufacturers makes it difficult to determine a comprehensive evaluation of market value. Two-stage analysis is more useful to management, helping to discover the causes of inefficiency and engage in efforts to improve them.

Analysis of overall efficiency shows that of the companies showing relatively lower production efficiency levels, the inefficiencies of AUO, CMO, CPT, and ODI arise from issues in technical efficiency, while Hannstar, Samsung, and Sharp's inefficiencies arise from scale efficiency issues. Marketing efficiency analysis shows that of the companies showing relatively lower marketing efficiency levels, the inefficiencies of AUO, CMO, and LPL arise from issues in technical efficiency, while those of QDI, Samsung, and Sharp arise from issues in scale efficiency.

The overall marketing efficiency of Taiwanese firms is generally stronger in the production efficiency aspects, while they are also generally weaker than foreign firms in terms of overall marketing efficiency. The panel industry is largely dependent on imports for materials, and the stability or lack thereof of upstream suppliers can influence the operation of manufacturers, and improving relationships and operating procedures with said suppliers can improve production efficiency. Additionally, with the high-level technologies involved in TFT-LCD manufacture, with some critical technologies still in need of breakthroughs and some tightly controlled by Japanese companies, this can lead to R&D expenses dragging down production efficiency each year, due to the important position R&D staff hold in the industry. Establishing effective R&D teams can reduce bottlenecks in production efficiency through technological breakthroughs.

Future research

Large-area panels are the future of the industry, particularly in light of the move toward large-screen LCD televisions, by they do not have the flexibility of the medium- and small-area panel industry. Follow-up research may focus on efficiency evaluation of medium- and small-area panel manufacture, and as costs involved in panel manufacture increase, the industry is facing a situation like that of the semiconductor industry, where the big continue to get bigger, as can be seen from the April 2006 merger of AUO and QDI. Follow-up research may focus on potential merger strategies and post-merger efficiency evaluation.

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