Using DEA Windows Analysis to Estimate Taiwan Hsinchu Science Park Operational Performance

Chia-Chi Sun[1]　Grace T R Lin[2]

(Received: Oct. 3, 2008；First Revision: Mar. 3, 2009；Accepted: May. 6, 2009)

Abstract

Science Park provides a unique environment for accelerating technological innovation, nurturing new star-up firms, attracting investment and generating economic growth. However, how to make the best decision in allocating resources and creating more profits is now an important issue for industrialist and Government policy. The purpose of this paper is to analyze efficiency and productivity growth of the six high-tech industries in Hsinchu Science Park in Taiwan for the period 2000-2006. This paper applied data envelopment analysis (DEA), a multiple inputs-multiple outputs evaluation, to analyze the relative performance. In order to find out the long-term effectiveness in productivity, the Window Analysis is adopted to seek the most recommended set of industries for Hsinchu Science Parkin Taiwan by measuring the performance changes over time. From the results, we know that industrial industrialist not only enhance their managerial skills but also increase and improve innovative performance and upgrade technology level. We think that each industry should enhance the linkage between different sectors and strengthen cross-industry relationship, in turn, improve the innovation and technology. Government also plays an important and critical role for industrial upgrading and promotion. Government must become a facilitator, enabling business and consumers to adapt to the demands and opportunities of the new economy. Therefore, they should build an innovative-cluster. The results of these analyses illustrate some policy implications for Taiwan and other countries facing the similar problems.

Keywords: DEA, Window Analysis, Hsinchu Science Park

[1] 國立交通大學科技管理研究所博士候選人
[2] 國立交通大學科技管理研究所副教授

1. Introduction

Taiwan is one of the world’s largest manufacturers of high-technology components and products. Taiwan maintains its current competitive position through investment in research and development (Lai & Shyu, 2005). In order to do that, the establishment of a business friendly environment and local innovation cluster, the creation of an environment to enhance innovation capabilities, is a pressing task (Hu et al., 2005). The development of high-tech industry has obviously reached maturity in Taiwan. According to the World Economic Forum’s “2007-2008 Global Competitiveness Report,” Taiwan has again taken first place in the world in the “State of Cluster Development” index.With the government’s vigorous promotion of the industrial strategy of “Two Innovations” (technological innovation and brand innovation) and “Two Highs” (high-tech intensive and high value-added), the competitiveness of Taiwan’s industrial clusters has continuously strengthened.

Hsinchu Science Park was established by the government of Taiwan, ROC on December 15, 1980 with investment from the Kuomintang. It straddles Hsinchu City and Hsinchu County on the island of Taiwan. The first in a series of high-tech industrial parks, Hsinchu Science Park (HSP) was established in northwestern Taiwan as a focal point for high-tech R&D and production. Since the park's beginnings in 1980, the government has invested approximately US$3.67 billion in it. By the end of March 2007, 475 high-tech companies in six industries (integrated circuits, computers and peripherals, telecommunications, optoelectronics, precision machinery, and Bio-tech) were situated within the 625-hectare park. At the end of 2006, the park's total paid-in capital exceeded US$35.4 billion, and more than 100 park companies were listed on Taiwan's main exchange, the Taiwan Stock Exchange (TAIEX), and on over-the-counter markets (Chen, 2007).

In this paper we apply a new approach based on frontier production function to research the productivity growth of Taiwan Hsinchu Science Park. The data envelopment analysis (DEA) is our research analysis tool. DEA is a nonparametric method in operations research and economics for the estimation of production frontiers. It is used to empirically measure productive efficiency of decision making units. There are also parametric approaches which are used for the estimation of production frontiers.

The main advantages of DEA that make it suitable for measuring the efficiency of vehicle inspection agencies are: (i) it allows the simultaneous analysis of multiple outputs and multiple inputs, (ii) it does not require an explicit a priori determination of a production function, (iii) efficiency is measured relative to the highest observed performance rather than against some average and (iv) it does not require information on prices (Odeck, 2000). Since the Taiwan Hsinchu Science Park are part of the public sector where economic behavior is uncertain and there is no price information on the services produced, the Window Analysis based on DEA approach is well suited for productivity measurement in this sector.

Under such a competitive environment, performance measurement is not only a powerful management tool for port operators, but also constitutes a most important input for informing regional and national port planning and operations. Kumbhakar and Lovell (2000) stated that cross-sectional data provide a snapshot of producers and their efficiency and panel data provide more reliable evidence on their performance, because they enable us to track the performance of each producer through a sequence of time periods. In order to overcome this potential problem associated with an analysis based on cross-sectional data, in this paper DEA Window Analysis is, for the first time, applied to the port industry to deduce efficiency trends.

The reminder of this paper is as follows. Section 2 gives a brief summary of the Hsinchu in Taiwan. Section 3 presents the methodology, DEA, includes the Window Analysis. Section 4 introduces the research design, which includes the research framework, research procedure, and variable measurement and sample selection. Section 5 presents the empirical results and some managerial implications and ways of improving efficiency. Concluding remarks are given in Section 6.

2. Hsinchu Science Park in Taiwan

The science park concept was originated in the late 1950s. The idea was, and still is, to provide a technical, logistical, administrative, and financial infrastructure to help young enterprises gain a toehold for their products in an increasingly competitive market. Science parks are usually based around universities and interact continuously with them. Monck, Porter, Quintas, Storey & Wynarczyk (1988) argued that funding for science parks generally come from five sources: universities (including bank borrowing); local authorities; government development agencies; private sector institutions, and the tenant enterprises themselves (Lai & Shyu, 2005).

Colombo & Delmastro (2002) define a “science park” as a property-based initiative which (i) has formal operational links with centers of knowledge creation, such as universities and (public and/or private) research centers, (ii) is designed to encourage the formation and growth of innovative (generally science-based) businesses, and (iii) has a management function which is actively engaged in the transfer of technology and business skills to “customer” organizations.

Taiwanese Science and Technology Parks (STP) such as the Hsinchu Science Industrial Park (HSIP), established in 1980, and the Taiwan Science-based Industrial Park (TSIP), established in 1995, has become closely integrated with regional industries and local development. Thus, high-tech and innovative firms generally remain concentrated in specific locations, use shared facilities, and enjoy common economic benefits (Hu, Lin & Chang, 2005).

Science parks provide an important resource cluster for new technology-based enterprises. Castells & Hall (1994) listed three motivations for establishing science parks:

reindustrialization, regional development, and synergy creation. The first two motivations are straightforward and could be described as science and technology (S&T) development and regional renewal. The third motivation involves the promotion of technology transfers from universities or research institutes to enterprises (Lai & Shyu, 2005). In the twenty years since the HSIP was established, the government has invested NT$18 billion in ‘software’ and ‘hardware’ construction at the Park, turning it into the main centre of Taiwan’s industrial development. Then we briefly introduce the current industry situation of each industry.

The electronics industry is the largest and fastest growing manufacturing industry in the world. The rapid rate of globalization is made possible by the rapid development and expansion of the internet economy, which in turn is fueled by the unprecedented growth of high-tech electronics manufacturing. Taiwan’s Hsinchu Science Park is one of the world's most significant areas for semiconductor manufacturing. Taiwan semiconductor industry consists of more than 100 design companies, 20 firms producing wafers, over 40 packaging firms, and 30 testing firms. Taiwan Semiconductor Manufacturing (TSMC) and United Microelectronics (UMC) have become the number 1 and 2 IC foundry operators in the world.

And Taiwan’s computer industries also play a dominative role around the world. Taiwan’s computer industries in Hsinchu Science Park become the largest in the world – the growth has been accompanied by a transition from original equipment manufacture and original design manufacture to original design logistic. The market share has ranked first globally from 2001 to 2007 (Chen, 2007).

Then, Taiwan’s Bio-tech industry that there were over 1,100 companies in the medical device, pharmaceutical and emerging Bio-tech sectors in Taiwan, employing over 35,000 people. Pharmaceutical products and medical devices are the two biggest sectors in the bio-tech industry. According to the Industrial Development Bureau, the total revenue of the Taiwan bio-tech industry reached NT$177.2 billion in 2006. The medical device industry generated revenue of NT$69 billion or NT$10 billion in 2006. Compared to the NT$65 billion from the pharmaceutical industry, the medical device industry surpassed the pharmaceutical sector in revenue generated (Lin, 2007).

Taiwan also plays an important and critical role in Photo-electronics that include TFT-LCD industry and LED industry among the world. Taiwan began its aggressive output in the TFT–LCD industry in 1998 with abundant capital, great vision, and a comprehensive industry chain. A technology transfer from Japan was crucial to the industry's growth. TFT–LCD panel production capacity began to expand rapidly after third- and fourth-generation plants launched production in 1999 (Chang, Lin & Lou, 2007). The supply of Taiwan TFT-LCD panels will own 43.7% of total global market share that exceeds Korea's 41.1% to be the number one suppliers in the world (Sun, Tasi & Chang, 2006). Taiwan LED makers produced NT$30.3 billion worth of LEDs accounting for 25 percent of the global LED market. Taiwan ranks second, after Japan, in LED production in terms of value, according to ITIS, a government-funded market research center based in Hsinchu (Lu, 2008).

The Taiwan MOEA's Industrial Development Bureau has projected that Taiwan's wireless communications industry will grow to a size of US$6 billion by the year 2005. In the future, Taiwan will have the opportunity to follow path steps of Finland in achieving world domination in mobile phones. Europe, the U.S. and China have all submitted their recommendations for 3G standards to the International Telecommunication Union (ITU), and it has been predicted that China could possibly decide to adopt its own standards through the advantage of its own huge market base. Taiwanese businesses should pay close attention to this tendency and take appropriate action in the future (Chen, 2007).

The turnover of Taiwan's machinery industry exceeded NT$440 billion in 2003 according to preliminary estimations, up 8.2% from 2002, of which the machine tool sector recorded the highest output valued more than NT$70 billion. According to the long-term trend report published by the ITIS under the Ministry of Economic Affairs, the turnover of the machinery industry will continue to grow beyond the NT$460 billion mark. By the ranking statistics published by the US Metalworking Insiders, Taiwan is the sixth largest machine tool producer, behind only Germany, Japan, Italy, China and the US. The machinery industry is expected to continue its growth pattern in 2004, with yearly turnover breaking the 2000 highs to the tune of NT$470 billion, but might experience slow growth after 2005, for which machine makers should be prepared. In terms of sector, it is estimated the woodworking machine sector will turn out NT$23.2 billion worth of products in 2004, up 14.85%, while the cutting machine and molding machine sectors are expected to output NT$43.4 billion and NT$20.8 billion respectively, representing a modest growth of 5.08% and 4.52% (Chen, 2007).

3. Data Envelopment Analysis (DEA) Model

DEA is a mathematical linear programming, approach based on the technical efficiency concept, it can be used to measure and analyze Technology efficiency (TE_k) of different entities: productive and non productive, public and private, profit and non profit seeking firms. It is a non-parametric approach that calculates efficiency level by doing linear programming for each unit in the sample. DEA measures the efficiency of the decision-making unit by the comparison with best producer in the sample to derive compared efficiency.

As we have seen DEA is based on TE_k concept which is formula (1):

$$TE_k = \frac{\sum weighted\ output}{\sum weighted\ input} \tag{1}$$

Mathematically we can express the above relation by the following formula (2):

$$E_k = \frac{\sum_{j=1}^{M} U_j O_{jk}}{\sum_{i=1}^{N} V_i I_{ik}} \qquad (2)$$

E_k : TE for the DMU_k (between 0 and 1).

k : Number of DMU_k in the sample ($k = 1, \cdots, K$).

N : Number of the inputs used ($i = 1, \cdots, N$).

M : Number of outputs ($j = 1, \cdots, M$).

O_{jk} : The observed level of output j from DMU_k

I_{ik} : The observed level of input i from DMU_k

V_i : The weight of input i

U_j : The weight of output j

To measure TE_k for DMU_k by using linear programming the following problem must be solved which is formula (3):

$$\begin{aligned} & Max \quad TE_k \\ & \quad s.t. \\ & \quad E_k \le 1 \quad k = 1, 2, \cdots K \end{aligned} \qquad (3)$$

Where TE_k is either maximizing outputs from given inputs, or minimizing inputs for a given level of outputs. The above problem cannot be solved as stated because of difficulties associated with nonlinear (fractional) mathematical programming. Charnes, Cooper and Rhodes (1978) have developed a mathematical transformation which converts the above nonlinear programming to linear one.

Modified linear programming by the following formula (4):

$$\begin{aligned} & Max \sum_{j=1}^{M} U_j O_{jk} \\ & s.t. \\ & \sum_{i=1}^{N} V_i I_{ik} = 1 \\ & \sum_{j=1}^{M} U_j O_{jk} \le \sum_{i=1}^{N} V_i I_{ik} \\ & U_j, V_i \ge \varepsilon > 0 \\ & \varepsilon > 0 \end{aligned} \qquad (4)$$

3.1 Window analysis

Based on rule of thumb, the number of DMU should be greater than double of the sum of inputs and outputs. In order to overcome the constraint of limited DMU in this study, the Window Analysis Method proposed by Charnes et al. (1985) is adopted. Windows analysis is a time dependent version of DEA. In order to capture the variations of efficiency over time, Charnes et al. (1985) proposed a technique called ‘window analysis’ in DEA. Window analysis assesses the performance of an DMU over time by treating it as a different entity in each time period. This method allows for tracking the performance of a unit or a process.

The basic idea is to regard each DMU as if it were a different DMU in each of the reporting dates. Then each DMU is not necessarily compared with the whole data set, but instead only with alternative subsets of panel data. The windows analysis is based on the assumption that what was feasible in the past remains feasible forever, and that the treatment of time in windows analysis is more in the nature of an averaging over the periods of time covered by the window. (Tulkens and van den Eeckaut, 1995). DEA is initially used to analyze cross-sectional data, where a given DMU is compared with all other DMU_k that produce during the same time period and where the role of time is ignored. However, this can be rather misleading since a dynamic context may give rise to seemingly excessive use of resources that are intended to produce beneficial results in future periods. As such, panel data prevail over cross-sectional data in that not only do they enable a DMU to be compared with other counterparts, but also because the movement of efficiency of a particular DMU can be tracked over a period of time. In so doing, panel data are more likely to reflect the real efficiency of a DMU .

We briefly introduce the meaning of window analysis. Assume there are N alternatives, $l = 1, \cdots, N$, and each alternatives has data for period 1 to M , $m = 1, \cdots, M$. The window length is fixed to be K , the data from period $1, 2, \cdots, K$ will form the first row, and the data from period $1, 2, 3, \cdots, K, K+1$ will form the second row, and so on. One more periods on the right will need to be shifted to, and a total of $M - K + 1$ window rows are existed. Each window is represented by $i = 1, \cdots, M - K + 1$, and the ith window consists of the data in periods $j = i, \cdots, i + k - 1$. There are K sets of data to be evaluated. Therefore, there are a total of $N \times K$ DMU in that window.

In order to apply window analysis, DEA is used to evaluate the performance of all DMU in the same window, and the efficiency, $E_{i,j}^{l}$, of each DMU will be entered in the right window position. The procedure will be repeated $M - K + 1$ times to obtain all the efficiency values in all windows. Window analysis used all the efficiency values of an alternative to generate some statistics values. There include average efficiency (M_l), variance among efficiencies of alternative l (V_l) , Column range ($CR_{l,m}$), and the total range for alternative $l (TR_l)$.

The average efficiency (M_l) of alternative l is obtained by the following formula (5):

$$M_l = \frac{\sum_{t=1}^{M-K+1} \sum_{j=1}^{i+K-1} E_{i,j^l}}{K \times (M - K + 1)}, \quad l = 1, \cdots, N \tag{5}$$

The variance among efficiencies of alternative l , V_l , is calculated by the following formula

(6):

$$V_l = \frac{\sum_{i}^{M-K+1} \sum_{j}^{i+K-1} (E_{i,j}^l - M_l)^2}{K \times (M-K+1) - 1}, \quad l = 1, \ldots, N \tag{6}$$

The variance of efficiency reflects the fluctuation of efficiency values for each alternative. If an alternative has higher average efficiency and small variance, its ranking can be higher compared to other alternatives.

Column range, $CR_{l,m}$, can be used to compare the fluctuations of efficiencies among the alternatives. In each alternative, because the data of the first period $(m=1)$ and last period $(m=M)$ are being analyzed in only the first and the $M-K+1$ window only one efficiency value is obtained for each of the two windows, the efficiencies in the first and last periods will not be included in the calculation of CR values. For the other periods, the data of each alternative is used at least twice and at least two efficiency values are available for calculating CR values.

$CR_{l,m}$ is the difference between the largest and the smallest efficiencies for alternative l in period m by the following formula (7).

$$\begin{aligned} &CR_{l,m} = Max(E_{i,m}^l) - Min(E_{i,m}^l) \\ &i = \max(m-K+1, 1), \ldots, \min(m, M-K+1) \\ &m = 1, \ldots, M \end{aligned} \tag{7}$$

$CR_{l,m}$ can be used to evaluate the stability of efficiency of an alternative in each period. Then, CR_l is the overall column range for alternative l, and it shows the greatest variation in efficiency of an alternative over different periods by the following formula (8):

$$CR_l = Max_{m=2,\ldots,M-1}(CR_{l,m}) \tag{8}$$

Finally, in order to understand the stability of an alternative over different periods, we can use total range to evaluate it. Total range is the difference between the maximum and minimum efficiency values of alternatives in all windows.

The total range (TR) for alternative l is formula (9):

$$\begin{aligned} &TR_l = Max(E_{i,j}^l) - Min(E_{i,j}^l) \\ &i = 1, \ldots, M-K+1 \\ &j = i, \ldots, i+K-1 \end{aligned} \tag{9}$$

Window analysis of DEA has been adapted in many academic fields, such as industry analysis. Carbone (2000) explains how window analysis can be used in a semiconductor manufacturing environment to identify areas of best practice within a fabricator. Cullinane, Song, Ji and Wang (2004) apply DEA Windows Analysis to Container Port Production Efficiency. Chung & Hwang (2005) use window analysis to evaluate Taiwan's bulk shipping firms' performance. Shahooth & Battall (2006) use Data Envelopment analysis and window analysis in measuring and analyzing the relative cost efficiency of 24 Islamic banking institutions. Chang, Lin, Lou (2007) applied window analysis to analyze dynamical efficiencies of Taiwan's TFT-LCD firms for the period from 2001 to 2005.

4. Research design

In this section, we propose our research framework and describe our variable measurement and sample selection.

4.1 Research framework

This research try to measure the performance on six high-tech industries in Hsinchu Science Park in Taiwan for the period 2000-2006 (see figure 1). The output variables of this research are Number of Patents and Annual Sales Then the input variables are R&D expenditures, number of employees and working capital. This allows identification of efficiency differentiators, which proves very useful for inefficient industries because it allows them to spot their weaknesses and improve performance. This study applies the DEA approach to reveal the extent to which inputs can be augmented while maintaining the same level of outputs. We employ window analysis to find out the long-term effectiveness in productivity. This study uses a DEA model to establish a foundation for measuring the efficiency of six high-tech industries in Hsinchu Science Park.

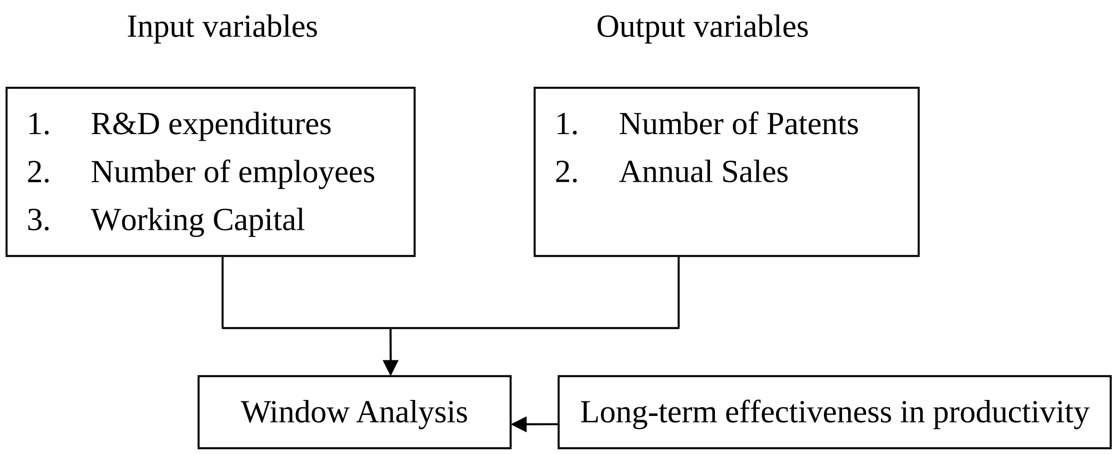

Figure 1 Research framework

4.2 Variable measurement and sample selection

Frontier models require the identification of inputs (resources) and outputs (transformation of resources). Several criteria can be used in their selection. The first of these, an empirical criterion, is availability. Secondly, the literature survey is a way of ensuring the validity of the research and thus represents another criterion to be taken into account. The samples of this research are six high-tech industries in Hsinchu Science Park, which are

Bio-tech, Photo-electronics, Communication, Computer, Precision equipment and Semiconductor. The period time of this research is from 2000 to 2006. There are 42 DMU totally. We use three input variables and two output variables. The input variables are R&D expenditures, number of employees and working capital, and the output variables are number of patents and annual sales. The sources of data are from the bureau of Hsinchu Science Park (as Appendix 1).

5. Empirical results

In this section, we conduct the correlation analysis and Window Analysis.

5.1 Correlation Analysis

A remark concerns the "isotonicity" relations which are assumed for DEA. When an increase in any input should not result in a decrease in any output. Consequently, the values of some factors may have to be inverted before they are entered into the analysis (Charnes, Cooper & Rhodes, 1978). This study applies coefficient of correlation (r) to test the "isotonicity". The correlations of the input/output data (correlation ratio) are show as Table 1. It can be understand the relation of DMU. It shows that all relationships between input variables and output variables are significant. From the correlation analysis may indicate that the five factors satisfy the requirement of isotonicity and are already represented and suitable for our research.

Table 1 correlation analysis

	R&D expenditures	Number of employees	Working Capital	Number of Patents	Annual Sales
R&D expenditures	1	.340(*)	.990(**)	.916(**)	.949(**)
Number of employees		1	.327(*)	.342(*)	.445(**)
Working Capital			1	.924(**)	.969(**)
Number of Pattens				1	.907(**)
Annual Sales					1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

5.2 Window analysis

DEA window analysis can be done by Excel Solver via Visual Basic application that proposed by Microsoft Company, 2003 Microsoft Company, (2003). Excel. Seattle, USA. In this paper, we assume constant returns to scale; that is, as all inputs double, all outputs will double. The window analysis enables us to identify the best and the worst industries in a relative sense, as well as the most stable and variable industries in DEA scores. The overall efficiency for each DMU is calculated by using CCR model, and the DEA window analysis is applied. The efficiency scores reported above are from panel data analyses, where the observations for six high-tech industries in Hsinchu Science Park in different years are treated as separate observations, and all measured against each other. This may not be a reasonable assumption because of technological improvements happening over the 7 year period under analysis, and that could make the comparison of units in different years unfair or unrealistic. The results above indicate this expected general tendency of improvements over time. To deal with the problem of unfair comparisons occurring when including all 7 years in the same analysis, we suggest using a window rather than a panel data approach, with a window width of 3 years. This means that observations are only compared to other observations within a 3-year time span.

The scores for an industry in different years within the same window show how the efficiency of an industry changes from one year to another. The column view shows the efficiency for the same year but measured against different windows, and illustrates the impact of changing the units used to generate the frontier.

The information in Table 2 can be used to compare the performance of the different banks as illustrated in Figure 2. Figure 2 shows the average efficiency score for the different industries for each window in the analysis.

Observing the average efficiency values, Semiconductor industry is the highest with a mean of 0.9849. On top of that, this Semiconductor industry has the lowest Standard division of 0.0279. In a highly variant demand changing environment, Semiconductor industry has a quite stabilized performance over the years.

The second best industry is Computer industry. It has relatively high efficiency over the periods, and their variances are not too big either; therefore, the overall performance of the system under Computer industry is quite stabilized too. Regarding the CR value, the best industry is Bio-tech industry, and the second best is Semiconductor industry. Semiconductor industry also has the best TR value of 0.0731, followed by Computer industry and Bio-tech industry.

From our research results, we can find out that the Semiconductor industry and Computer have the excellent performance and are relatively stabile. However, the semiconductor industry and computer industry face a profit and price declines. Each new process node demands tighter integration between chip designers, library designers and process engineers (Grant, 2008). Industrial practitioners for the semiconductor industry and computer industry should understand what the market’s needs are, providing unique and high-quality products and applying customer relationship management to continuously strengthen customer satisfaction and loyalty. In addition, they should re-structure supply chains and build up a virtual manufacturing network to counteract profit and price declines. Grant (2008) suggests that the industrial practitioner should design a flexible supply chain and develop a flexible and robust virtual manufacturing network. A supply-chain strategy employs a pull-oriented approach to the process. This strategy also aligns with an asset-lite manufacturing model where separate physical locations are used for distinct manufacturing processes. Then, the successful asset-lite manufacturing strategy combines the external network with an organization’s internal manufacturing capabilities. This combination can create a finely tuned, cross-functional, decision-making capability focused on making astute build-versus-buy decisions. Moreover, Taiwan’s Government also plays a critical role in grading up industrial level for semiconductor industry and computer industry. These two industries are belonging to mature industry. Therefore, we suggest that the Government agents should put efforts in promoting the international linkages and establishing broker framework for semiconductor industry and computer industry. Broker framework policies mean that public authorities can support the establishment of linkages between firms through the creation of platforms for dialogue (Andersson, Serger, Sörvik & Hansson, 2004). The platform also provides supports of knowledge-enhancing organization linkages through public-private partnership. Promotion of international linkages policy means that the elimination of trade barriers and strengthening of transport and communication systems, along with the harmonization of market regulations have greatly improved conditions of resource flows and enhanced specialization of value chain across national borders (Andersson, Serger, Sörvik & Hansson, 2004).

Taiwan's biotech industry has come of age in recent years. With the supporting infrastructure in place and with strong government backing, the island is poised to become Asia's hub for the life sciences. Taiwan's renowned IT, manufacturing and logistics strengths are being newly-utilized in such fields as biopharmaceutical manufacturing, medical devices design and manufacturing and Bio-IT. Bio-tech would be the next engine of growth for Taiwan's economy (Murray & Efendioglu, 2003). With growing interest from the government, businesses and venture capital firms, hopes are high in Taiwan that the factors which led to the island's strength in semiconductor manufacture and IT-related industries will also translate to Bio-tech. Taiwan government has identified and promoted research targets to build up an academic infrastructure and subsequently plans to interlink these centers to provide resources for the greater Taiwanese research community (Harris, 2002). They are looking forward to establish an industrial cluster for Bio-tech in the future. It is believed that industrial clusters can help to improve the performance of region economies by fostering innovation and strengthening the competitiveness of firms (Cappllin, 2004).An industry cluster is a group of firms and related economic actors and institutions located near one another and that draw productive advantage from their mutual proximity and connections (Cortright, 2006).

Furthermore, Taiwan has many strengths and competitive advantages. Taiwan that close to China and straddling Northeast and Southeast Asia is located at an important position in the Asia. Then, venture capital markets are important to industrial development and upgrading (Wonglimpiyarat & Yuberk, 2007). Venture Capital activity can help overcome agency and information problems among entrepreneurs, innovators and financiers. Taiwan has established a mature venture capital and incubation environment, as well as its people having high entrepreneurial capacity (Wonglimpiyarat & Yuberk, 2007).Venture capital has been an important source of financing for Taiwan’s start-ups, particularly in high-tech industries. Taiwan’s venture capital industry is the third most active venture capital market in the world, ranking behind the US and Israel. In the aftermath of the Asian Economic Crisis of 1997, Taiwan's SMEs have survived and built a stronger foundation for growth. The Bio-tech industry is still in pioneering sage for Taiwan industry (Chang & Shih, 2004). The human resource and government’s support and encouragement are the decisive and crucial drivers for Bio-tech industry. The demand side policy and training policy are required for Bio-tech industrial upgrading and development. Demand side policy aim at increasing openness to new ideas and innovative solutions. One instrument for demand side policy is public procurement (Andersson, Serger, Sörvik & Hansson, 2004). Public Procurement has a strong potential for developing and strengthening clusters. Training policy focuses on upgrading skills and competencies which are essential for effective cluster of SMEs. Apart from catalyzing inter-firm networks and university-industry linkages, cluster processes may strengthen the incentives for SMEs to upgrade their internal competencies. Special programs may be needed to realize and sharpening such effort (Andersson, Serger, Sörvik & Hansson, 2004).

Table 2　2000~2006 Total Efficiency-Window Analysis

	2000	2001	2002	2003	2004	2005	2006		Mean efficiency	Standard division	Total range
Bio-tech	0.2146	0.1888	0.1808					0.1947	0.2480	0.0901	0.2878
Bio-tech		0.2051	0.2067	0.1895				0.2004			
Bio-tech			0.1901	0.1866	0.2381			0.2049			
Bio-tech				0.1808	0.2381	0.3789		0.2659			
Bio-tech					0.2654	0.3876	0.4686	0.3739			
$CR_{1,m}$	x	0.0163	0.0259	0.0087	0.0273	0.0087	x	CR_1	0.0273		
Photo-electronics	0.7539	0.5498	0.7503					0.6847	0.8746	0.1315	0.4502
Photo-electronics		0.7757	0.9411	1.0000				0.9056			
Photo-electronics			0.8792	0.9504	1.0000			0.9432			
Photo-electronics				0.7921	0.8822	1.0000		0.8914			
Photo-electronics					0.8438	1.0000	1.0000	0.9479			
$CR_{2,m}$	x	0.2259	0.1908	0.2079	0.1562	0	x	CR_2	0.2259		
Communication	0.8506	0.7514	0.6827					0.7616	0.8571	0.0932	0.3173
Communication		0.8633	0.7835	0.8338				0.8269			
Communication			0.7616	0.8690	1.0000			0.8769			
Communication				0.8690	1.0000	0.8787		0.9159			
Communication					1.0000	0.8945	0.8189	0.9045			

$CR_{3,m}$	x	0.1119	0.1008	0.0352	0	0.0158	x	CR_3	0.1119		
Computer	1.0000	0.8130	1.0000					0.9377	0.9668	0.0669	0.1870
Computer		0.9839	1.0000	1.0000				0.9946			
Computer			0.9928	1.0000	1.0000			0.9976			
Computer				1.0000	1.0000	0.8212		0.9404			
Computer					1.0000	0.8910	1.0000	0.9637			
$CR_{4,m}$	x	0.1709	0	0	0	0.0698	x	CR_4	0.1709		
Precision equipment	1.0000	1.0000	0.7632					0.9211	0.8980	0.1380	0.3302
Precision equipment		1.0000	0.7111	0.9600				0.8904			
Precision equipment			0.9419	1.0000	0.6698			0.8706			
Precision equipment				1.0000	0.6698	1.0000		0.8899			
Precision equipment					0.7549	1.0000	1.0000	0.9183			
$CR_{5,m}$	x	0	0.2308	0.04	0.0851	0	x	CR_5	0.2308		
Semiconductor	1.0000	1.0000	0.9987					0.9996	0.9849	0.0279	0.0731
Semiconductor		1.0000	1.0000	1.0000				1.0000			
Semiconductor			1.0000	0.9269	1.0000			0.9756			
Semiconductor				0.9269	1.0000	0.9754		0.9674			
Semiconductor					1.0000	0.9451	1.0000	0.9817			
$CR_{6,m}$	x	0	0.0013	0.0731	0	0.0303	x	CR_6	0.0731		

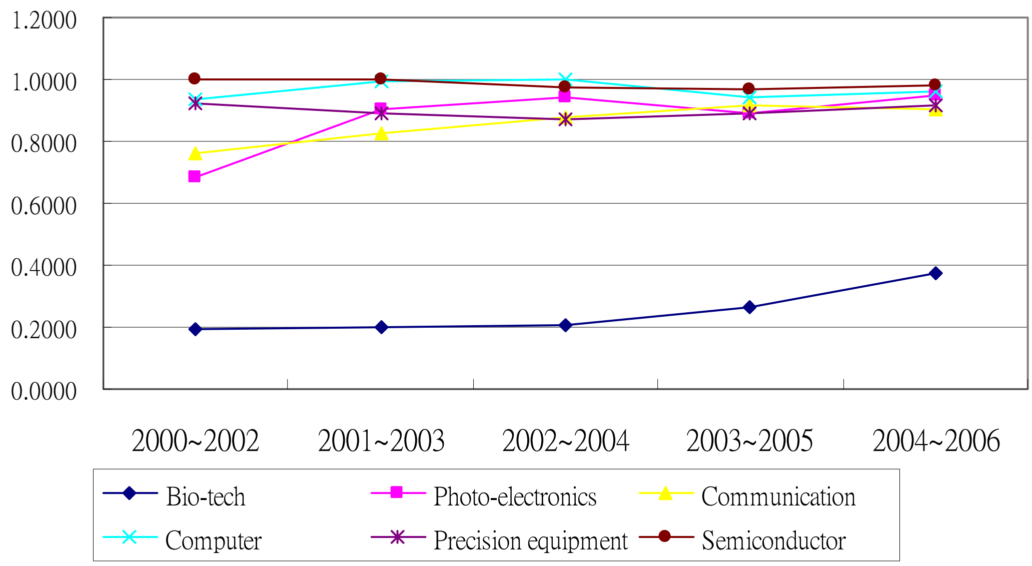

Figure 2　Window analysis

6. Conclusions

The study analyzes the operation efficiency of six high-tech industries in Hsinchu Science Park in Taiwan for the period 2000-2006. The study has indicated how use DEA approach to identify individual year that are less efficient that other comparable year in terms of output factors relative to input factors. The most recent style in measuring efficiency is Data Envelopment Analysis, which is a linear programming approach based on this concept. Data Envelopment Analysis measures the efficiency of Decision Making Units by doing linear programming for each in comparison to other units. Accordingly the Decision Making Units lie on frontier curve is efficient in choosing the optimal mixture of inputs to achieve the aimed level of outputs. Besides we make use of Data Envelopment Analysis to advise inefficient units by doing certain change in inputs and /or outputs to improve their efficiencies.

This paper applies DEA Windows Analysis in order to determine the efficiency of the world’s leading industries in Hsinchu Science Park in Taiwan over time. This approach is advocated in favor of the commonly used cross-sectional data analysis. We have shown how this approach enables the calculation of efficiency scores even for a small number of different units and a fairly large number of variables. We can use DEA Window Analysis to evaluate the efficiency of different industries under a long term and obtain a best industry that is relatively more efficient for performance. The issue of how same period efficiencies should be defined in a window analysis was discussed and illustrated empirically. In a situation which industries has made a recent investment to achieve beneficial results in the future, or simply just as a result of random effects, the traditional cross-sectional approach may produce misleading results. This study concludes that the efficiency of the different industries can fluctuate over time to different extents. Observing the average efficiency values from window analysis, Semiconductor industry is the highest with a mean of 0.9849. On top of that, this Semiconductor industry has the lowest Standard division of 0.0279. In a highly variant demand changing environment, Semiconductor industry has a quite stabilized performance over the years. The second best industry is Computer industry. It has relatively high efficiency over the periods, and their variances are not too big either; therefore, the overall performance of the system under Computer industry is quite stabilized too. Regarding the CR value, the best industry is Bio-tech industry, and the second best is Semiconductor industry. Semiconductor industry also has the best TR value of 0.0731, followed by Computer industry and Bio-tech industry. Indeed, the empirical results reveal that substantial inefficiency exists in some industries at some point in time. In consequence, this validates the necessity for using DEA Windows Analysis in preference to an analysis based upon cross-sectional data. By adopting the proposed mechanism, government or industries analyst can have a guidance regarding strategies for order management. Based on our research results, we also conclude that the practicer of semiconductor industry and computer industry should design a flexible supply chain and develop a flexible and robust virtual manufacturing network. Moreover, the Government agents should put efforts in promoting the international linkages and establishing broker framework for semiconductor industry and computer industry. On the other hand, Bio-tech industry has more potential in the future from our research result. The Bio-tech industry is still in pioneering sage for Taiwan industry. The human resource and government's support and encouragement are the decisive and crucial drivers for Bio-tech industry. The demand side policy and training policy are required for Bio-tech industrial upgrading and development.

There are two extensions to this study can be undertaken. First, although the input side of the DEA model considered three relevant input dimensions in our industry. Our study only considered two industry performance measures (namely, Number of Patents and Annual Sales) due to certain limitations in the numbers of variable associated with DEA implementation. Future studies should consider a more extensive set of business performance measures. Of particular interest would be a DEA model incorporating market-oriented measures such as market share and sales growth.

Second, in evaluating the relative efficiency scores using DEA, we did not restrict any input or output weights. This may affect the results if certain input or output measures are more important than others. In future research, it may be interesting to identify such weights to reflect relative importance and integrate them into the analysis. This would provide more robust results and conclusions.

Appendix 1 Descriptive of raw data

Variables / Industry(year)	R&D expenditures	Number of employees	Working Capital	Number of Patents	Annual Sales
Bio-tech (2000)	780	1.78	2,463	4	11.34
Bio-tech (2001)	265	1.88	3,073	3	13.35
Bio-tech (2002)	402	1.98	3,235	2	14.16
Bio-tech (2003)	443	2.18	4,586	11	18.41
Bio-tech (2004)	412	2.48	4,794	7	25.39
Bio-tech (2005)	438	2.96	3,194	4	29.97
Bio-tech (2006)	537	3.11	4,853	14	30.63
Mean	468.14	2.34	3742.57	6.43	20.46
Photo-electronics (2000)	4214	4.98	62,191	80	809.22
Photo-electronics (2001)	4427	3.86	97,668	145	623.55
Photo-electronics (2002)	3002	3.54	115,140	166	600.35
Photo-electronics (2003)	4630	4.86	133,856	353	943.35
Photo-electronics (2004)	6296	5.26	152,476	170	1,312.63
Photo-electronics (2005)	5379	5.25	106,955	494	1,372.64

Variables / Industry(year)	R&D expenditures	Number of employees	Working Capital	Number of Patents	Annual Sales
Photo-electronics (2006)	4949	5.7	206,832	681	1,605.98
Mean	4699.57	4.78	125016.86	298.43	1038.25
Communication (2000)	2363	6.92	24,499	12	507.7
Communication (2001)	3367	8.05	30,696	31	561.23
Communication (2002)	3337	8.23	34,083	23	565.58
Communication (2003)	2203	18.17	32,651	47	564.59
Communication (2004)	2595	10.72	25,985	41	605.3
Communication (2005)	2334	8.35	24,348	39	485.27
Communication (2006)	2454	7.91	26,164	92	452.65
Mean	2664.71	9.76	28346.57	40.71	534.62
Computer (2000)	6060	13.22	87,876	248	2,124.89
Computer (2001)	6443	12.05	99,426	366	1,610.71
Computer (2002)	4608	9.72	62,265	577	1,245.28
Computer (2003)	4570	10.97	63,633	952	1,347.71
Computer (2004)	5907	9.87	71,632	441	1,382.45
Computer (2005)	4684	8.12	71,867	259	1,018.80
Computer (2006)	4046	8	75,512	415	1,014.96
Mean	5188.29	10.28	76030.14	465.43	1392.11
Precision equipment (2000)	380	5.37	2,720	4	72.58
Precision equipment (2001)	101	5.69	2,714	26	47.97
Precision equipment (2002)	194	6.03	4,248	29	53.89
Precision equipment (2003)	256	6.11	5,389	56	57.89
Precision equipment (2004)	515	6.05	6,294	16	92.47
Precision equipment (2005)	610	6.89	3,494	12	98.18
Precision equipment (2006)	750	9.05	4,848	15	132.84
Mean	400.86	6.46	4243.86	22.57	79.40
Semiconductor (2000)	26268	9.42	514,734	2018	5,757.11
Semiconductor (2001)	44335	6.43	625,246	2420	3,757.19
Semiconductor (2002)	48364	7.55	691,024	1891	4,562.59
Semiconductor (2003)	46755	9.18	752,336	1607	5,632.75
Semiconductor (2004)	47671	11.22	788,924	2426	7,427.38
Semiconductor (2005)	54065	10.61	830,355	1535	6,851.10
Semiconductor (2006)	52149	11.56	843,711	1623	7,947.94
Mean	45658.14	9.42	720904.29	1931.43	5990.87

Reference

1. Andersson, Thomas, Sylvia Schwaag Serger, Jens Sörvik and Emily Wise Hansson (2004), T*he Cluster Policies Whitebook*, IKED.
2. Cappllin, R. (2004), *International knowledge and innovation networks for European integration, cohesion, and enlargement*, Unesco.
3. Castells, P. and P. Hall (1994), *Technopoles of the World: The Making of the 21st Century Industrial Complexes*, Routledge, London.
4. Chang, Shih-Chi, Che-Peng Lin and Mon-Sing Lou (2007), "A Study on the Dynamic Operational Efficiency Analysis of Taiwan's TFT-LCD Industry," *Taiwan Business Performance Journal*, 1(1), pp. 27-52.
5. Charnes, A., W. W. Cooper and E. Rhodes (1978), "Measuring the Efficiency of Decision Making Units," *European Journal of Operational Research*, 2(6), pp. 391-465.
6. Chen, C.-J. (2007). White Paper on Science and Technology, National Science Council Republic of China, Executive Yuan, available at: <http:web.nsc.gov.tw/public/data/74141117271.pdf>.
7. Colombo, Massimo G. and Delmastro, Marco (2002), "How effective are technology incubators? Evidence from Italy," *Research Policy*, 31, pp. 1103–1122.
8. Cortright, Joseph (2006), "*Making Sense of Clusters: Regional competitiveness and Economic Development*, " The Bookings Institution Metropolitan Policy Program.
9. Cullinane, Kevin, Dong Wook Song and Ping Ji (2004), "An Application of DEA Windows Analysis to Container Port Production Efficiency," *Review of Network*, 3(2), pp. 184-206.
10. Froot, K. A. and P. D. Klemperer (1989), "Exchange rate pass-through when market share matter," *American Economic Review*, 79(4), pp. 637-654.
11. Grant, Scott (2008), "*Using hybrid supply chains and virtual manufacturing to overcome profit and price declines*," Electronic Business.
12. Harris, Sara (2002), "Biotechnology: the next engine of growth for Taiwan's economy?" EMBO reports,7, pp. 598–600.
13. Hu, Tai-Shan, Chien-Yuan Lin and Su-Li Chang (2005), "Technology-based regional development strategies and the emergence of technological communities: a case study of HSIP, Taiwan," *Technovation*, 25 (4), pp. 367-380.
14. Kumbhakar, S. C. and C. Lovell (2000), "*Stochastic Frontier Analysis*," Cambridge: Cambridge University Press.
15. Lai, Hsien-Che and Joseph Z. Shyu (2005), "A comparison of innovation capacity at science parks across the Taiwan Strait: the case of Zhangjiang High-Tech Park and Hsinchu Science-based Industrial Park," *Technovation*, 25 (7), pp. 805–813.
16. Lin, Erica (2007), "*Mackay Center makes inroads in bio-tech industry*," Small and Medium Enterprise Administration, Ministry of Economics Affairs.

17. Lu, Jason (2008), “Global LED industry,” *Optolink*, 73, pp. 38-39.

18. Monck, C.S.P., R.B. Porter, P. Quintas, D.J. Storey and P. Wynarczyk (1988), *Science Parks and the Growth of High Technology Firms*, Croom Helm, London.

19. Murray, L. W. and Alev M. Efendioglu (2003), “Clustering and the development of Biotechnology in Taiwan,” *Conference in honour of Professor Sebastiano Brusco*, Modena, Italy. 12 -13,

20. Odeck, James (2000), “Assessing the relative efficiency and productivity growth of vehicle inspection services: An application of DEA and Malmquist indices,” *European Journal of Operational Research*,126 (3), pp. 501-514

21. Potworowski, J. Andre (2002), “*Creating and growing technology clusters: observations and best practices from NRC Managers engaged in the creation and development of technology based clusters*,” National Research Council Canada.

22. Shahooth, Khalid and Battall, Hussien (2006), “Data Envelopment analysis and window analysis in measuring and analyzing the relative cost efficiency of 24 Islamic banking institutions,” Scientific Journal of Administrative Development, 4, pp. 134-156.

23. Sun, Chin-Huang, Chih-Hung Tsai and Huei-Wen Chang (2006), “A Study on the Growth Strategy of Taiwan TFT-LCD Industry Using Competence-Based Growth Perspective,” East-Asia Review, 452, pp.71-82.

24. Thomas A Carbone (2000), “Measuring Efficiency of Semiconductor Manufacturing Operations using Data Envelopment Analysis (DEA),” *2000 IEEElSEMl Advanced Semiconductor Manufacturing Conferenc.*, pp 56-62.

25. Tulkens, H. and P. Vanden Eeckaut (1995), “Nonparametric Efficiency, Progress and Regress Measures for Panel-Data: Methodological Aspects,” *European Journal of Operational Research*, 80 (3), pp. 474-499.

26. Wonglimpiyarat, Jarunee and Napaporn Yuberk (2007), “Successes and failures in managing innovations: bridging the interface between technology and business,” *International Journal of Technology, Policy and Management*, 6(1), pp. 33-48.