國立交通大學

管理學院碩士在職專班經營管理組

碩士論文

全球半導體設備產業績效評估–隨機邊界法之應用

Performance Measurement for Semiconductor Equipment Industry

– a Stochastic Frontier Analysis Approach

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摘 要

本研究應用隨機邊界法，以兩階段模型，分別就公司獲利效率與市場效率等兩個面向，並納入兩個外生環境變數:產品市場區隔與公司國籍，來評估全球半導體設備產業的績效。實證研究以 32 家 DMU 為對象，蒐集三年(2006~2008)的面板資料；第一階段獲利效率投入項為員工數，研發費用與固定資產，產出項為營業額與股東權益報酬率；市場效率以獲利效率之產出項做為投入項，以每股盈餘(EPS)與股價淨值比(P/B)為產出，分別計算其效率值，並定義總體效率為獲利效率與市場效率之相乘項。研究結果顯示，各階段之技術無效率項皆佔有隨機邊界模型中之誤差組合項達百分之七十三以上。從產業面來看，日系設備公司之總體績效顯著高於歐美設備公司；產品為半導體前段設備之公司其總體績效亦顯著高於後段設備公司。就半導體設備產業而言，亞洲與歐美公司的經營績效有顯著差異；半導體前段製程設備公司與後段設備公司之經營績效亦有顯著差異。

關鍵詞: 隨機邊界法，半導體設備，技術無效率

Performance Measurement for Semiconductor Equipment Industry – a Stochastic Frontier Analysis Approach

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Abstract

The principle objective of this study is to measure and compare the performance of semiconductor equipment firms. A stochastic frontier approach, a two stages model, and 3 years panel data were employed to evaluate the performance. Profitability efficiency applies number of employee, fixed asset, and R&D expenditure as inputs, and total revenue and return to equity as outputs. These outputs are applied as inputs for marketability efficiency; the outputs are price to book ratio and earnings per share. Empirical study also considers two variables: market segment, and nationality for the environmental effect on the model. The results show that the technical efficiency term weights more than 73% in the error composite at each stage. The total efficiencies of Japanese firms are significant higher than the EU/US firms; the total efficiencies of the semiconductor front-end equipment firms are also significant higher than the back-end equipment firms.

Keywords: semiconductor equipment, performance measurement, technical efficiency, SFA

誌　　謝

本論文能夠順利完成，首先要感謝楊千老師的指導，為本論文擘劃出正確的方向，得以運用適當地計量經濟模型，結合理論與實務，以深入研究全球半導體設備產業之績效。其次要感謝劉顯仲、傅振華、林君信、胡均立、與林介鵬等諸位教授的審查，使本論文不足與疏漏之處得以補正。由衷感恩經管所師長們的敦敦教誨，滿足學生求知的渴望。雖然這兩年，身體是疲憊的，但心靈與學識卻是無比地富足。當然，家人的體諒與陪伴是支持的最大動力。感謝妻子 靜萍，辛苦的付出，讓我無後顧之憂。還有我親愛的同學們，能和大家一起學習是最快樂的事，謝謝你們。

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1. Introduction

1.1 Background and motivation

Gordon E. Moore (1965) introduced his observation and prediction of the long-term trend in semiconductor industry: the number of the components on the integrated circuit doubles in about every two years with the unit cost falling as the more components per circuit rises. It is so called the "Moore's Law" which is still tested valid today. For example, there are only 2,300 transistors per CPU but now an Intel Core 2 CPU has more than 100 million transistors on it. The more components per circuit means the more powerful a chip can perform. The size of the devise will be smaller. That is why the capability of a personal PC today is much better than a super computer in old days. It did dramatically change the way we live. Thanks to the effort, the researchers have made in the lab, but without putting their innovation to mass production, the application is limited. In reality, one has to balance the production yield and the cost. The production efficiency is constrained by the limitation of the equipment or tools we used. It is also true for the innovation of new technology. Semiconductor equipment makers have played an important role in the moving of the Moore's law. They do not just only invest in developing new equipments in house but also co-work closely with labs and IC manufacturing firms for the next generation of new production process. They also provide stable maintenance capacity to support the IC factory to smooth the production.

According to the forecast from IC Insights, the number of the percentage of equipments expenditure in its revenue for a IC manufacturing firm hits a record low in 2009. It is only 12 %. The number kept between 20-22 % from 2004 to 2007. The forecast says that the number will be still at low level: 12~13% in the next 3 years. Only big IC firms like Intel, TI, and TSMC are willing to invest more on their production line. The data provided by VLSI Research Inc. shows that the market volume of the IC & related equipments are about 32.6B in 2009. The sequential change is -24.7%. The equipments providers will face more serious competition and challenge in the future. Without good strategy to direct the company, many companies are hard to survive.

Table 1: VLSI annual sales by market segment

VLSI Record (US$)		
	2008	2009
Integrated Circuit	$214.1B	$199.4B
Sequent change	-1.7%	-1.9%
IC & Related equipment	$43.3B	$32.6B
Sequent change	-24.1%	-24.7%
Display equipment	$8.2B	$4.5B
Sequent change	+33.7%	-45.4%

Source: VLSI Research Inc.

1.2 Research purpose

The purpose of the study is to evaluate the performance of the firms in semiconductor equipment industry. With the study, we can identify the frontier line of the industry, and find out the efficiency and non-efficiency firms. The financial capital market was seriously hit by the collapse of the giant banking institutions. Firms are hard to gain money from the capital market and the demand is contracted. The free cash flow is a key for sustainable operations. Many firms started cutting a lot of expenditure in operation cost and shortened the investment in production lines. By minimizing the input factors or maximizing the output factors, a non-efficiency firm can become an efficiency one. The study provides a reference for management teams to understand the behavior and performance of their competitors. Then they can lean from them to make right decisions and strategies to face the challenge in the future.

1.3 The trend of semiconductor market

Demand:

According to the statistics from the Semiconductor Industry Association (SIA), global semiconductor sales began to decline in the 4th quarter of 2008 after six years of strong growth since 2001. The global financial crisis seriously hit the financial system and it caused many companies very hard to get financial support from financial market. Capacity addition has slowed and the trend and expected to continue into 2010.

The worldwide recession from the end of 2008 reduced the demand for semiconductors. The memory market was suffered in both prices and sales. For example, the average selling price of DRAM chip dropped sharply from US$3.81 in 2007 to US$1.5 in 2008, in response to significantly oversupply and inventory. The demand will remain poor as the financial crisis continues to hit the end-user industries, such as PC and mobile phone, which makes up about 60 % share of the demand for the semiconductor market.

The SIA projected that the global semiconductor sales in 2009 is around US$246.7 billion, resume to rise to US$264.9 billion in 2010, US$284.7 billion in 2011. The global sales listed by device type and region are list down in the table below.

Table 2 : Annual global semiconductor sales by products

Global semiconductor sales	*2007*	*2008*	*2009*	*2010*
By type (US$ Billions)				
Discrete semiconductors	16.8	17.7	16.9	17.4
Optoelectronics	15.9	18.0	18.5	19.7
Sensors	5.1	5.4	5.6	5.9
Integrated circuits	217.8	220.8	209.0	216.0
Analog	36.5	37.6	35.5	36.8
Micro	56.2	57.1	54.1	55.7
Logic	67.3	77.1	74.7	77.7
Memory	57.9	49.1	44.7	45.8
Total	256.6	261.9	250.1	259.0
% change	3.2	2.5	-4.5	3.6

Source: World Semiconductor Trade Statistics; EIU forecasts

Table 3 : Annual semiconductor sales by region

By region (US$ billions)	*2007*	*2008*	*2009*	*2010*
Asia /Pacific	123.5	132.9	131.9	137.1
Americas	42.3	38.9	35.1	36.4
Europe	41.0	40.7	37.5	38.6
Japan	48.8	49.4	45.7	46.9

Source: World Semiconductor Trade Statistics; EIU forecasts

Price:

As per the data from the Economist Intelligence Units which have tracked three main types of semiconductor prices, and the average selling price (ASP)of the integrated circuit from 2006, the ASP of IC tends to be much lower than the increasingly capacity and capability of flash memory, DRAM, and microprocessor. The ASP of the integrated circuit started to drop down from US$1.7 in 2007 due to the surplus capacity shrinks and over expand in inventory. The forecast expects the trend is downward until 2011 as the worldwide demand is contracted under recession and the supply side is still over capacity. Another force may drive the price up. It is the US dollar currency. After the G20 meeting in 2009, the major industry countries decided to inject more money in the financial market. The inflation rate is a potential problem especially the weak US dollars that are widely used for international trading for raw materials, oil, and many industry products. The price change is list down in the below table.

Table 4 : Semiconductor annual average selling price(ASP) change

Semiconductor prices (US$/unit)					
	2006	2007	2008	2009	2010
IC average	1.56	1.70	0.70	0.50	0.50
% change	-6.1	8.8	-58.8	-28.6	0.0
DRAM (all types)	3.58	1.50	3.81	1.10	1.02
% change	-4.4	-58.1	154.0	-71.1	-7.3
Flash Memory	4.53	1.80	4.45	1.30	1.20
% change	9.4	-60.3	147.2	-70.8	-7.7
Microprocessor	96.37	100.00	39.40	26.80	28.90
% change	-9.5	3.8	-60.6	-32.0	7.8

Sources: Economist Intelligence Unit; national statistics offices; Semiconductor Industry Association.

2. Literature review

2.1 Firm performance measurement

The issues of evaluating performance in firm level have been an important and interesting topics for researchers for a long time. A firm can be discriminated as excellent or non-excellent due to different criteria or indexes. One of the traditional ways to exam a firm's performance or production efficiency is to measure its financial performance. Woo and Willard (1983) analyzed the 14 quantitative financial variables in the PIMS database. The 14 variables are ROI, ROS, growth in revenues, cash flow/investment, market share, market share gain, new product activities relative to competitors, direct cost relative to competitors, product quality relative to competitors, R&D expenditure in product and process, variations in ROI, percentage point change in ROI and cash flow/investment. The results show that profitability factors such as return on investment (ROI), return on sales (ROS), are important measurements in performance. Though there are inherent problems in ROI, it is the essential comprehensive representation of performance. However, this kind of measurements relied on the financial accounting data. Accounting data are historic. They reflect the firm's short-term performance and only consider the stockholder's benefit. Firms have to carefully manage and purchase right strategies to increase their ability to response to the changes in environment. For example, one may heavily invested in R&D expenditure for innovations to capture the business opportunity in the future. It hurt its short-term profitability and the performance was poor compared to its rival. Chakravarthy (1986) analyzed the computer industry from 1964 to 1983 in U.S. and demonstrated the inadequacy of traditional measurements that are based on a firm's profitability for evaluating its strategy performance. Instead, Chakravarthy(1986) measured the quality of a firm's transformation to discriminate the excellent and non-excellent firms. The transformation processes that a firm pursued have two different types: adaptive specialization and adaptive generalization. Adaptive specialization emphasizes the power of a firm on profitably exploiting its current environment and generating a net surplus of the contribution to its stakeholders. Adaptive generalization focuses on the investment of a firm's net surplus of slack resources for improving its ability to face the future challenge and uncertainty (Cyert and March, 1963). The eight slack variables are cash flow/investment ratio, sales by total asset, R&D by sales ratio, market to book value, sales per employee, dept by equity ratio, working capital by sales ratio, and dividend payout ratio.

Boulding and Staelin (1995) provided an approach to assess general effects of strategy actions on firm performance. Before one can confidently gain the strategy generalization, he has to address and answer the following five questions:

1. What allows a firm to sustain strategy relationship in face of the competitive reactions?
2. Is it possible to find out the direction of causality in strategy relationship?
3. Can one identify the unobserved factors that influence firm performance and they correlate to strategy actions?
4. Are the strategy relationships measurable?
5. Are the strategy relationships unique to a particular firm? Or they are generalized over a wide range of conditions?

Empirically studying of the 2177 strategic business units for 4 years data in the PIMS (Profit Impact of Marketing Strategy) database, Boulding and Staelin concluded that the investment in R&D has positive effect on firm performance. The firms, which have high ability and motivation to leverage R&D asset, can increase the demand-side returns.

2.2 Empirical applications

Zhu (2000) provides a two stages model to evaluate the Fortune 500 firms in 1996. He selected eight financial variables which are provided by the Fortune magazine: number of employee, total asset, stockholder's equity, revenue, profits, market value, total return to investors, and earnings per share instead of using total revenue as a single index for ranking firms. The total efficiency of a firm can be decomposed by two stages by adopted these eight variables. Stage 1 considered the ability of a firm to make profitability. Stage 2 uses the output factors in stage 1 as input factors to measure the performance of a firm to make marketability from yhe view of investors. Then stage 3 evaluates the total performance. Empirical results showed that revenue-top-ranked firms do not necessarily have top-ranked performance in terms of profitability and marketability.

Tsai et al. (2006) reconcile diverse efficiency measures to characterize the productivity efficiency of 39 Forbes 2000 ranked global telecom firms. Empirical results indicated that top-ranked Forbes telecom firms are not the same as those having top-ranked OTE (CRS TE). The study also showed that Asia-Pacific telecom firms have better OTE than those in Europe and America but the differences are not significant. Another interesting found is that the stated-owned firms show relative high efficiency than privatized telecoms (except China) because they provide full service (fixed-line, mobile, and internet).

Chen et al. (2006) evaluated six high-tech industries: semiconductor, computer, communications, photo-electronics, precision equipment, and biotech in Taiwan's Hsin Chu Science Park. Empirical results show that the computer and semiconductor industry have the best performance in OTE while the other four industries are operated in inefficiency. Since the computer and semiconductor industries are the two major government supported policies and have had allocated many resources on them, the results confirmed that the investment were in the right direction.

Wong et al. (2007) applied two DEA model: technical efficiency and cost efficiency to evaluate the performance in supply chain. Fifty semiconductor firms listed in the database of Penang Development Corporation, Malaysia, were selected to be decision-making units (DMUs). The results indicated that not all technical efficiency firms are also al-locative efficient. The opportunity cost derived from the model combining with the scenario analysis on the mix input allocation can help manage do better decision for resources allocation and planning.

Hung et al. (2008) used the DEA approach with the classical radial measure, non-radial efficiency measure and efficiency achievement measure to characterize the productivity efficiency of the IC packaging/testing firms in Taiwan. The results showed that the inefficiencies in OTE of these firms are primarily due to pure technical (VRS TE) inefficiencies rather than scale inefficiencies. Further mergers and acquisitions in this industry are good business strategy to correct the scale inefficiency problem.

The input and output variables selected by the above papers are summarized in the below tale.

Table 5: Summary of Input / Output variables

AUTHOR	YEAR	INPUTS	OUTPUTS
Zhu, Joe	2000	stage1&3: Number of employees ; Total asset; Stockholder's equity; Stage2: Revenue; Profits;	Stage1: Revenue; Profits; Stage2&3: Market value; Total return to investors; EPS;
Tsai, Hsiang Chih, Chen, Chun-Mei and Tzeng, Gwo-Hshiung	2006	Total asset; Capital expenditure; Number of employees;	Revenue; EBITDA; EBIT;
Chen, Chung-Jen, Wu, Hsueh-Liang and Lin, Bou-Wen	2006	Number of emploees; R&D expenditure; Working capital; Land of area;	Revenue; Number of patterns
Wong, W. P. and Wong, K.Y.	2007	Internal manufacturing capacity(days); Cycle time(hour); Operating cost;	Revenue; On-time delivery rate;
Hung, Shiu Wan and Lu, Wen-Min	2008	Operating expenses; Cost of goods sold; Number of employees ; Fixed asset;	Revenue; Income before tax; Market Value;

Capital expenditure (CAPEX) is expense used for company to purchase newly physical asset or maintain the assets' current condition. It may include from factory roof to production equipments. The items counted in CAPEX are different from firms to firms. Adopted CAPEX as an input variable may cause large variation in our results. EBITDA is net income with interest, taxes, depreciation, and amortization added back to it. The disadvantage is the same with CAPEX. It's non-GAAP measure that allows firms to manipulate numbers.

3. Analytical Framework and Methodology

3.1 Analytical framework and hypothesis

This study adopted the concept of the two stage performance model proposed by Zhu (2000). A firm's performance can be measured in two dimensions. Stage 1 measures the efficiency to leverage its resources to generate profits. Stage 2 takes into account the value and potential of a firm from investors' view. According to the literature review, the investment on research and development is very important on firm's performance in hi-tech industry. It was selected as one of the inputs in the stage1. There are parametric and non-parametric methods to evaluate firm level performance. Though using DEA (data envelopment analysis) method does not need to know the specific function forms between outputs and inputs, it does not take into account the statistic noise of the observation data. The study employs the stochastic frontier analysis method and assumes that the output can be expressed as translog function form as inputs. The total efficiency of a firm is decomposed to profitability efficiency and marketability efficiency.

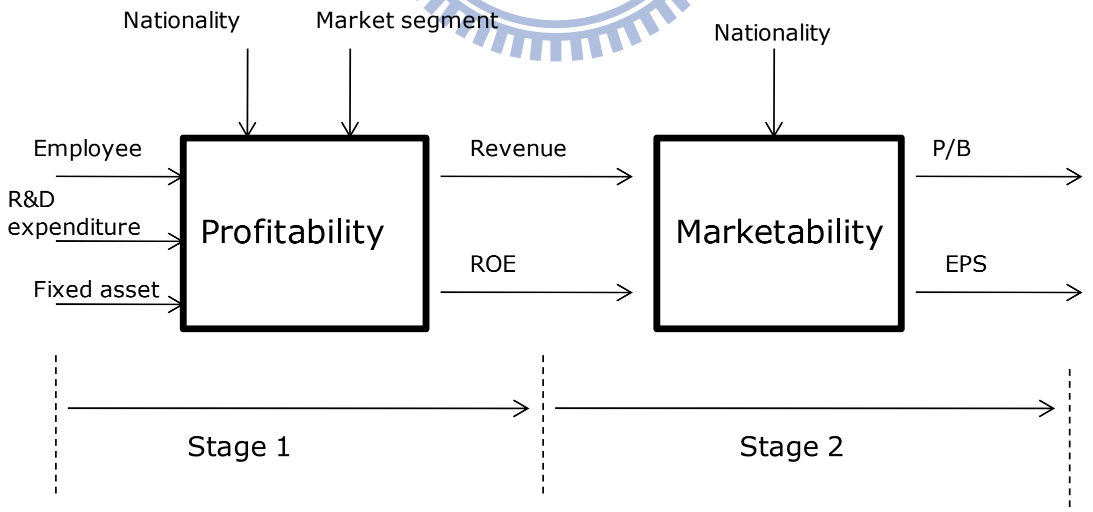

Figure 1: Research model

And defines the

Total efficiency = (Profitability efficiency) x (Marketability efficiency). (3.1)

The definitions and explanation of these variables are listed on the below table 6.

Table 6: Definition of variables

Variable	*Definition*
Stage1:Inputs	
Employee	The total number of employees in the year –end.
R&D	Firm's investment on research and development activities.
Fixed asset	Firm's long-term, tangible asset held for business use, such as equipment, real estate, and furniture.
Stage1:Outputs	
Revenue	Total amount of money received by the company for goods sold or services provided.
ROE	The amount of net income returned as a percentage of shareholders equity.
Stage 2:Inputs	The same as the outputs in stage1.
Stage2:Outputs	
P/B	Price to book ratio. Firm's share price divided by its book value per share. The value is calculated base on the data on 12/31.
EPS	Firm's net income divided by its total common shares outstanding.

Hypothesis:

As we are interesting in how the performances of these firms are affected by the two environment factors? We set up the following two hypothesizes:

H1: The performances of Japanese firms are different from EU/US firms'.

H2: The performance of the front-end firms and the back-end are different.

3.2 Data selection and Collection

The study uses the firms (DMU) listed in the library of the VLSI research Inc. There are 32 cross-sectional DMUs in each period, giving the total 96 DMUs. The numbers of input and output factors are financial release and withdraw from Thomson's data stream on- line database from year 2006 to 2008. All numbers are expressed in US dollar in thousands and the yen to U.S. dollar currency is the annual average number provided by Bank of Japan. In order to avoid the negative value for logarithm calculating, then we replace ROE as ROE+10, and EPS as EPS+3 for all periods. Since the data covers three years, so we deflated the financial variables by CPI (CPI=1, y2006)

All the input and output data are derived from Thomson Financial / Data stream on-line database.

Table 7: Currency

Year	USD to JPY*	CPI(2006=1)**
2006	116.20	NA
2007	117.60	2.85%
2008	102.46	5.85%

Source: * Foreign exchange rate on 11/29/2008: Bank of Japan.

** Data derived from Inflationdata.com

3.3 The stochastic frontier model for panel data

Consider a single output “y” which can be expressed as a production function of N inputs:

$$y = f(x_1, x_2 \ldots, x_N), \qquad (3.2)$$

Where y is the dependant variable, the x_n(n=1, 2… N) is explanatory variable.

A translog production function form has been widely employed by researchers.

$$y=\exp\left[\beta_0 + \sum_{n=1}^{N} \beta_n \ln x_n + \frac{1}{2}\sum_{n=1}^{N}\sum_{m=1}^{N} \beta_{mn} \ln x_n \ln x_m\right] \qquad (3.3)$$

If set all $\beta_{mn} = 0$, then the Cobb-Douglas production function is obtained.

Aigner et al., (1977), Meeusen and Van Broeck (1977), both independently proposed a stochastic frontier model which assumed that the technical inefficiency for an individual firm is time invariant.

An extended model proposed by Battese and Coelli(1992,1995) allows us to deal with the technical inefficiency term in time –varying levels. Since the technical inefficiency term is not constant, it’s important to seek how the variation is explanatory by appropriate environmental variables. Some early researchers like Pitt and Lee (1981) employed a so called two stages model. The first stage contains estimating the technical inefficiency in stochastic frontier model without considering the environmental variables. The second stage is to regress the predicted technical inefficient effects on the environmental variables. However this approach violates the consistent assumptions regarding to the identical distribution of the technical efficiency variation in these two estimation stages. To avoid this inconsistent problem, Battese and Coelli (1992, 1995) introduced a one stage method for dealing with panel data. The efficiency effects of the observable environmental variables are directed incorporated into the stochastic frontier model.

Consider a single output y in the i th firm (i=1.., N) and at period t (t=1.., T),

$$y_{it} = \exp(x'_{it}\beta + v_{it} - \mu_{it}) \quad , \qquad (3.4)$$

$$\mu_{it} = z_{it}\delta + W_{it} \qquad (3.5)$$

Where

x'_{it} : a (1 x k) vector of inputs.

v_{it} : Statistic error of the normal distribution. It can be negative or positive.

u_{it} : Non-negative random variable associated with technical inefficiency of production. It is truncated at zero of the normal distribution, N~ $(z_{it}\delta, \sigma^2)$.

β : (k x 1) vector of unknown parameters to be estimated.

z_{it} : (1 x m) vector of explanatory variables associated with technical inefficiency of production of firms over time.

δ : (m x 1) vector of unknown coefficients.

W_{it}: defined by the truncation of the normal distribution, N~ (0, σ^2).

Equation (3.4) specifies the stochastic production function as a form of the original function. Equation (3.5) specifies the technical inefficiency effects. The U_{it}s which are assumed to be a function of the explanatory environmental variables, z_{it}s and the unknown vector of coefficients, δ.

The method of maximum likelihood is proposed for simultaneous estimation of these parameters of the stochastic frontier model. The parameters, $\sigma^2 = \sigma_v{}^2 + \sigma_u{}^2$ and $\gamma = \sigma_v{}^2$ / $(\sigma_v{}^2 + \sigma_u{}^2)$, defined by Battese and Corra (1977), are also obtained with the calculation of the maximum likelihood estimation.

3.4 Distance Function

Equation (3.3) is a case of single output production function. In reality, the majority of econometric cases are multiple outputs production problem with a set of combinations of multiple inputs. A distance function approach was adopted by many researchers (e.g. Lovell et al., 1994).

The output distance function defined by Shephard (1970) is as below:

$$Do(x, y) = \min \{ \theta : \left(\frac{y}{\theta}\right) \in P(x) \} \quad (3.6)$$

$$\text{Where } P(x) = \{ y \in R_{+}^{M} : x \text{ can produce } y \} \; ; x \in R_{+}^{K} \quad (3.7)$$

If $Do(x, y) < 1$, it means that y belongs to production possibility set of $y \in P(x)$, and if $Do(x, y) = 1$, it means that y is on the frontier of the production possibility set of P(x). Then the stochastic distance function form can be specified as:

$$Do(x, y) = f(x, y, \delta) \; e^{\nu} \quad (3.8)$$

Where δ is an unknown parameters to be estimated, and ν is a random variable to catch the statistical noise and measurement error. $\nu \sim N(0, \sigma_{\upsilon}^{2})$.

Many researchers (e.g. Grosskopf et al., 1996; Coelli and Perelman, 2000) have employed the translog formula form as the f(.) in equation (3.8) for study. Consider the nth firm in the sample, the translog distance function with M outputs and J inputs can be specified as:

$$\ln D_{on} = \alpha_0 + \sum_{m=1}^{M} \alpha_m \ln y_{mn} + \frac{1}{2} \sum_{m=1}^{M} \sum_{k=1}^{M} \alpha_{mk} \ln y_{mn} \ln y_{kn} + \sum_{j=1}^{J} \beta_j \ln x_{jn} + \frac{1}{2} \sum_{j=1}^{J} \sum_{h=1}^{J} \beta_{jh} \ln x_{jn} \ln x_{hn} + \sum_{m=1}^{M} \sum_{j=1}^{J} \lambda_{mj} \ln y_{mn} \ln x_{jn} + \nu_n, \; n = 1, \dots, N, \quad (3.9)$$

The restriction of linear homogeneity in outputs requires:

$$\sum_{m=1}^{M} \alpha_m = 1, \sum_{k=1}^{M} \alpha_{mk} = 0, m = 1, \dots, M; = 0, m = 1, \dots, M; \text{and } \sum_{m=1}^{M} \lambda_{mj} = 0, j = 1, \dots, J. \quad (3.10)$$

The restriction of symmetry requires:

$$\alpha_{mk} = \alpha_{km},\ \ m, k = 1, \ldots, M, \text{and } \beta_{jh} = \beta_{hj},\ \ j, h = 1, \ldots, J. \qquad (3.11)$$

To solve the unobservable dependent variableD_{on}, we impose the linear homogeneity in outputs. Equation (3.9) becomes:

$$\ln \frac{D_{on}}{y_{Mn}} = \propto_0 + \sum_{m=1}^{M-1} \alpha_m \ln {y^*}_{mn} + \frac{1}{2} \sum_{m=1}^{M-1} \sum_{k=1}^{M-1} \propto_{mk} \ln {y^*}_{mn} \ln {y^*}_{kn} +$$

$$\sum_{j=1}^{J} \beta_j \ln x_{jn} + \frac{1}{2} \sum_{j=1}^{J} \sum_{h=1}^{J} \beta_{jh} \ln x_{jn} \ln x_{hn} + \sum_{m=1}^{M-1} \sum_{j=1}^{J} \lambda_{mj} \ln {y^*}_{mn} \ln x_{jn} + \nu_n,$$

$$n=1,\ldots, N, \qquad (3.12)$$

where $ {y_i}^* = \frac{y_i}{y_M}$

Then equation (3.12) can be rewritten as:

$$-\ln y_{Mn} = \propto_0 + \sum_{m=1}^{M-1} \alpha_m \ln {y^*}_{mn} + \frac{1}{2} \sum_{m=1}^{M-1} \sum_{k=1}^{M-1} \propto_{mk} \ln {y^*}_{mn} \ln {y^*}_{kn}$$

$$+ \sum_{j=1}^{J} \beta_j \ln x_{jn}$$

$$+ \frac{1}{2} \sum_{j=1}^{J} \sum_{h=1}^{J} \beta_{jh} \ln x_{jn} \ln x_{hn}$$

$$+ \sum_{m=1}^{M-1} \sum_{j=1}^{J} \lambda_{mj} \ln {y^*}_{mn} \ln x_{jn} + \nu_n - \ln D_{on}, \qquad n = 1, \ldots, N, \quad (3.13)$$

Replace$(-\ln D_{on})$ with u_n. And u_n is assumed to be iid of ν_n, and truncated at zero of $N(u, {\sigma_\mu}^2)$. The predicted value of $\widehat{D_{on}}$ can't be obtained directed because it is only part of the composed error term, $\varepsilon_n = \nu_n + u_n$. Then the predicted value of $\widehat{D_{on}}$ can be predicted by given the condition of $\varepsilon_{n.}$

$$\widehat{D_{on}} = E[\exp(-u_n)|\varepsilon_n] \quad (3.14)$$

The parameters in Equation (3.13) can be estimated by using the maximum likelihood method [Coelli and Perelman, 2000].

4. Empirical Results

4.1. Descriptive statistic

This study is targeted at 20 Japanese firms, and 12 EU/US firms, giving total 32 cross-sectional DMUs. These 32 DMUs can be classified into two categories: market segmentation and nationality. The market of the semiconductor equipment industry is typically divided into two segments: front-end and back-end, according to its different application. For considering the other environmental effect: nationalities, these 32 DMUs are also classified into two groups by their ownership: EU/US, and JP. In our model, two stages approach is employing for evaluating the performance. The seven put/output factors are number of employee, fixed asset, R&D expenditure, revenue, ROE, EPS, and price to book ratio; and the two environmental variables are z1(country/region), and z2(market segment). The period is from year 2006 to 2008, giving total 672 observations. Table 8 shows the DMU's classification by two environmental variables. Table 9 is the descriptive statistics of the sample sets. Table 10 provides us a ranking list of these DMUs by their revenue in each period.

Table 8: DMUs classified by environmental variables

z1:country/region		z2:market segment	
DMU (EU/US)	DMU(JP)	DMU(Front-end)	DMU(Back-end)
AGILENT TECHS.	ADVANTEST	APPLIED MATS.	AGILENT TECHS.
APPLIED MATS.	JEOL	ASM INTERNATIONAL	CASCADE
ASM INTERNATIONAL	NISSIN ELECTRIC	ASML HLDG.ADR 1:1	KULICKE & SOFFA INDS.
ASML HLDG.ADR 1:1	DAINIPPON SCREEN	DISCO	LTX-CREDENCE
CASCADE	SHINKAWA	FEI	NANOMETRICS
DISCO	TOKYO ELECTRON	KEITHLEY INSTRUMENTS	OXFORD INSTRUMENTS
FEI	TOWA	KLA TENCOR	RUDOLPH TECHS.
KEITHLEY INSTRUMENTS	ULVAC	LAM RESEARCH	TERADYNE
KLA TENCOR	Seiko Epson	NOVELLUS SYSTEMS INC	VERIGY
KULICKE & SOFFA INDS.	Cannon	VARIAN SEMICON.EQU.	ADVANTEST
LAM RESEARCH	Nikon	VEECO INSTRUMENTS	SHINKAWA
LTX-CREDENCE	Hitachi KoKusai Electric	JEOL	TOKYO ELECTRON
NANOMETRICS		NISSIN ELECTRIC	TOWA
NOVELLUS SYSTEMS INC		DAINIPPON SCREEN	ULVAC
OXFORD INSTRUMENTS		Cannon	Seiko Epson
RUDOLPH TECHS.		Nikon	
TERADYNE		Hitachi KoKusai Electric	
VARIAN SEMICON.EQU.			
VEECO INSTRUMENTS			
VERIGY			
Total: 20	Total:12	Total:17	Total:15

Table 9: Descriptive statistics of the input/output variables

variable	year	Minimum	Maximum	Mean	Std. Dev.	Valid N
Outputs						
y1: Total revenue	'06	96,374.00	35,772,452.67	3,211,334.16	6,533,220.95	32
	'07	143,658.00	38,106,658.16	3,442,385.75	6,879,919.71	32
	'08	102,101.00	39,958,627.76	3,564,214.60	7,262,158.68	32
y2: ROE	'06	-40.85	219.40	17.30	41.32	32
	'07	-9.24	53.32	13.55	13.67	32
	'08	-83.15	29.74	0.97	23.69	32
y3:P/B	'06	1.19	10.17	3.18	1.73	32
	'07	1.11	9.23	3.18	1.96	32
	'08	0.52	4.94	2.04	1.18	32
y4:EPS	'06	0.30	6.27	3.87	1.40	32
	'07	0.20	7.85	4.23	1.51	32
	'08	0.54	8.80	4.00	2.00	32
Inputs						32
x1: R&D expenditure	'06	5,097.71	2,653,243.55	276,307.30	506,341.31	32
	'07	3,070.65	3,131,470.24	306,456.10	581,829.18	32
	'08	7,293.07	3,650,448.96	342,986.49	667,472.17	32
x2: Employee	'06	418.00	118,499.00	10,800.97	25,334.23	32
	'07	436.00	131,352.00	11,426.88	26,866.66	32
	'08	465.00	166,980.00	12,744.56	32,322.55	32
x3:Fixed Asset	'06	14,425.00	10,898,666.09	704,497.62	1,974,926.25	32
	'07	13,699.00	11,604,608.84	733,328.81	2,072,322.28	32
	'08	13,152.00	13,246,008.20	825,761.66	2,353,412.97	32

Notes: Total revenue, R&D expenditure, and fixed asset are numbers in $1000US. EPS is number in $US. The numbers of y1, y2, y4, x1, and x3 are adjusted by annual inflation rate for each period.

Table 10: Annual revenue ranking

Rankin	*2006*	*2007*	*2008*
1	Cannon	Cannon	Cannon
2	Seiko Epson	Seiko Epson	Seiko Epson
3	APPLIED MATS.	APPLIED MATS.	Nikon
4	Nikon	TOKYO ELECTRON	TOKYO ELECTRON
5	TOKYO ELECTRON	Nikon	APPLIED MATS.
6	AGILENT TECHS.	AGILENT TECHS.	AGILENT TECHS.
7	ASML HLDG.ADR 1:1	ASML HLDG.ADR 1:1	ASML HLDG.ADR 1:1
8	DAINIPPON SCREEN MNFG.	KLA TENCOR	DAINIPPON SCREEN MNFG.
9	ADVANTEST	DAINIPPON SCREEN MNFG.	KLA TENCOR
10	KLA TENCOR	LAM RESEARCH	LAM RESEARCH
11	ULVAC	ULVAC	ULVAC
12	NOVELLUS SYSTEMS INC	ADVANTEST	Hitachi KoKusai Electric
13	LAM RESEARCH	Hitachi KoKusai Electric	ADVANTEST
14	TERADYNE	NOVELLUS SYSTEMS INC	TERADYNE
15	Hitachi KoKusai Electric	ASM INTERNATIONAL	ASM INTERNATIONAL
16	ASM INTERNATIONAL	TERADYNE	NISSIN ELECTRIC
17	JEOL	VARIAN SEMICON.EQU.	NOVELLUS SYSTEMS INC
18	VERIGY	JEOL	JEOL
19	NISSIN ELECTRIC	NISSIN ELECTRIC	DISCO
20	VARIAN SEMICON.EQU.	VERIGY	VARIAN SEMICON.EQU.
21	KULICKE & SOFFA INDS.	DISCO	VERIGY
22	DISCO	KULICKE & SOFFA INDS.	FEI
23	FEI	FEI	CASCADE
24	CASCADE	CASCADE	VEECO INSTRUMENTS
25	VEECO INSTRUMENTS	VEECO INSTRUMENTS	KULICKE & SOFFA INDS.
26	SHINKAWA	SHINKAWA	SHINKAWA
27	LTX-CREDENCE	TOWA	TOWA
28	RUDOLPH TECHS.	OXFORD INSTRUMENTS	OXFORD INSTRUMENTS
29	TOWA	RUDOLPH TECHS.	KEITHLEY INSTRUMENTS
30	OXFORD INSTRUMENTS	LTX-CREDENCE	LTX-CREDENCE
31	KEITHLEY INSTRUMENTS	NANOMETRICS	RUDOLPH TECHS.
32	NANOMETRICS	KEITHLEY INSTRUMENTS	NANOMETRICS

4.2. Coefficient and TE

Following, we describe the distance production function forms applied in our model.

<u>Stage 1: Profitability efficiency</u>

According to the equation (3.10), the distance function at stage 1 can be specified as below:

$$-\ln(\mathrm{ROE}) = \alpha_{0}+\alpha_1 \ln\left(\frac{\mathrm{revenue}}{\mathrm{ROE}}\right) + \beta_1 \ln(\mathrm{R\&D}) + \beta_2 \ln(\mathrm{employee}) + \beta_3 \ln(\mathrm{F.asset}) + \frac{1}{2}\alpha_{11}[\ln\left(\frac{R\&D}{\mathrm{ROE}}\right)]^2 +$$

$$\frac{1}{2}\beta_{11}[\ln(\mathrm{R\&D})]^2 + \frac{1}{2}\beta_{22}[\ln\,(\mathrm{employee})^2 + \frac{1}{2}\beta_{33}[\ln(\mathrm{F.asset})]^2 + \beta_{12}\ln(\mathrm{R\&D})\ln(\mathrm{employee}) +$$

$$\beta_{13}\ln(\mathrm{R\&D})\ln(\mathrm{F.asset}) + \beta_{23}\ln(\mathrm{employee})\ln(\mathrm{F.asset}) + \lambda_{11}\ln(\mathrm{R\&D})\ln\left(\frac{\mathrm{revenue}}{\mathrm{ROE}}\right) +$$

$$\lambda_{12}\ln(\mathrm{employee})\ln\left(\frac{\mathrm{revenue}}{\mathrm{ROE}}\right) + \lambda_{13}\ln(\mathrm{F.asset})\ln\left(\frac{\mathrm{revenue}}{\mathrm{ROE}}\right) + \upsilon_1 - u_1 \qquad (4.1)$$

And the external environmental effects on the technical inefficiency can be specified as:

$$u_1 = \delta_{10} + \delta_{11}z_1 + \delta_{12}z_2 + \omega_1 \qquad (4.2)$$

Stage 2: Marketability efficiency

The distance function at stage 2 can be specified as:

$$-\ln(\mathrm{PB}) = \alpha_{0+}\alpha_1 \ln\left(\frac{\mathrm{EPS}}{\mathrm{PB}}\right) + \beta_1 \ln(\mathrm{revenue}) + \beta_2 \ln(\mathrm{ROE}) + \frac{1}{2}\alpha_{11}[\ln\left(\frac{\mathrm{EPS}}{\mathrm{PB}}\right)]^2 + \frac{1}{2}\beta_{11}[\ln(\mathrm{revenue})]^2 + \frac{1}{2}\beta_{22}[\ln\,(\mathrm{ROE})^2 + \beta_{12} \ln(\mathrm{ROE}) \ln(\mathrm{revenue}) + \lambda_{11} \ln(\mathrm{revenue}) \ln\left(\frac{\mathrm{EPS}}{\mathrm{PB}}\right) + \lambda_{12} \ln(\mathrm{ROE}) \ln\left(\frac{\mathrm{EPS}}{\mathrm{PB}}\right) + \upsilon_2 - u_2 \quad (4.3)$$

And the external environmental effects on the technical inefficiency at stage 2 can be specified as:

$$u_2 = \delta_{20} + \delta_{22} z_2 + \omega_2 \quad (4.4)$$

Base on the equation 4.1~4.4 described above, a maximum likelihood method is employed to estimate the unknown coefficients. The software program: Frontier 4.1 which is developed by Tim Coelli has been widely applied for calculation. The results of the estimated unknown parameters at stage1 are showed on Table 11

Table 11: Coefficients at stage1 (profitability)

	Stage1:Profitability		
variable	coefficient	standard-error	t-ratio
constant	-1.2867068*	0.998	-1.290
ln(revenue/ROE)	1.3962613***	0.563	2.480
ln(R&D)	-0.42606901*	0.291	-1.463
ln(employee)	-1.8559723***	0.376	-4.936
ln(F. asset)	0.133	0.376	0.355
0.5 x [ln(revenue/ROE)]^2	0.47712463***	0.164	2.904
0.5 x ln(R&D)^2	-0.038	0.055	-0.699
0.5 x ln(employee)^2	0.51237364***	0.122	4.213
0.5 x ln(F.asset)^2	-0.1776385**	0.093	-1.905
ln(R&D) x ln(employee)	0.15840376**	0.072	2.214
ln(R&D) x ln(F. asset)	0.020	0.045	0.438
ln(employee) x ln(F. asset)	0.13931386***	0.055	2.555
ln(R&D) x ln(revenue/ROE)	-0.087417766*	0.062	-1.410
ln(employee) x ln(revenue/ROE)	-0.66327545***	0.122	-5.435
ln(F. asset) x ln(revenue/ROE)	0.074	0.108	0.686
Constant	-1.9112467*	1.154	-1.656
Z1: nationality	-0.069	0.190	-0.365
Z2: market segment	-3.0256931**	1.769	-1.710
sigma-squared	0.388	0.190	2.039
gamma	0.957	0.030	31.623

*Significant at 10 % level

**Significant at 5 % level

***Significant at 1 % level

Note: Coefficients are calculated under homogeneity condition. N=96.

log likelihood function = 0.34238212E+02

The gamma value is 0.957 means that 95.7 % of the error composition term is due to technical inefficiency, and 4.3% is due to statistic noise. The coefficient of the environmental variable z_2 is -3.0256931, giving a significantly negative effect on technical inefficiency u_1.

However the coefficient of z1 is -0.069 and the t-ratio indicates that the result is not significant at 10% level. This result shows that by giving the same inputs, EU/US firms have same efficiency to make profits as Japanese firms.Table 12 is the estimated results of unknown parameters at stage 2.

Table 12: Coefficients at stage 2 (Marketability)

	Stage 2: Marketability		
variable	coefficient	standard-error	t-ratio
constant	-11.412342*	7.326	-1.558
ln(EPS/PB)	-0.030	0.667	-0.045
ln(Revenue)	-19.666486*	12.995	-1.513
ln(ROE)	21.098353*	13.590	1.552
0.5 x [ln(EPS/PB)]^2	0.337	0.094	3.596
0.5 x ln(Revenue)^2	-67.172	80.663	-0.833
0.5 x ln(ROE)^2	208.17297**	92.206	2.258
ln(Revenue) x ln(ROE)	-70.549	71.493	-0.987
ln(Revenue) x ln(EPS/PB)	-31.278309**	17.447	-1.793
ln(ROE) x ln(EPS/PB)	31.317044**	17.446	1.795
Constant	0.311	0.277	1.121
Z2:market segment	-0.17942971**	0.093	-1.938
sigma-squared	0.115	0.019	6.024
gamma	0.739	0.261	1.453

*Significant at 10 % level

**Significant at 5 % level

***Significant at 1 % level

Note: Coefficients are calculated under homogeneity condition. N=96.

log likelihood function = -0.29630460E+02

The gamma value at stage 2 is 0.739 which means that 73.9% of the error composition term is due to technical inefficiency, and 22.1% is due to statistic noise. The coefficient of the external environmental variablez_2 is -0.17942971, giving a significantly negative effect on the technical inefficiency u_2. The t-ratio indicates that the result is significant at 5 % level.

Base on these results, the model can be modified as:

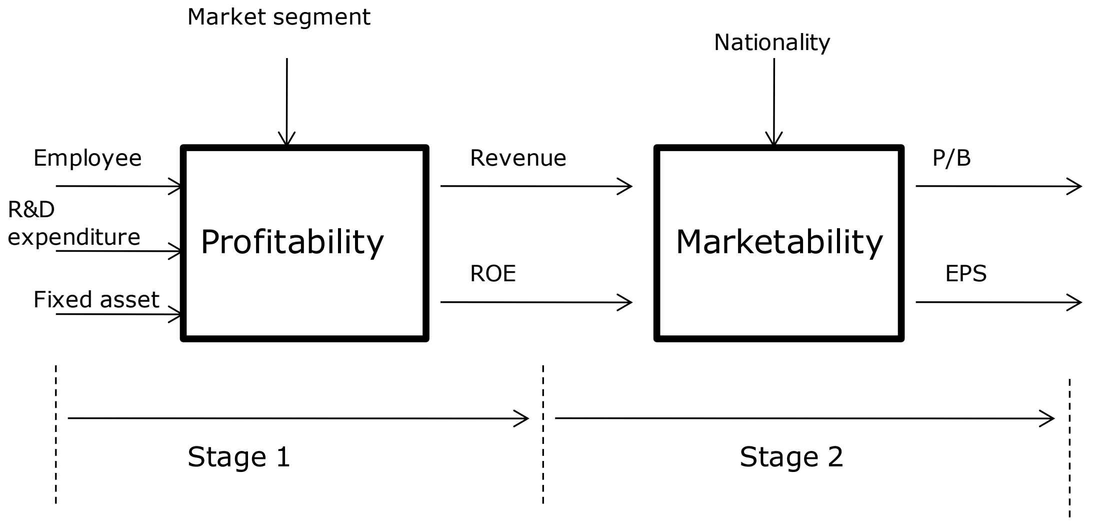

Figure 2: Modified research model

The values of the technical efficiency of the firms, TE_1, TE_2 and TE_t at each stage are shown at Table 13.

Table 13: Annual technical efficiency at each stage

	year	2006			2007			2008		
	DMU	TE1	TE2	TE t	TE1	TE2	TE t	TE1	TE2	TE t
1	AGILENT TECHS.	0.6434	0.4901	0.3153	0.9328	0.5076	0.4735	0.9170	0.5190	0.4759
2	APPLIED MATS.	0.9547	0.5914	0.5646	0.9366	0.6279	0.5881	0.9620	0.6622	0.6371
3	ASM INTERNATIONAL	0.9403	0.5643	0.5306	0.9191	0.5695	0.5234	0.9259	0.6594	0.6106
4	ASML HLDG.ADR 1:1	0.9177	0.5622	0.5159	0.9142	0.5625	0.5142	0.9351	0.6159	0.5759
5	CASCADE	0.8109	0.4436	0.3597	0.8301	0.4327	0.3592	0.8392	0.4095	0.3437
6	DISCO	0.9137	0.5474	0.5002	0.9220	0.5240	0.4831	0.9219	0.5454	0.5028
7	FEI	0.9307	0.6075	0.5654	0.9112	0.5858	0.5338	0.9496	0.6683	0.6346
8	KEITHLEY INSTRUMENTS	0.9367	0.5754	0.5390	0.9549	0.5812	0.5550	0.9536	0.6329	0.6035
9	KLA TENCOR	0.9594	0.6242	0.5989	0.9456	0.5482	0.5184	0.9579	0.5686	0.5446
10	KULICKE & SOFFA INDS.	0.3952	0.4041	0.1597	0.8759	0.4124	0.3612	0.9433	0.5235	0.4938
11	LAM RESEARCH	0.9392	0.5402	0.5073	0.8385	0.4849	0.4066	0.9048	0.5279	0.4776
12	LTX-CREDENCE	0.7815	0.4775	0.3732	0.9339	0.4699	0.4388	0.9299	0.4896	0.4552
13	NANOMETRICS	0.9324	0.5304	0.4945	0.8701	0.5242	0.4561	0.9533	0.5343	0.5094
14	NOVELLUS SYSTEMS INC	0.9483	0.5849	0.5546	0.9464	0.5958	0.5639	0.9672	0.7828	0.7571
15	OXFORD INSTRUMENTS	0.9350	0.4904	0.4585	0.9237	0.4645	0.4291	0.9187	0.3516	0.3230
16	RUDOLPH TECHS.	0.7815	0.5056	0.3951	0.8994	0.5091	0.4578	0.9509	0.5965	0.5672
17	TERADYNE	0.9116	0.5688	0.5186	0.9349	0.5896	0.5512	0.9738	0.7992	0.7783
18	VARIAN SEMICON.EQU.	0.9192	0.5985	0.5501	0.8724	0.4876	0.4254	0.8643	0.6071	0.5247
19	VEECO INSTRUMENTS	0.9341	0.5443	0.5084	0.9392	0.5506	0.5171	0.9538	0.7890	0.7525
20	VERIGY	0.8855	0.6007	0.5319	0.8599	0.5132	0.4414	0.8991	0.5899	0.5304
21	ADVANTEST	0.8683	0.6198	0.5381	0.9152	0.6563	0.6006	0.9284	0.7279	0.6758
22	JEOL	0.9425	0.8405	0.7922	0.9396	0.8299	0.7798	0.9414	0.8624	0.8119
23	NISSIN ELECTRIC	0.9490	0.8201	0.7783	0.9455	0.8540	0.8075	0.9456	0.8462	0.8002
24	DAINIPPON SCREEN	0.9152	0.7834	0.7170	0.9153	0.8088	0.7403	0.9017	0.8640	0.7791
25	SHINKAWA	0.6243	0.6696	0.4180	0.6162	0.6714	0.4137	0.7306	0.7386	0.5396
26	TOKYO ELECTRON	0.8860	0.6616	0.5862	0.7973	0.6040	0.4816	0.8602	0.5903	0.5077
27	TOWA	0.9587	0.8144	0.7807	0.8665	0.6923	0.5999	0.8599	0.6869	0.5906
28	ULVAC	0.8538	0.7057	0.6025	0.9108	0.7142	0.6504	0.9308	0.7646	0.7117
29	Seiko Epson	0.9226	0.8797	0.8115	0.9053	0.8332	0.7544	0.9196	0.7880	0.7247
30	Cannon	0.9374	0.7946	0.7449	0.9144	0.7939	0.7259	0.9101	0.8086	0.7359
31	Nikon	0.9552	0.8154	0.7788	0.9595	0.7950	0.7628	0.9557	0.7516	0.7183
32	Hitachi KoKusai Electric	0.9469	0.8328	0.7886	0.9351	0.8173	0.7643	0.9467	0.8269	0.7829
mean	Industry	0.8791	0.6278	0.5519	0.8994	0.6129	0.5512	0.9204	0.6603	0.6077
mean	EU/US DMUs	0.8686	0.5426	0.4713	0.9080	0.5271	0.4786	0.9311	0.5936	0.5527
mean	JAPAN DMUs	0.8967	0.7698	0.6903	0.8851	0.7559	0.6690	0.9026	0.7713	0.6962
mean	Front-end DMUs	0.9377	0.6604	0.6193	0.9241	0.6480	0.5988	0.9351	0.7070	0.6611
mean	Back-end DMUs	0.8127	0.5908	0.4801	0.8715	0.5730	0.4993	0.9036	0.6073	0.5488

4.3 Efficiency Change Index

The efficiency change from period “s” to period “t” is defined as:

$$\text{Efficiency change} = \frac{TE_t}{TE_s} \qquad \text{[Coelli et al., (2005)]} \qquad (4.5)$$

If efficiency change >1, the efficiency is improved.

If efficiency change <1, the efficiency becomes worse.

If efficiency change=1, the efficiency keeps constant.

Then the yearly sequential efficiency change can be obtained by using equation 4.5. From the results on Table 14, 15 and 16, one can have a whole picture about the trend in this industry.

Table 14: Technical efficiency change index at stage 1 (profitability)

Year	*2007*	*2008*
Industry	1.0231	1.0233
by nationality		
EU/US DMUs	1.0455	1.0254
JAPAN DMUs	0.9871	1.0198
by market segment		
Front-end DMUs	0.9855	1.0120
Back-end DMUs	1.0723	1.0369

At stage 1, the “industry” efficiency change is greater than 1 in 2007 and 2008, means that capability to make profits in the whole semiconductor equipment industry are improved in this three years period. We may say that the market is on the upward cycle. The values of the EU/US firms and of the back-end firms are also greater than 1 means that performance of these specific firms are also continued improved. In contrast, the values of Japanese firms and of the front-end firms are smaller than 1 in 2007, but returns back to greater than 1 in 2008. It means that these firms did not perform well from year 2006 to 2007, but the performances are recovered back in 2008.

Table 15: Technical efficiency change index at stage 2 (marketability)

Year	*2007*	*2008*
Industry	0.9762	1.0774
by nationality		
EU/US DMUs	0.9714	1.1263
JAPAN DMUs	0.9819	1.0205
by market segment		
Front-end DMUs	0.9813	1.0910
Back-end DMUs	0.9698	1.0599

At stage 2, the “industry” efficiency change is slightly down to 0.9762 in 2007 but returns to 1.0774 in 2008, means that the efficiency of the whole industry dropped down in 2007 but got improved in 2008. We also observed the similar pattern whether the firms are classified by nationality or market segment.

Table 16: Total Efficiency Change Index

Year	*2007*	*2008*
Industry	0.9988	1.1025
by nationality		
EU/US DMUs	1.0156	1.1549
JAPAN DMUs	0.9692	1.0407
by market segment		
Front-end DMUs	0.9671	1.1040
Back-end DMUs	1.0399	1.0990

The total “industry” efficiency is slightly down to 0.9988 in 2007, but returns back to 1.1025 in 2008. However we see different pattern for the firms which are classified as EU/US firms or back-end equipment firms. The values of efficiency change for these firms kept greater than 1 for all 3 years; mean that total efficiency of these specific firms are continued improving year by year even the industry is slowly down in 2007.

4.4. Summary and Hypothesis test

To understand deeply about how these specific firms perform and the effect of the environmental variables, we now plotted the DMU's average TE at each stage(Fig.3~Fig.8).

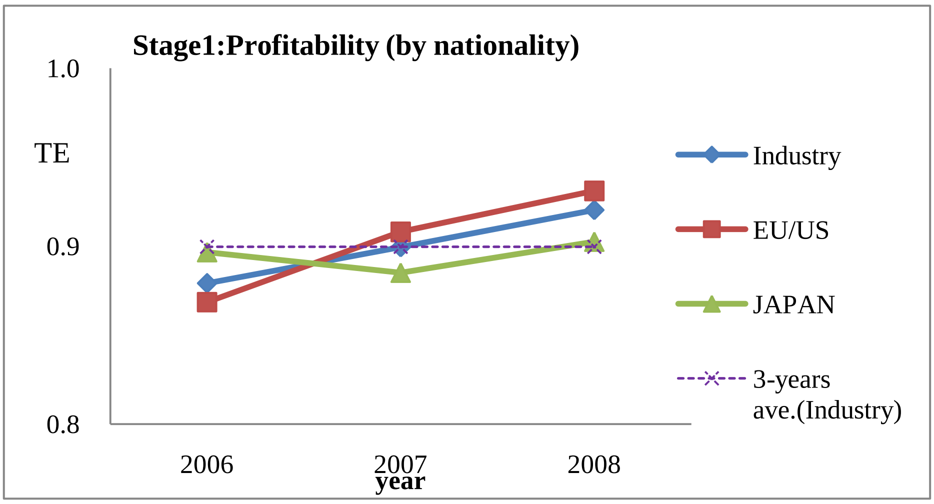

Figure 3: Annual TE (classified by nationality) at stage1

At stage 1(Fig.3), the performance improvement of the EU/US firms overcame the performance drops down in the Japanese firms from 2006 to 2007. The performance of the Japanese firms is under 3- years' average level.

At stage 2(Fig.4), the marketability efficiency of the Japanese firms is much better than the EU/US firms for our analysis period. And it is behind the average level. From the comparison of the EU/US firms at stage 1 and 2, we found that the EU/US firms have a good efficiency to generate profits but failed to get respect from investors (marketability efficiency).

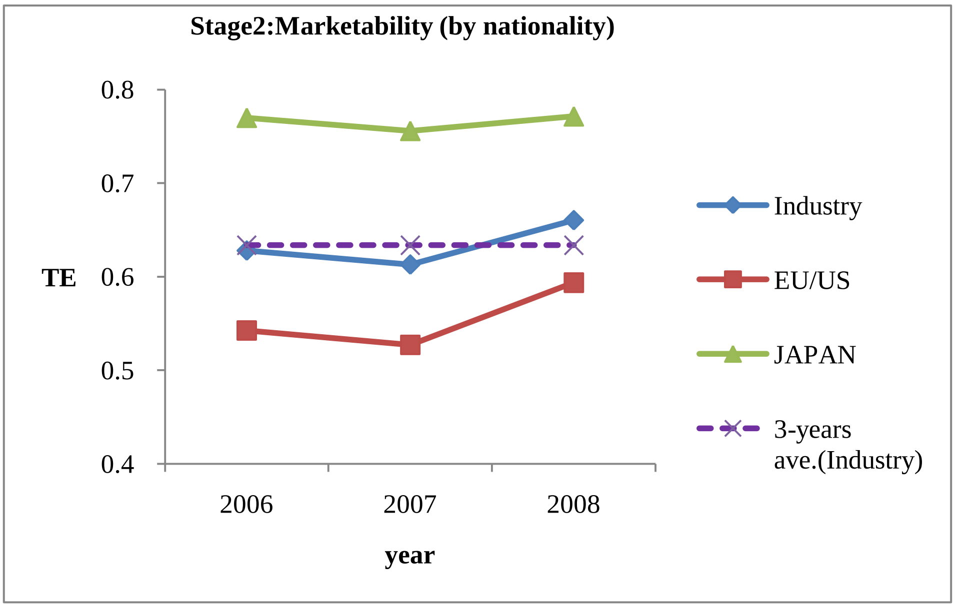

Figure 4: Annual TE (classified by nationality) at stage 2

By definition, in order to obtain the total efficiency, we multiply the profitability efficiency and the marketability efficiency. Then the results are plotted on Fig.5.

The figure shows that the total efficiency of the Japanese firms is better than the EU/US firms. We begin to test our hypothesis#1.

H1: The performances of Japanese firms are different from EU/US firms'.

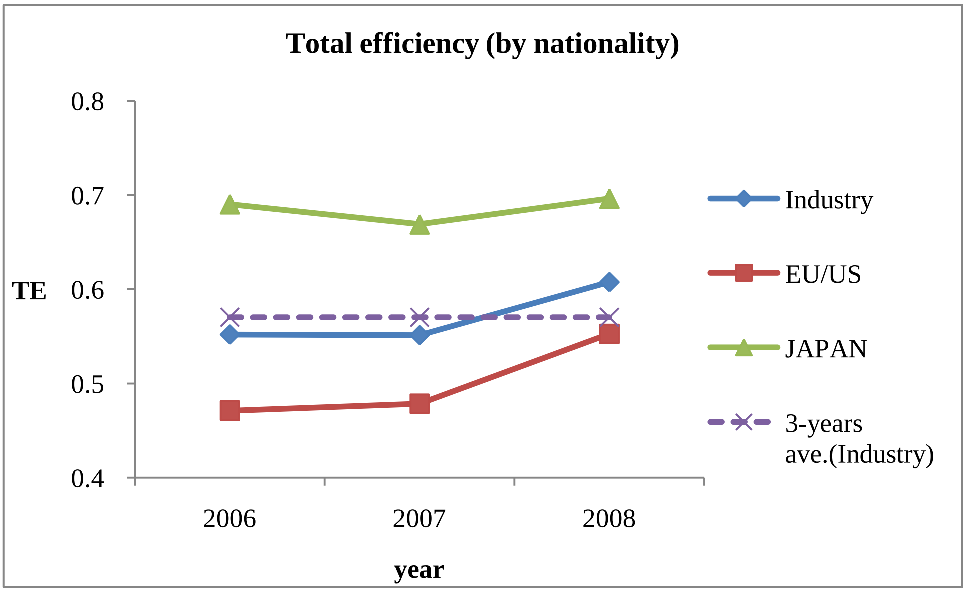

Figure 5: Annual total TE (classified by nationality)

A Mann-Whitney U test has been widely applied for this kind of Non-parametric Statistics. From the results shown on Table 17, we can conclude our hypothesis#1 as:

H1: The total efficiencies of Japanese firms are significantly higher than the EU/US firms (p<0.01).

Table 17: Mann-Whitney U test for Hypothesis#1

N1	N2	U	P(two-tailed)	P(one-tailed)
60	36	1876.5	<2 e-06	<2 e-06
Normal approx, Z=6.02787			1.661376e-09***	8.30688e-10***

Note: ***significant at 1 % level

Below we discuss and summarize the performance in different market segment.

As the results shown on Fig.6, at stage 1, the front-end firms have better capability to make profits than the back-end firms. However the performance improvement which comes from the Japanese firms drives the industry continuously improving in our analysis period.

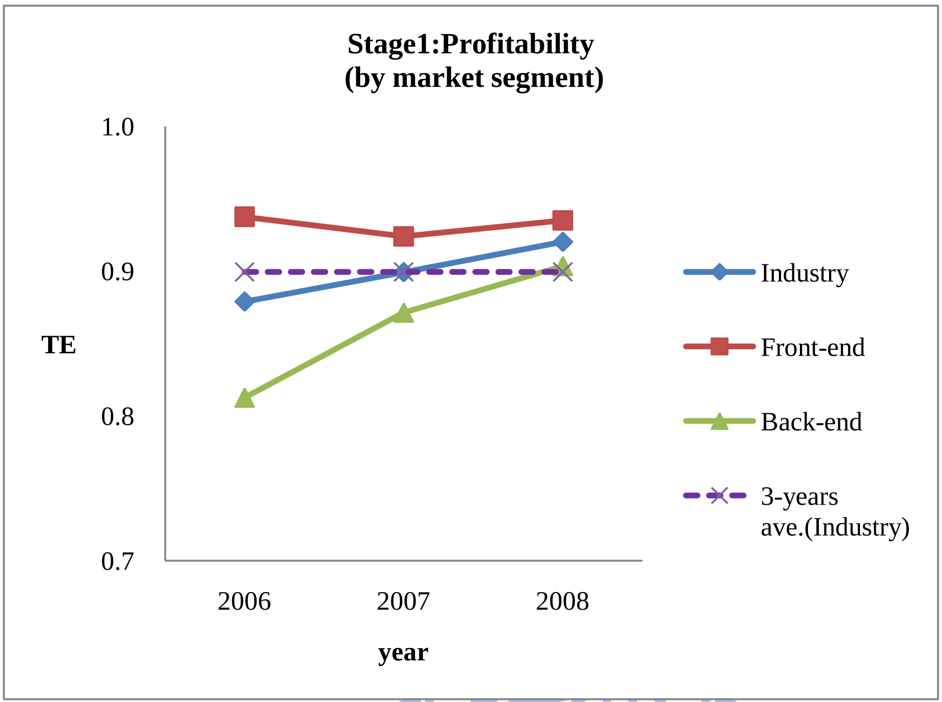

Figure 6: Annual TE (classified by market segment) at stage 1

At stage 2(Fig.7), the performance of the front-end firms is better than the back-end firms. And the average profitability efficiency for industry is slightly gone down in 2007.

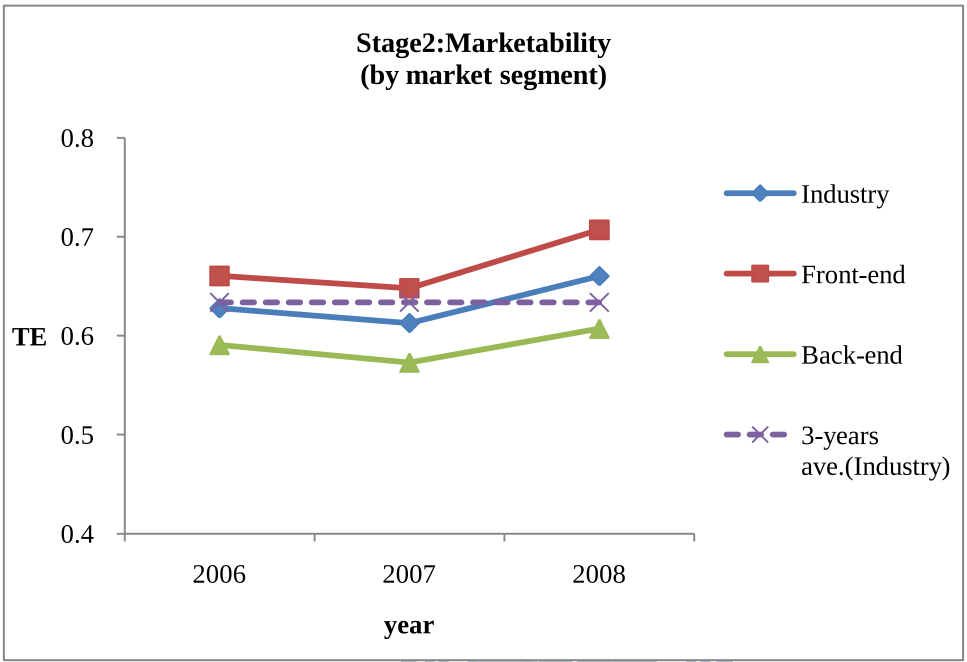

Figure 7: Annual TE (classified by market segment) at stage 2

Upon our definition of the total efficiency, the final result is showed on Fig.8. From the figure, we found that the total performance of the front-end firms is better than the back-end firms. We begin to test our hypothesis#2.

H2: The performance of the front-end firms and the back-end are different.

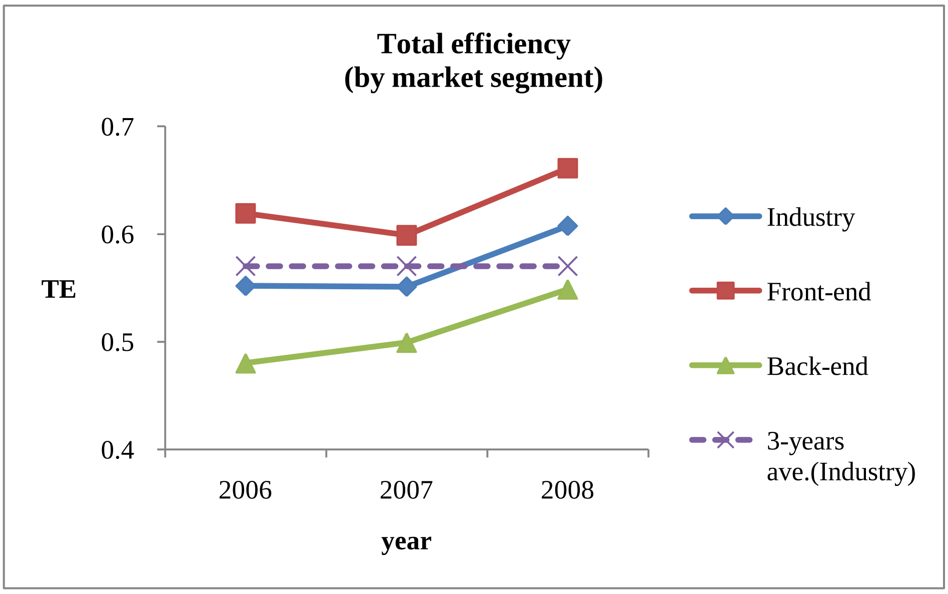

Figure 8: Annual total TE (classified by market segment)

The results of the Mann-Whitney U test are showed on Table 18. So we concluded that the hypothesis#2 as:

H2: The total efficiencies of the front-end equipments firms are significantly higher than the back-end equipments firms (p<0.01).

Table 18: Mann-Whitney U test for Hypothesis#2

N1	N2	U	P(two-tailed)	P(one-tailed)
51	45	1699.5	<2e-05***	<1e-05***
Normal approx, Z=4.05277			5.06136e-05***	2.53068e-05***

Note: ***significant at 1% level

5. Conclusion

As the cycle of the semiconductor market becomes shorter and shorter, it's important to for firm to make right strategy to survive and to be competitive in this market. The empirical results show that the efficiencies of the EU/US firms to generate profits can catch the cycle of the market. They kept improving their profitability as the market grew. Usually, the EU/US firms employ more active operating strategy than Japanese firms. They expanded their production capacity and men power quickly as the market grows. In contrary, they lay off employees and close their factory as the market constricts. Japanese firms maintain their capability and cost conservatively. The total efficiencies of Japanese firms are significantly higher the EU/US firms may indicate that firms should always carefully maintain their cost and resources even they make good profits from the market.

Another indication from the empirical results shows that efficiencies to generate profits of the back-end-equipments firms increasing dramatically at the beginning of the recovery of the market compared to slightly decreasing efficiencies of the front-end-equipments firms. It can be explained by the "bull-whip effect" in the supply chain. Base on the results we obtained, top management teams should carefully make the strategy plans, decisions, and allocate the proper resources during the market cycle to win business.

The empirical results also show that the front-end-equipments firms have better performance than the back-end-equipments firms. Generally the capital expenditure, market entering barrier, and switching cost in the front-end (wafer processing) semiconductor equipment market are higher than in the back-end (packaging/testing) market. A good strategy for those firms which mainly provide back-end equipments to purchase is to try their best to cooperate with other providers to bundle package for offering total solutions for customers.

Thus increasing the customers' switching cost and vendors' bargaining power will have more opportunity to improve their performance.

One point has to notice is that the financial data is historic. Any models bases on these indexes only reflect the firm's short-term performance. For example, a firm may invests a lot on research and development and expanding production capacity will have worse financial performance in the next year but the strategy help him win long-term competency and success.

6. Limitations and suggestions

Recently Korean firms have won a lot portion of market share especially in the middle to low end market segment. However this research does not include these firms. And we have observed some symptoms in the market: small firms have been acquired by their competitor, for example TERADY merged Nextest, and Eagle Test, in order to expand its market share and product scopes; and more and more firms cooperate together to offering better package for customers. Our environmental variables, nationality and market segment are not enough to catch the dynamic change in the market. Base on the results this study provided, one may study more deeply on the strategy behavior of these firms to help management teams understand the environment and purchase the right decision.

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