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Measuring the Changing Capabilities of Computer Display Projectors Using TFDEA

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Abstract--This paper applies technological forecasting using data envelopment analysis (TFDEA) to computer display projector (CDP) technology. The objective is to analyze the technological change CDP products. The results indicate that the rate of technological change for CDP technology is accelerating, which is consistent with an understanding of the industry. A methodological issue of infeasibility is described and methods for dealing with it are presented. Future work may extend to examine over additional years and product releases.

I. INTRODUCTION

This paper applies technological forecasting using data envelopment analysis (TFDEA) to computer display projector (CDP) technology. The objective of this study is to measure CDP's technological rate of change. Future work may extend this to assist decision makers with new product development (NPD) target setting.

II. TFDEA

TFDEA was originally developed by Anderson *et al.* [1] and further expanded in [5]. This section provides a brief overview of the methodology. For more detailed explanation, one is referred to [5]. Previous TFDEA studies have examined microprocessors, disk drives, enterprise database systems, and fighter jets. This paper is the first application of TFDEA to the computer display projector market.

The first step in TFDEA is to build a model representing the technology by decomposing products of the technology into structural and functional components. Structural components are those structural elements which are required for a technology product to function. Examples may be volume, cost, and power consumption. Functional components represent measurements of the function delivered by the product, which may correspond to TFDEA uses both functional and structural product specifications as defined by the model with data envelopment analysis (DEA) to determine a technology's state of the art (SOA). As technology advances, its ability to better deliver functional performance, represented by DEA efficiency, improves.

For each period, the SOA is determined using all available products. Those products that are not SOA receive a technological index, which is not equal to one. The rate of technological change is then calculated by averaging the periodic change of all former SOA product's technology indexes over time. After a rate of change is calculated, practitioners can use it to estimate future SOAs based on the last known SOA to provide a multidimensional map of future technology characteristics.

III. COMPUTER DISPLAY PROJECTOR APPLICATION

The CDP industry was chosen due to its fast growth and size. This study uses CDP data for the years between 2001 and 2003 based on information obtained in [2-4, 6].

TABLE I
SUBSET OF COMPUTER DISPLAY PROJECTOR DATA

Company	Model	Price[2] (MSRP)	Weight (lbs)	Resolution[1] (Horizontal)	Brightness (lumen)[4]	Contrast Ratio[3]	Time
Acer	7763P	3999	5	800	800	450	2000
Acer	7765PE	4499	5	1024	800	450	2000
Boxlight	XD-9m	5499	4.8	1024	1000	400	2000
Compaq	MP1400	2999	4.2	800	700	400	2000
Bo-light	P-10m	4799	3	1024	1100	400	2001
Canon	LV-5100	2199	5.9	800	700	250	2001
Canon	LV-5110	2599	6	800	850	250	2001
Dukane	8045	5495	5	800	800	200	2001
InFocus	LP70	3199	2.4	1100	768	800	2002
InFocus	LP240	1999	5.7	1000	600	400	2002
InFocus	LP250	2999	5.7	1100	768	400	2002
CTX	PS-5140	1559	6	800	1400	400	2003
Dell	3200MP	2199	3.5	1024	1300	1800	2003
Dukane	8747	3300	3	1024	1100	400	2003
Dukane	8046	2000	5	800	1100	200	2003
1: Native Resolution		2: Manufacturer's Suggested Retail Prices (MSRP) Price					
3: Full On/Off contrast measures		4: ANSI					

Based on the data in table 1, the CDP technology model is composed of five variables, which are weight, price, resolution, brightness, and contrast ratio. Although not all inclusive, the structural variables (weight and price) are often trade-offs taken to achieve better functional specifications such as resolution, brightness, and contrast ratios. Several other variables such as operating noise level and speaker power were considered but omitted due to data limitations. The CDP model used is represented by Figure 1.

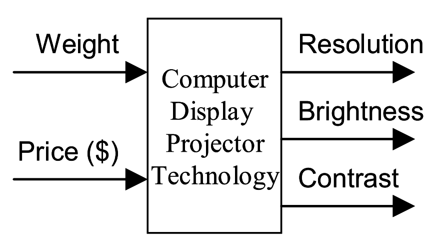

Figure 1. Basic input-output model of computer display projectors.

For clarity, a definition of each variable in the model is in order. The first variable price refer to the current manufacturer's suggested retail price on the date that the data point was taken (MSRP) [2-4, 6]. Although street prices are much lower than MSRP, they were not available for this study. The next variable in the CDP model is brightness. Brightness measures the output of projector light using the ANSI standard in unit of lumens, the higher the number, the brighter the light output. In general, when choosing between projectors with similar specifications, those with higher lumen ratings cost more.

The next variable of the CDP model is weight in pounds. Weight and volume are critical characteristics limiting the portability of a computer display projector. High weight and volume limit the computer display projector to fixed applications while low weight and volume allow mobile professionals to carry it with them to client sites. Volume is not reported as readily or consistently. Weight was therefore used as an input.

Resolution is defined as the number of pixels, projectors use to create an image [2-4, 6]. The more pixels, the higher the resolution, but the higher resolution, the more the projector will cost. The benefit to higher resolution projectors is that they can show small details with more sharpness and clarity. While computer display projectors are typically compatible with several resolutions, the hardware is tailored to only one native resolution and the other resolutions are converted to this native resolution by the CDP. Non-native resolutions then display artifacts and are not recommended.

Resolution is typically quoted in two numbers, such as 800 x 600, where the 800 is the number of pixels from side to side across the screen, and 600 is the number of pixels vertically from top to bottom. The common computer display resolutions are provided in Table II.

TABLE II
COMMON COMPUTER DISPLAY RESOLUTIONS

	Resolution		
	Horizontal	Vertical	Pixel Count
VGA	640	480	307,200
SVGA	800	600	480,000
XGA	1024	768	786,432
SXGA	1280	1024	1,310,720
UXGA	1600	1200	1,920,000

The contrast ratio in the CDP model is defined as the measurement of the difference in light intensity between the brightest white and the darkest black [2-4, 6]. A high contrast ratio, such as 400:1, represents a better color representation (the better the information will appear against a darker background) than a lower contrast ratio, such as 150:1. The CDP model in Figure 1 also indicates that the inputs of the model are weight and price and the outputs of the model are resolution, lumen, and contrast ratio.

Both input and output orientations with variable returns to scale were used to determine the technological rate of change. The input-oriented TFDEA model emphasizes reducing the inputs (weight and price) over increasing outputs. Conversely, the output-oriented TFDEA model emphasizes increasing outputs.

IV. RESULTS

A. Modeling Process

The preliminary results of TFDEA will be expanded to cover all 800 projectors from 2000 to 2003.

TABLE III
THE RATE OF CHANGE FOR THE OUTPUT-ORIENTED VRS MODEL.

Time	Gamma (γ^t)	95% Confidence Interval (CI)	Below 95% CI	Above 95% CI
2000	0	0	0	0
2001	1.196888	0.149656	1.047232	1.346544
2002	1.390434	0.132116	1.258319	1.522545
2003	1.324237	0.087173	1.237064	1.411409

Table III indicates that for a given price and weight the ability of CDP technology to deliver functional specifications increased around 19% from 2000 to 2001, 39% from 2001 to 2002, and 32% from 2002 to 2003. In 2001, there is around 4% below 95% confidence interval of ROC and around 34% above 95% confidence interval of ROC. For 2002 and 2003, the results can be interpreted the same as 2001.

TABLE IV
THE RATE OF CHANGE FOR THE INPUT-ORIENTED VRS MODEL.

Time	Beta (β^t)	95% Confidence Interval (CI)	Below 95% CI	Above 95% CI
2000	0	0	0	0
2001	0.625979	0.137635	0.488344	0.763614
2002	0.537905	0.096225	0.441680	0.634120
2003	0.508440	0.069523	0.438910	0.577960

Table IV indicates that capabilities are expected to increase 62% from 2000 to 2001, 53% from 2001 to 2002, and 50% from 2002 to 2003. In 2001, there is around 48% below 95% confidence interval of ROC and around 44% above 95% confidence interval of ROC. For 2002 and 2003, the results can be interpreted the same as 2001.

The rate of change can be interpreted so that numbers further from 1 indicate a faster rate of change. In this case, we found that apparently products in this category are changing at an accelerated pace. This is consistent with an understanding of the industry. This industry is getting much more competitive and major vendors such as Sony are leveraging their strengths from related industries to put much greater pressure on the original players in this industry such as In-Focus. To see how the rate of change is varying, the following figures are presented.

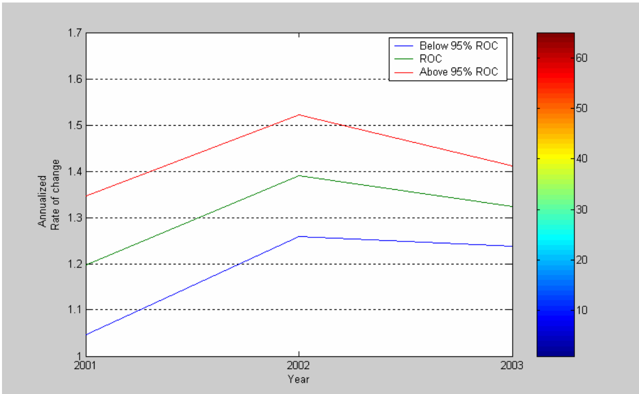

Figure 2. Graphical result on the rate of change (output-oriented VRS model)

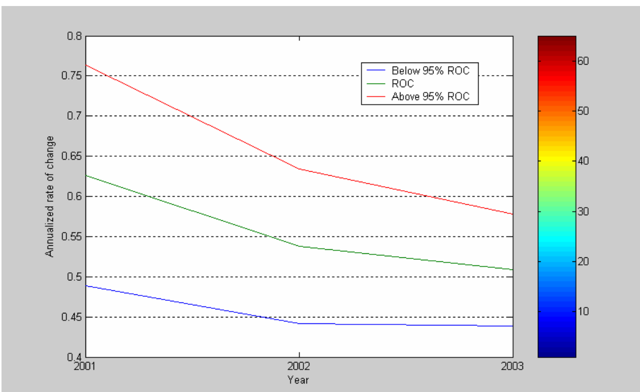

Figure 3. Graphical result on the rate of change (input-oriented VRS model)

In general, TFDEA evaluated all of the products' data in the database to examine the overall rate of change (ROC). The ROC can be used to determine the future SOA. These frontiers are tested against the performance characteristics of the actual future state of the art using super-efficiency. The following table summarizes the forecasting results of ROC with both input and output oriented model.

TABLE V
THE RATE OF CHANGE FOR THE INPUT-ORIENTED VRS MODEL.

Forecasting Summary	Number	Percentage
Prediction Range	9	18.75%
Above Conservative Estimates	24	50.00%
Below Aggressive Estimates	10	20.83%
Not Forecasted	5	10.42%
Total	48	100%

Table V predicts the characteristics of future SOA products under the 95% confidence interval. This table indicates that the specification of SOA products are accurately predicted 18.75% of the time. In other words, those products that defined the SOA fell within the predicted range 18.75% of the time. There are some products that are not within the predicted SOA range. That means those products are above or below 95% confidence interval ROC. From the Table III, the products that above 95 CI ROC are about 50% and below 95 CI ROC is about 20.83%. The products (DMUs) that are not forecasted resulted in infeasible solutions to the super-efficiency model. The infeasibility of the super-efficiency model can be represent on the following figure.

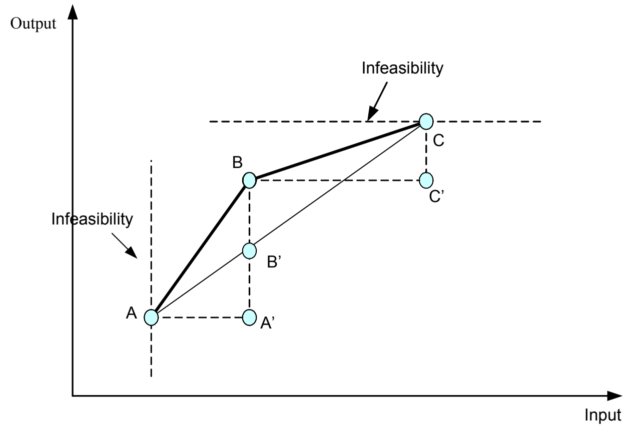

Figure 4. Examples of super-efficiency infeasibilities (Adapted from [7])

Figure 5 shows a simple example of super-efficiency under variable returns to scale. All three DMUs, (A, B, and C) are efficient. Under an input-orientation, B has feasible super-efficiency targets with an input-orientation and an output orientation. A has a feasible super-efficiency target, A', based upon the performance of B. A is infeasible under an output-orientation because neither B nor C are able to operate using as little input as A used. Similarly, C has a feasible solution with an input-orientation but is infeasible with an output-orientation because neither A nor B can produce a high enough level of output. The DMUs that are considered super-efficiency are the DMUs in the set of extreme efficiency. The DMUs can be partitioned into four classes: a set of extreme efficiency, a set of not extreme points, a set of weak efficiency, and a set of inefficiency.. The issue of super-efficiency is investigated in detail by Zhu [7].

Since TFDEA uses a super-efficiency construct, it also has instances of infeasibility. The infeasibility of products can be reduced by increasing surface area. To increase surface area, it needs to use the movement of frontiers to take into account both the increasing of output and the decreasing of input. We accomplish this by using both input and output-oriented models simultaneously to forecast the future frontier as described by Inman in 2004, [5]. The results in Table V used the combined input and output-oriented model to forecast the future frontier, so the final reduction of infeasibility of products that can be is around 10%. Table V also indicated that the total 48 products of all future SOAs are evaluated.

V. CONCLUSION

Four years of data from the computer display projector industry were examined. There is some evidence of an acceleration in the rate of technology change in this industry but additional data should be examined to verify these interpretations. Future work may extend this work to earlier projectors and add more projectors to the analysis. Future work could also apply this model to setting performance targets and examining the different successes of companies in this industry as a function of corporate strategy.

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