Effects of Product Price on Profitability of Semiconductor Firms: Evidence from Global DRAM Industry

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Abstract

DRAM has always been treated as the "commodity" of hi-tech industry, which has not only the shorter product life cycle, but also the intensive price competition between oligopoly firms. This study calculates average price of DRAM product and cooperates with DRAM Exchange Index (DXI) of "volume-price compound indicator", as well as explanatory variables such as business cycle, technical innovation, capacity investment, cost and efficiency. The Panel Data is used as a tool to discuss the effect of profitability on the world's top 10 memory manufacturers. The empirical results indicate that DXI has positive significant effect towards the firms' profitability, and the effect is far greater than the negative effect caused by pure change of price. This study proves that consequence of DRAM firms' price competition will damage the profitability and that strategic alliance via inter-firm virtual teams (i. g.: virtual integration) is an effective way of reducing cost and improving profits.

Keywords: DRAM, DRAM Exchange Index (DXI), Price Competition, Virtual Team, Virtual Integration

INTRODUCTION

Features of DRAM Product

The DRAM (Dynamic Random Access Memory) is provided in desk-top or lap-top computer to execute the task of primary memory. In the computer market, consumers' selection on different generation of computer is equivalent to the selection on different generation of DRAM; therefore, the demand of DRAM is closely related to business cycle of computer industry and it is therefore a derivative demand. Whether the new generation of DRAM product can replace product of old generation, it is determined by the choice behavior of consumers. The consumers base on limited resource and maximum product efficiency to decide which product they want to adopt. Since the speed of replacing old technology with new technology increases, the life cycle of new product decreases. Consumers confuse when they make purchasing decision – since they do not know which generation of product to select from; furthermore, it also complicates the behavior of consumers and increases frequency of generation replacement for products (Jun and Park 1999).

The speed of generation replacement for DRAM products can be observed from the firms' frequency of announcing new products. Popma, Waarts and Wierenga (2006) carried out a study on whether New-Product Announcement (NPA) would cause violent reaction from the competitors or not. They selected the DRAM industry as the object of study since the top 10 DRAM firms made 64 NPA within the two years covering 1999 and 2000, which shows rapid generation replacement for DRAM products distinctively. The study by Popma Waarts and Wierenga (2006) pointed out that frequent NPA did provoke the competitors to react: In addition to launch new products more rapidly, the competitors would also lower price in order to sell old products. Victor and Ausubel (2002), Kim, Lee and Kim (2005) and Popma Waarts and Wierenga (2006) made identical description on the trend of DRAM price: Only the new product that has just been introduced into the market can be sold at high price and enjoy the price premium; after that, the decreasing tends of price are more than that of increasing. The result of rapid generation replacement for products does not only speed up the rate of depreciating price for old products, but also creates huge price gap between products of new and old generations, which leads to more intense price competition between firms.

Victor and Ausubel (2002) described that the market life for every generation of DRAM product is as short as the fruit flies. They carried out an study on technological evolution of DRAM products and pointed out that from 1977 to 2001, the DRAM products had replaced with 8 generations (from 4K to 64MB), and the growth time of each generation of mainstream product had only 3.9 to 4.1 year. In order to grasp prime opportunity in the market, the firms have to introduce new product and new process rapidly. In order to cope with the price competition, the firms have to rapidly bring the Learning Curve Effect into full play; so they can achieve the scale economy of mass production and reduce production cost via "Learning by Doing" (Gruber 1998; Macher and Mowery 2003; Zulehner 2003).

Price Trend for Contemporary DRAM Products

The bold line in Figure 1 shows the trend of DRAM Exchange Index (DXI) from 2002Q1 to 2007Q1. The fine line shows the price trend for DRAM products of 9 major specifications under 2 generations (i.e. 256MB and 512MB) on the market during the same period. Among them, the 512 MB Double Data Rate (double channel) Synchronous DRAM (512MB DDR2 SDRAM) has become the mainstream product after 2005. From Figure 1, the co-existence for 2 generations of DRAM products on the market can be observed from 2004Q4 onwards; this study will detail the DXI from 2002Q1 to 2007Q1, as well as price change and amplitude for DRAM products of 9 major specifications in Table 2.

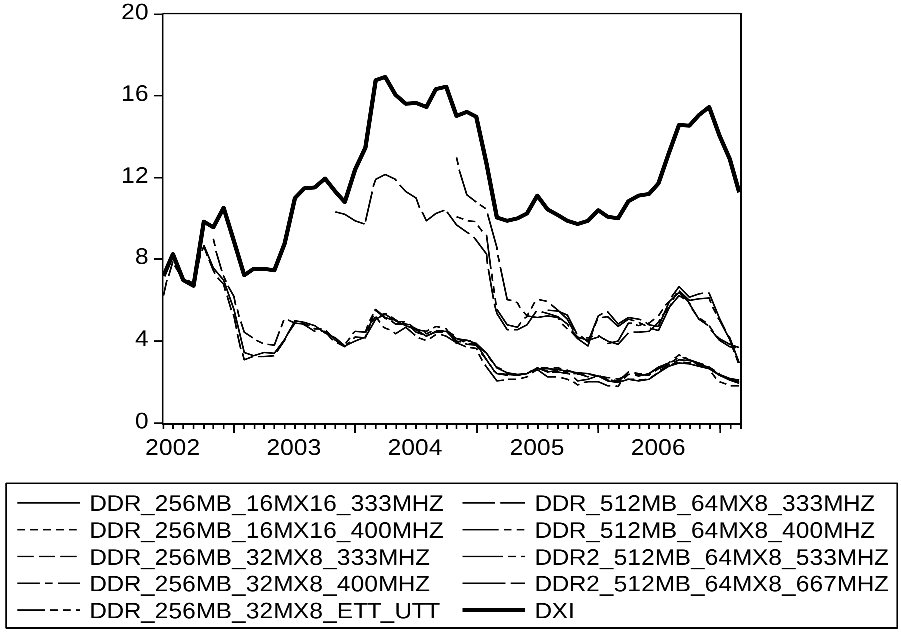

Figure 1: Trend of DRAM Price and DXI

Note: 1. The vertical axis represents the DRAM price in unit of US$. The unit of DXI is in "point" and the value in the figure has reduced to 1/300. 2. Data source: Thomson's Datastream database.

From Figure 1 and Table 1, we know that from 2004Q1 to 2007Q1, the amplitude of price deduction for 9 major products is approximately between -25.84% and -63.87%; even the DXI shows deduction of -10.32%.The amplitude of price change for product is 2.5 to 6.1884 times of the amplitude of DXI change; this shows the intense price competition among firms.

Table 1: Change on Price of DRAM Product and DXI (2004Q1 to 2007Q1)

Product Specification	Price in 2004Q1	Price in 2007Q1	Change of Price	Amplitude
DDR 256MB(16M×16) 333MHZ	4. 4267	2. 1033	-2. 3233	-52. 49%
DDR 256MB(16M×16) 400MHZ	3. 2033	2. 0300	-1. 1733	-36. 63%
DDR 256MB(32M×8) 333MHZ	4. 6200	2. 1600	-2. 4600	-53. 25%
DDR 256MB(32M×8) 400MHZ	4. 8067	2. 1800	-2. 6267	-54. 65%
DDR 256MB(32M×8) ETT UTT	4. 5400 (2004Q2)	1. 8467	-2. 6933	-59. 33%
DDR 512MB(64M×8) 333MHZ	10. 5000	3. 7933	-6. 7067	-63. 87%
DDR 512MB(64M×8) 400MHZ	8. 1767 (2005Q1)	3. 8733	-4. 3033	-52. 63%
DDR2 512MB(64M×8) 533MHZ	9. 9067 (2005Q1)	3. 9900	-5. 9167	-59. 72%
DDR2 512MB(64M×8) 667MHZ	5. 4700 (2005Q3)	4. 0567	-1. 4133	-25. 84%
DXI	4263. 13	3823. 15	-439. 97	-10. 321

Data source: Thomson's Datastream database.

Global DRAM Industry

Since Robert Dennard invented the DRAM in 1968, both the US firms in 1970's and Japanese firms in 1980's have once dominated the development of such product. Up till the 1990's, the market of DRAM products is already under the territory of Korean firms. Table 2 shows the top 10 manufacturers of global memory industry; among them, the two largest firms, name Samsung and Hynix are both Korean companies and occupy 43% of market share for DRAM products. One representative firm each is provided in Europe, USA and Japan, which is Elpida, Micron and Qimonda respectively; the market share for these 3 firms together is 35%. Furthermore, 5 Taiwanese firms also possess 11.5% of market share. The high level of industrial concentration (i.e. market share of the top 10 firms exceeds 98%) and vast expenditure in capital do not only constitute an obstruction of new firms' entry, but also an barrier for old firms' exit. The DRAM industry has thoroughly revealed the characteristics of oligopoly market.

Table 2: Top 10 of the Global DRAM Industry (2006)

Firms	2006 Sales Records			2006 Market Share	
	Memory	DRAM	DRAM/ Memory	Memory Market	DRAM Market
Samsung (Korea)	200.10	98.34	0.4915	0.3388	0.2769
Hynix (Korea)	79.50	56.44	0.7099	0.1346	0.1589
Qimonda (Germany)	54.25	53.70	0.9899	0.0919	0.1512
Micron (USA)	54.40	36.97	0.6796	0.0921	0.1041
Elpida (Japan)	36.32	34.89	0.9606	0.0615	0.0982
Nanya (Taiwan)	23.06	21.11	0.6153	0.0390	0.0594
Powerchip (Taiwan)	28.25	14.79	0.5235	0.0478	0.0416
ProMOS (Taiwan)	18.41	14.62	0.7941	0.0312	0.0412
Winbond (Taiwan)	10.58	6.78	0.6505	0.0179	0.0191
Inotera (Taiwan)	12.53	12.53	1.0000	0.0212	0.0353
Others	73.14	4.96	--------	0.1239	0.0140
Total	590.54	355.13	0.6014	1.0000	1.0000

Note: 1. This table is made by referring to Dataquest (March 2007), iSuppi (March 2007) and financial report of each firm. (Unit: thousand million USD). 2. Qimonda was originally the memory department of Infineon from Germany and established its own company in May 2004 with the Headquarter located in Munich. In April 2006, the firms changed its name to Qimonda and in August of the same year, the firm was listed as American Depository Share (ADS) in NYSE. 3. Elpida was originally the NEC-Hitachi Memory, Inc. In March 2003, it took over the Semiconductor Department of Mitsubishi Electric and in September of the same year, Elpida was established. In November 2004, the firm was listed in Tokyo Stock Exchange.

According to the above description, we know several features of the DRAM industry: First, due to the continuous innovation of technology, the generation replacement of DRAM products has sped up and the life cycle of DRAM has become shorter relatively. Since the frequent announcements of new product made by the firms have caused more intense price competition, the firms must rapidly introduce new technology process and new products, as well as swiftly bring the learning curve effect to reduce production cost, so they can survive in the market. Second, the DRAM industry is an oligopoly market; the firms seek all methods to get rid off their opponents, so it is normal to have price competition in such industry. The top 10 firms listed in Table 1 happen to be the survivors under long-term competition of DRAM industry. Third, DRAM is a cyclical commodity, but the characteristics of DRAM industry's business cycle －expansion, peak, recession and trough －have been distinctively reflected on the price trend of product. Based on these characteristics, we find that the price change of DRAM products imposes significant effect on the firms' performance and the industry's ecology, which is worth discussing profoundly. However, most of the past studies on DRAM industry are qualitative or case studies that focus on product innovation, industrial policy, technological evolution and the firm's experience for success (Jun and Park 1999; Victor and Ausubel 2002; Kim, Lee and Kim 2005; Popma, Waarts and Wierenga 2006). The topic of such importance is lack of discussion and hence initiates our motive of executing this study.

For studying profitability of DRAM firms, the price and volume of products must be considered at the same time. Since there was no way to obtain data on price and volume, which means no relevant research has been made yet. This study obtained representative data of product's price and the DXI that represents "volume-price compound indicator" from the Thomson's Datastream database, so an empirical study on DRAM firm's profitability can be carried out accordingly. This study has calculated the historical average price to cooperate with important explanatory variables such as DXI, business cycle indicator, technical innovation, capacity investment, cost and efficiency, which uses Panel Data as the tool to discuss effect of these variables upon profitability of the world's top 10 memory manufacturers. In addition to examine real effect of DRAM price towards the firm's profitability, the objective of this study is to find an effective way for helping the firms against price competition.

Section 2 of this article provides a review on past financial performance of the DRAM industry and semi-conductor firms. Section 3 describes methodology in details, which includes empirical model, sample companies and variable design. Section 4 analyses results and discusses the empirical findings according to panel data. Section 5 proposes the conclusions and suggestions to describe limitation of the study and direction of future study.

LITERATURE REVIEW

The Industry-Level and Firm-Level Studies

Korea is one of the four major production countries in the world for semi-conductors and also the contemporary leader in DRAM industry; thus most of the industry level and firm level studies have targeted on Korean firms. The trait of Korean semiconductor industry is that there are few firms, and these firms are only well-known world-wide for the memory products. Byun (1994) described the progress of Korean early development on DRAM products in details, which explained the way of surviving and maintaining competitiveness in the global market of semi-conductor, as well as providing Korean Government with some options for policies and industrial strategies. Cho and Lee (1994) studied the path of developing networking capability for semiconductor firms in Korea. They considered that Korean firms' experience on networking for acquiring technology and accumulating technological capability is unique, thus firms in other countries might not be able to imitate. Choung, Hwang and Choi (2000) studied the way of semi-conductor firms in Korea on development of their technological capability. Chung (2001) studied the effect of applying learning curve by semi-conductor firms in Korea; he argued that effective elaboration of learning curve effect was the major cause of success in memory products for Korean firms. On the other hand, Gil and Lee (2003) and Leachman, Kang and Lin (2002) carried out case studies on Samsung, the leading firm in DRAM. Among their studies, Leachman, Kang and Lin(2002) indicated out the SLIM (Short Cycle Time and Low Inventory in Manufacturing) program promoted by Samsung Semiconductor from 1996 to 1999, will reduce the manufacturing cycle time of DRAM from 80 days to 30 days and this was Samsung's major reason of success in DRAM products. The abovementioned studies have induced three major lines of studies on Korean DRAM industry: industrial policy, technological evolution and successful experience. All these studies are descriptive and qualitative studies. As for the quantitative and comparative studies of performance between firms, especially the international and inter-firm studies, there is always a lack of discussion. This study targets on the 10 memory firms over Korea, US, Europe, Japan and Taiwan for finding the reasons of affecting international firms' profitability with econometric model, which replenish the part that is lacking from previous studies on DRAM industry.

Study on Semiconductor Firms' Profitability

The regression model that values operational outcome, the financial situation or the cash flow of the company is referred as the financial performance valuation model. The objective of developing the model is to satisfy the needs of external investors and internal managers. A feature of this model is that the explained variable used must be a financial ratio or account of the financial statement; among them, the ROA, ROE and ROS of profitability are used most often (Qian and Li 2003; Roberts and Dowing 2002; Chu, Teng and Huang 2005; Yu, Chiao and Chen 2005; Lin, Lee and Hung 2006; Yu and Park 2006; Thornhill 2006). There have been few studies about the financial performance of semiconductor firms; however, Sher and Yang (2005) used data on the semiconductor industry in Taiwan to study the effects from innovation capacity and R&D clustering on a company's financial performance (ROA) and concluded that higher R&D intensity and more R&D manpower are predictors of improved financial performance. Chu, Teng and Huang (2005) studied the effects of virtual integration and integrated device manufacturing strategies on the financial performance of Taiwan's integrated circuit industry and found that the ROA and ROE for virtual integration firms (the design house and pure foundry) are significantly better than they are for integrated device manufacturing firms. They also found that the "Book-to-Bill ratio (BB ratio) for North American Headquartered Semiconductor Equipment Manufacturers" that represents the business cycle of the semiconductor industry also significantly affects the financial performance of integrated circuit firms.

Since the policy of large DRAM firms in each country for financing long-term capital differs (in favor of acquiring capital via issuance of debentures or equity securities), it will be biased to carry out comparative study that addresses only the ROE (Return On Equity). Owning to the difference of the criterions of accounting disclosure in each country and the method of recognizing asset value and impairment, the comparative study cannot be carried out by addressing only the ROA (Return On Assets). This study takes the three profitability indicators, namely the ROA, ROE and ROS (Return On Sales) as the explained variables, which is sufficient to overcome the abovementioned defects, as well as improving internal and external validity of the study.

METHODOLOGY

In order to execute the panel data analysis, this study uses ROS, ROA and ROE as the explained variables for representing the firm's profitability, which constitutes a set of multiple regression equation to execute the empirical study. In addition to the major explanatory variables—DRAM price and DXI, this study has adopted several global industry level variables and firm level variables to represent the five dimensions (technology, scale, efficiency, cost and industrial business cycle) that might affect profitability of DRAM firms, we try to develop a integrity model that can achieve high explanatory power. Figure 2 shows the study structure in this article.

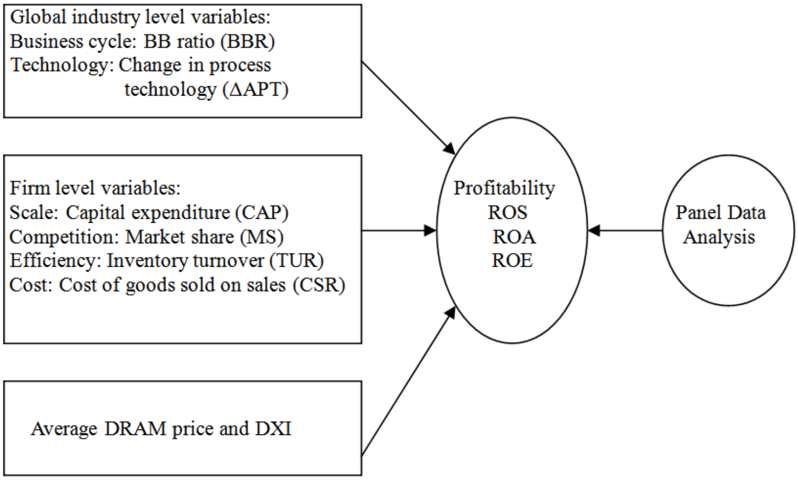

Figure 2: Study Framework

Empirical Model

The panel data analysis is a pooled regression model that can execute a cross-sectional and a time series analysis at the same time. There are two different valuation models for the panel data analysis: the Fixed-Effects Model and the Random-Effects Model. Due to the difference in unit of measurement, this study processes CAP, DXI and P in logarithm. The separate valuation regression equations for the two models are:

- **Fixed Effects Model:**

$$Profitability_{i,t} = \sum_{j=1}^{n} \alpha_i D_{j,t} + \beta_1 BBR_t + \beta_2 MS_{i,t} + \beta_3 CSR_{i,t} + \beta_4 TUR_{i,t} + \beta_5 \ln CAP_{i,t} + \beta_6 \Delta APT_t + \beta_7 \ln DXI_t + \beta_8 \ln DXI_{t-1} + \beta_9 \ln P_t + \beta_{10} \ln P_{t-1} + \varepsilon_{i,t} \quad (1)$$

$D_{j,t} = 1$, when $j = i$ (D: dummy variable; i is the i^{th} firm, $i = 1, 2, 3, \ldots, n$)

$= 0$, when $j \neq i$

- **Random Effects Model:**

$$Profitability_{i,t} = \lambda + \mu_i + \beta_1 BBR_t + \beta_2 MS_{i,t} + \beta_3 CSR_{i,t} + \beta_4 TUR_{i,t} + \beta_5 \ln CAP_{i,t} + \beta_6 \Delta APT_t + \beta_7 \ln DXI_t + \beta_8 \ln DXI_{t-1} + \beta_9 \ln P_t + \beta_{10} \ln P_{t-1} + \varepsilon_{i,t} \quad (2)$$

When there are different intercepts between cross-sections of sample firms for the same time series data, the Fixed-Effects Model of equation (2) is applicable and $\alpha i, t = \alpha i$. When the intercepts between cross-sections of sample firms for the same time series data are random, the Random-Effects Model of equation (3) is applicable and $\alpha i, t = \lambda + \mu i$. The situation that is applicable for the Fixed-Effects Model or Random-Effects Model will be determined with the Hausman Test (Hausman 1978).

Sample Company

This study takes the top 10 manufacturers in global DRAM industry (shown in Table 1) as samples. The market share of these 10 DRAM firms is 98.7% and it is sufficient to represent the industry. This study has collected 13 quarters of data from these 10 sample companies, which covers from 2004Q1 to 2007Q1. Among them, Qimonda and Inotera can only provide 8 quarters of data since their time of establishment is later.

Explanatory variables

This study has adopted a total of 8 explanatory variables and their detailed descriptions are as follows:

- **Book-to-Bill ratio (BBR)**

The Book-to-Bill ratio (BBR) is the ratio for North American Headquartered Semiconductor Equipment Manufacturers announced by Semiconductor Equipment and Materials International (SEMI) every month. The BBR is calculated by dividing bookings the equipment manufacturers receive by deliveries. When this ratio is greater than 1, the future business of the semiconductor industry is optimistic; when the ratio is less than 1, the future business of the semiconductor industry is pessimistic; and when it equals 1, the future business is neutral. The study by Chu, Teng and Huang (2005) used the BBR to represent the business cycle of the semiconductor industry as the control variable of the regression model and obtained significant findings. The current research also uses the BBR as the global industry-level variable to measure the effect of the business cycle in the semiconductor industry on the firms' profitability. Since the BBR is monthly data, this study calculates the 3-month moving average, and the quarter-end value is used as the explanatory variable.

- **Change in Average Processing Technology (ΔAPT)**

The study by Leiblein and Reuer (2004) argued that semi-conductor firms' process technology can act as their classification standard of "technological capability". Based on the quarterly MOS process technology and started wafers announced by SICAS (Semiconductor International Capacity Statistics), this study has calculated the change of average process technology (we name it ΔAPT) in each quarter for the semiconductor industry, where ΔAPT is used as one of the industry level explanatory variables. From the ΔAPT revealed in Table 3, the semiconductor industry's stable advance on technology can be observed and the process technology progresses at average of 0.0071μm per quarter.

Table 3: ΔAPT for Global Semiconductor Industry's MOS Process

	2004Q1	**2004Q2**	**2004Q3**	**2004Q4**	**2005Q1**	**2005Q2**	**2005Q3**	**2005Q4**
APT	0.2924	0.2896	0.2846	0.2595	0.2536	0.2484	0.2467	0.2407
ΔAPT	0.0043	0.0027	0.0050	0.0251	0.0060	0.0052	0.0017	0.0061
	2006Q1	**2006Q2**	**2006Q3**	**2006Q4**	**2007Q1**			
APT	0.2353	0.2280	0.2189	0.2128	0.2044			
ΔAPT	0.0054	0.0073	0.0091	0.0061	0.0083			

Note: 1. Data source: SICAS; (Unit: μm). 2. $\Delta APT = |APT_t - APT_{t-1}|$; absolute value is used to indicate that progress of process technology is in positive value. The APT of 2003 Q4 is 0.2966 μm. The ΔAPT of 2004Q1 is $|0.2924 - 0.2966| = 0.0043$.

- **Market Share (MS)**

The market share (MS) is an important variable to valuate the company's market value (Chauvin and Hirschey 2001; Yang and Chen 2003 and Churyk 2005). It is also used as the explanatory variable for valuating the company's profitability (ROA) (Michael 2003). Langlois and Steinmueller (2000) took MS as the indicator to compare performance of semi-conductor industries between US and Japan. The international DRAM firms often initiate the price war for the purpose of seizing MS and chasing the competitors off the market. However, there is lack of discussion on whether the increase of MS provides positive effect on the firm's profitability or not. This study selects relative market share as one of the firm level explanatory variables for the attempt of finding relation between MS and profitability. Here the MS is the related market share, which is calculated from dividing specific firm's sales by industry's sales that is the summation sales of the top 10 firms (the sample companies of this study). We collect the data from the official web site of the sample company.

- **Rate of Cost of Goods Sold to Sales (CSR)**

Porter (1980, 1985, 1996) indicated that if the cost can be reduced via mass production for cost advantage, the goods can be supplied at lower price for competition in the market. Coeurderoy and Durand (2004) indicated that if cost leadership is the relevant strategy of acquiring market share, it is beneficial for late-come firms. Many literatures on semi-conductor industry (e.g.: Chung 2001; Gil and Lee 2003; Wu, Hung and Lin 2006) consider that Asia's emerging semiconductor firms such as DRAM firms in Korea and foundry factories in Taiwan all started from "low-cost / low-end"; throughout the development of learning curve effect from learning by doing, the cost advantage was acquired and hence they could beat large IDM firms in advanced countries. The CSR (ratio of Cost of Goods Sold to Sales) can be used to determine if the DRAM firm has cost advantage. The CSR can be calculated from firm's quarterly financial statement which collected from the official web site of the sample company. If the relationship between regression coefficient of CSR with ROS, ROA or ROE is in negative direction, it represents that the cost reduction can generate better profitability.

- **Inventory Turnover (TUR)**

The empirical result by Liu (2005) was that inventory is an important variable in forecasting the business of the semiconductor industry. The life cycle of semiconductor products is short and excessive inventory of finished products may cause losses. This study adopts the rate of inventory turnover (TUR; ratio of Cost of Goods Sold to average inventory) as the firm's sales efficiency indicator and calculates it by dividing cost of goods sold by average inventory. The TUR can be calculated from firm's quarterly financial statement which collected from official web site of sample company. The higher the TUR value, the higher the sales efficiency. If the relationship between the regression coefficient of TUR and ROS, ROA and ROE is positive, improvements in sales efficiency can lead to better profitability.

- **Capital expenditure (CAP)**

Another empirical results by Liu's study (2005) indicated that wafer capacities is also an important variable of forecasting business cycle of semiconductor industry; however, most firms has not announced their capacity data of each quarter yet, and the Property, Plant and Equipment (PP&E) is not complete either (this study is only missing the quarter data of PP&E for semi-conductor department of the leading firm Samsung semi-conductor). Therefore, in the end we refer to the study made by West and Iansiti (2003), which used capital expenditure (CAP) to represent the firm's investment on capacity equipments and act as one of the explanatory variables. The CAP can be obtained from the firm's quarterly financial statement which collected from official web site of sample company.

- **DRAM Exchange Index (DXI)**

The DRAM Exchange Index (DXI) is edited by DRAMeXchange Corporation, a trader and information company of DRAM chips in China. The index is calculated by multiplying the output of mainstream DRAM chips with their respective price, which is an volume-price compound indicator of DRAM output. The main purpose of the DXI is to provide users, such as DRAM specialists, industry analysts and fund managers, with an easy way to understand the market trend of the DRAM industry. DRAMeXchange

Corporation makes use of two important criteria in selecting the chips. First, the spot price of related chips must always be able to be traded and maintained by DRAMeXchange. Second, the selected chips must reach DRAMeXchange's benchmark and contribute over 70% of the chosen DRAM producer's output. Once the selected chips fail to meet the criteria, DRAMeXchange will renew calculation base of the DXI. The DXI is the only volume-price compound indicator of DRAM products at present of the world. Data of the DXI is collected from Thomson's Datastream database. Table 4 shows the products (chips) that comprise the DXI for January 2006. We simplify the calculation of the DXI as a formula and show it as follows.

$$DXI = \frac{\sum_{k} P_{k,t} Q_{k,t}}{\sum_{k} P_{k,0} Q_{k,0}} \quad (3)$$

k represents different specification of DRAM products; we show them in Table 4.

Table 4: Composition of the DXI for January 2006

Type	Density	Organization
SDRAM	16MB	1Mx16
	64MB	2Mx32
		4Mx16
	128MB	8Mx16
		16Mx8
	256MB	16Mx16
		32Mx8
DDR	256MB	32Mx8
		16Mx16
	512Mb	64Mx8
DDR2	512Mb	32Mx16
		64Mx8

Source: DRAMeXchange Corporation (http://www.dramexchange.com).

- **Average price of product (P)**

Aizcorbe (2005, 2006) used Intel's price data of MPU for series of studies, and his conclusions supported the viewpoint of Jorgenson (2001): In the fast change technological environment, only the new product of introducing period can ask o higher price. The faster the technological change, the faster the chip price drops. The life cycle of new generation chip is getting shorter. Aizcorbe also indicated that the rapid declination of MPU price during 1990's was caused by quality improvement and product innovation jointly rather than the cost reduction for chips. The conclusion drew by Aizcorbe has denied Porter's opinion that cost reduction is the main reason of dropping price. This study attempts to examine whether the product price is the true reason of affecting DRAM firm's profitability. This study obtained the spot price of these products from Thomson Company's Datastream database. With reference to Figure 1 and Table 1, the sampling period is 2004Q1 to 2007Q1 and four types of DRAM products (including 3 types of 256MB and 1 type of 512MB) provide 13 periods of completed data on historical prices. This study calculatied the 3 months moving average for each product. The average price for 4 types of products are then calculated where the quarter-end price

(P_t) and the lag price (P_{t-1}) are taken as the sample data for this study. The calculation formula is shown as follows:

$$P_t = \{[(P1_{256MB,t} + P2_{256MB,t} + P2_{256MB,t}) \div 3] + P4_{512MB,t}\} \div 2 \qquad (4)$$

This study places the DXI and average price into the multiple regression equation (Formula (2) and (3)) as the explanatory variables and relie on the function of multiple regression equation to extract the pure effect on “Price” and “Volume-price compound indicator”. In equation (1) and (2), the regression coefficient β_9 (and β_{10}) for DRAM price P_t (and P_{t-1}) represents the effect from pure “Price” factor towards profitability after other variables completing the explanatory mission. The regression coefficient β_7 (and β_8) for DXI_t (and DXI_{t-1}) represents the effect from pure “Volume-price compound indicator” towards profitability after other variables completing the explanatory mission.

The Collinearity Test

In order to ensure that collinearity does not exist between explanatory variables and all variables can be used for panel data analysis. This study executes the collinearity test on explanatory variables. Table 5 shows the results of collinearity test for these explanatory variables; among them, column 2 shows that P_t and P_{t-1} have collinearity. Thus we divest lag price P_{t-1} and keep only the current price P_t. Column 3 shows that after omitting P_{t-1}, the VIF values of all variables are less than 10, which ensures that collinearity does not exist between explanatory variables.

Table 5: Results of Collinearity Test (VIF value)

Variables	VIF value of all variables	VIF value after omitting variable P_{t-1}
BBR	2.480	2.388
DXI_t	12.358	7.592
DXI_{t-1}	11.947	4.432
P_t	32.195	3.134
P_{t-1}	30.074	
DAPT	1.234	1.208
CAP	1.297	1.293
CSR	2.543	2.531
TUR	2.460	2.456
MS	2.345	2.338

EMPIRICAL RESULTS

The Firm’s Operation Data

The firm’s operation data shown in Table 6 contain means of all firm level variables (among them, the sales are not explanatory variables of this study). With reference to the trend diagram in Figure 3 to 10 simutaneously, the current competition situation (2007) in DRAM industry can be comprehended. In overall speaking, the company that shows best performance in Sales, MS, ROS, TUR and CSR is the leading firm Samsung (SAM) from

Korea. However, it can be found from the trend diagram that, the company's TUR is stable, yet the CSR is rising (unfavorable), and MS, ROS, ROA and ROE are all declining, which shows that Samsung is the challenging target for other firms in the DRAM industry and its profitability faces strict test. Over recent years, the Korean Hynix (HYN) continues to expand its productivity to great extent; the CAP increases extensively, the TUR rises clearly, both the Sales and MS achieved impressive growths. However, the CSR cannot be reduced, the profitability has not increased distinctively, the ROS and ROA only maintain stability and the ROE only achieves minor growth. For the German Qimonda (QIM), its TUR is declining; the Sales and MS are not growing and the performance is not as good as the Japanese Elpida (ELP). For Micron (MIC) from USA, the TUR, Sales and MS are all declining; although the CSR achieves minor decrease, the speed of the Company's cost reduction is not as fast as the loss of market share. Qimonda and Elpida have shown neutral profitability (ROS, ROA and ROE) while Micron faces slight recession. The profitability of these 3 firms cannot compete with Nanya (NAN), Powerchip (POW), ProMOS (PRO) and Inotera (INO) in Taiwan. In 2006, the market share of Taiwanese firms altogether was only 21.06% (refer to Table 1), but the capital expenditure of the same year occupied 32.09% of all firms. By strategic alliance with European and Japanese firms, as well as expanding the productivity extensively, Taiwanese firms will provide new pillar of DRAM production and become the greatest threat to Korean firms.

Table 6: Means of Firm Level Variables

	SAM	HYN	QIM	ELP	MIC	NAN	POW	PRO	WIN	INO
Sales	4508.6	1734.5	1069.4	656.3	1262.1	429.4	540.3	352.0	259.9	83.35
MS	0.4228	0.1453	0.0986	0.0581	0.1185	0.0390	0.0484	0.0317	0.0223	0.0220
ROS	0.3350	0.2551	0.00352	0.0378	0.0472	0.1488	0.2483	0.1331	0.0321	0.3230
ROA	0.0451	0.0428	0.0082	0.0069	0.0070	0.0312	0.0188	0.0208	0.0042	0.0263
ROE	0.0579	0.0778	0.0119	0.0174	0.0097	0.0557	0.0300	0.0354	0.0611	0.0447
TUR	3.3832	2.1725	1.2312	1.5094	2.2063	1.6399	2.7296	1.4668	1.1974	1.6368
CSR	0.5654	0.6288	0.8215	0.7775	0.7471	0.7397	0.6917	0.7166	0.7503	0.6514
CAP	349.43	631.09	205.80	324.39	417.61	404.2	332.08	197.04	127.20	258.80

Note: 1. All amounts are in million USD and all numbers indicate the quarterly data. 2. The data of departmental financial report for Samsung Electronic is not thorough. The Company only announces sales, CSR and operating profit of every quarter for its subsidiary company, i.e. Samsung Semiconductor. This study can only obtain 5 quarters of net income (2004Q2 to 2005Q2) and amount of capital expenditure for every year, which forces us to estimate profit for Semi-conductor Department over other 8 quarters and capital expenditure of every quarter. After repetitive verification, we have proved that the values estimated achieve more than 90% of accuracy. Furthermore, the Company did not announce the inventory data of Samsung Semiconductor, thus this study could only calculate TUR of holding company, i.e. Samsung Electronic.

RESULTS OF PANEL DATA ANALYSIS

In order to determine whether to express empirical results with Random Effects Model or Fixed Effects Model, this study has carried out the Hausman Test on all models of profitability and has listed the results in row 2 and 3 of Table 7. Among them, both the ROS Model and ROA Model adopt the Fixed Effects Model; as for ROE Model, since the Hausman statistics cannot be calculated, the Random Effects Model and Fixed

Effects Model are displayed together for convenience of comparison. Since BBR does not generate significant effect from ROS, ROA and ROE and can not improve Adjusted R^2, it has no explanatory effect on the model and is therefore divested. Table 7 does not list the regression coefficient and significance of BBR. This result indicates that business cycle indicator provides no assistance on forecasting DRAM firms' profitability, which shows different results compared to the study by Chu, Teng and Huang (2005) on semiconductor firms in Taiwan.

Table 7: Result of Panel Data Analysis

Model	ROS	ROA	ROE	ROE
Hausman test Chi-Square(Probabilities)	19.9813(0.0104)	14.7121(0.0650)	------	------
Adapting Model's Type	Fixed Effects	Fixed Effects	Fixed Effects	Random Effects
α or (λ+μ)	0.1184 (0.7851)	-0.0991 (0.1701)	-0.2323 (0.0927)*	-0.1210 (0.3565)
BBR	----	----	----	----
ΔAPT	-1.8851 (0.0268)**	-0.4325 (0.0024)***	-0.9023 (0.0010)***	-0.8868 (0.0011)***
ln(CAP)	-0.0141 (0.0677)*	-0.002235 (0.0791)*	-0.0028 (0.2454)	-0.0032 (0.1574)
CSR	-0.9652 (0.0000)***	-0.1139 (0.0000)***	-0.1789 (0.0000)***	-0.2026 (0.0000)***
TUR	0.0192 (0.1889)	0.0073 (0.0030)***	0.0118 (0.0111)**	0.0120 (0.0057)***
MS	0.4825 (0.0894)*	0.1425 (0.0028)***	0.2098 (0.0202)**	----
ln(DXI)	**0.1395 (0.0283)****	**0.0331 (0.0019)*****	**0.0647 (0.0015)*****	**0.0511 (0.0082)*****
ln(DXI_{t-1})	-0.0378 (0.2926)	-0.0084 (0.1563)	-0.0168 (0.1388)	-0.0121 (0.2789)
ln(P)	**-0.0790 (0.0006)*****	**-0.0111 (0.0032)*****	**-0.0162 (0.0236)****	**-0.0153 (0.0265)****
R^2	0.9311	0.9023	0.8712	0.7566
Adjusted R^2	0.9194	0.8857	0.8493	0.7388
D-W stat..	2.1758	1.8317	1.4311	1.3336
F statistic (Probabilities)	79.5008(0.0000)	54.3161(0.0000)	39.7962(0.0000)	42.3594(0.0000)
N	118	118	118	118

Note: 1. *$P < 0.1$; **$P < 0.05$; ***$P < 0.01$.

Table 7 indicates that DXI_t, P_t, ΔAPT, CSR, TUR and MS are the variables with more powerful explanatory ability in 4 sets of models while CAP is the variables with weaker explanatory ability. Detail descriptions are provided as follows:

- Cost factor — CSR generates significantly negative effect on all profitability models. The firms that are more capable of reducing CSR possess better cost advantages and hence the profitability becomes higher.

- Technology factor — ΔAPT generates significantly negative effect on all profitability models. Since the specifications of DRAM products are uniform, the mass production is easy. The DRAM firms' average process technology is not only most advanced in semiconductor industry, the "Yield" is also the highest. The result of extensive increase in production volume of chips has reduced cost on one hand, but also increased the pressure of competition with deducted price on the other hand. Once the negative effect of such competition is greater than the positive effect of cost reduction, the firms' profitability will reduce. Although ΔAPT generates significantly negative effect on profitability, it has to cooperate with the cost and price analysis for meaningful management as the result. However, this is not the key point addressed in this study.
- Efficiency factor — TUR generates significantly positive effect on ROA and ROE Models, but provides no significant effect on ROS Models (yet it can increase the models' explanatory ability). Thus it is evident that increase of TUR does not only create more sales, but also obtain higher profitability.
- Competition factor — MS generates significantly positive effect on 3 sets of profitability models with Fixed Effects, but provides no significant effect on ROE Model with Random Effects (which also cannot increase the models' explanatory ability). Such result is sufficient to describe that under most situations, the increase of MS does increase the firms' profitability.
- Scale factor — CAP only generates significantly positive effect on 2 sets of ROS and ROA Models, but provides no significant effect on ROE Model (yet it can increase the models' explanatory ability).

This study focuses on the effect on DRAM's average price (P) and volume-price compound indicator (DXI). Table 7 indicates that the current DRAM's average price (P_t) generates significantly negative effect on all profitability models and the current DXI_t generates significantly positive effect on all profitability models. DXI_{t-1} of fall-behind period, on the other hand, induces no significant effect on all profitability models, but it is capable of increasing the model's explanatory ability. Since the effects of P_t and DXI_t happen to be against each other, the question of whether reduction of product price can increase the firms' profitability or not can only be answered after further comparison on degree of effect from these 2 variables. Table 8 shows the comparison between level of P and DXI effect. Since we have processed the 2 variable in logarithm at beginning of establishing the multiple regression equation, the regression coefficients of the 2 variables can compare with each other. For the sake of comparison, we have adopted the following method: β_9 is the regression coefficient for P_t. $P_{average}$ indicates the average P_t ($\Sigma P_t/13$)and $\ln P_{average}$ indicates the logarithm of average P_t. We listed the product from β_9 and $\ln P_{average}$ on column 4. β_7 is the regression coefficient for DXI_t. $DXI_{average}$ indicates the average DXI_t ($\Sigma DXI_t/13$) and $\ln DXI_{average}$ indicates the logarithm of average value for DXI_t. We listed the product from β_7 and $\ln DXI_{average}$ on column 7. Finally, we carry out the comparison via dividing $\beta 7 \times \ln DXI_{average}$ by $\beta_9 \times \ln P_{average}$ and listed the result on column 8. We find that degree of $DXI_{average}$ effect is 9.1332 to 20.6255 times of $P_{average}$. Therefore, we can determine that positive effect from DXI towards the firm's profitability is greater than the negative effect of price. This study has proved that result from competition between DRAM firms with price deduction does cause damage to the profitability.

Table 8: Comparison between Degree of Effect from P and DXI

Model	β_9	$lnP_{average}$	(1)$\lambda i \times lnP_{average}$	B_7	$lnDXI_{average}$	(2)$\beta_7 \times lnDXI_{average}$	□(2)/(1)□
ROS	-0.0790	1.5960	-0.1261	0.1395	8.2562	1.1517	9.1332
ROA	-0.0111	1.5960	-0.0177	0.0331	8.2562	0.2733	15.44.6
ROE (fixed)	-0.0162	1.5960	-0.0259	0.0647	8.2562	0.5342	20.6255
ROE(random)	-0.0153	1.5960	-0.0244	0.0511	8.2562	0.4219	17.2910

CONCLUSIONS

According to the empirical results, the variables that affect DRAM firms' profitability (ROS, ROA and ROE) should also include DXI_t, P_t, ΔAPT, CSR, TUR and MS. CAP is the only variable with weaker explanatory ability. When measuring the effects of product related factors toward the firm's profitability, we cannot only consider the price factor since the effect of volume-price compound indicator shall also be considered. This study has used the multiple regression equation to extract the pure effect of DXI (a "Volume-price compound indicator") and verified that DXI provides positively significant effect on the firm's profitability, which is opposite to the effect of price. Moreover, the degree of DXI effect is 9.1332 to 20.6255 times of Price, which proves that competition between DRAM firms through price deduction does damage profitability. This study finds that since P generates significantly positive effect on the firm's profitability, most MS generates significantly positive effect on the firm's profitability, which explains why DRAM firms are eager to take price reduction as a strategy of seizing MS. However, the result of such strategy still relies on the DXI trends. In other words, in addition to the price factor, the volume of market transactions is also an important variable to determine whether the firm can make profit or not. By incorporating the conclusions from empirical results of this study and study by Zulehner (2003), the following inference applies: Since the DRAM industry has characteristic of "Dynamic oligopolistic interaction", once certain firm starts the price war, the other firms will follow. Finally, the profitability of all firms (including the firm that starts the price war) will be damaged. As the DXI curve shown in Figure 1 decline downwards, the profitability of all firms will suffer disfavor effect. For individual firm, it is very likely for the firm with poor profitability to disappear from the market unless it achieves excellent performance in reduction of CSR or increase of TUR.

According to the results of this study, firms adopt price war for expanding MS just as treat their profitability as a gamble. If there is no confidence of winning, the DRAM firms shall avoid engaging in internal strife. Based on past experience, however, price war in the DRAM industry is inevitable (refer to Figure 1 and Table 1). Since it is inevitable, the firms must devote full effort at improvement of efficiency and cost reduction. In addition to merger & acquisition (e.g.: case of Elpida and Qimonda), this study suggests for development of international and inter-firm virtual team. An equity based strategic alliance contract based on virtual integration with wafer factories of emerging countries in Asia is an effective way of reducing cost (Hsieh, Lin and Chiu 2002; Chu, Teng and Huang 2005). Since 2005, Elpida, Qimonda and Hynix have actively seek alliance with DRAM firms in Taiwan for challenging Samsung. Among them, Qimonda and Nanya have established Inotera under joint venture, Elpida executes virtual integration with Powerchip and Hynix executes virtual integration with ProMos, which all induce significant effect on future development of DRAM industry. By referring to Figures 11 and 12, the joint venture and virtual integration have obtained positive results since 2005Q2. The profitability (represented with ROS) gradually catch up with Samsung and the growth of profit is also better than Samsung. This study considers that the vast investment from Taiwanese firms on the 12-inch wafer factories will generate more alliance and integration; such trend will dominate the development of DRAM industry in 21st Century. For Samsung and Micron that are unwilling to execute large scale of internationally strategic alliance and virtual integration, Samsung will face to defense falling profitability and Mircon will face to protect survivability.

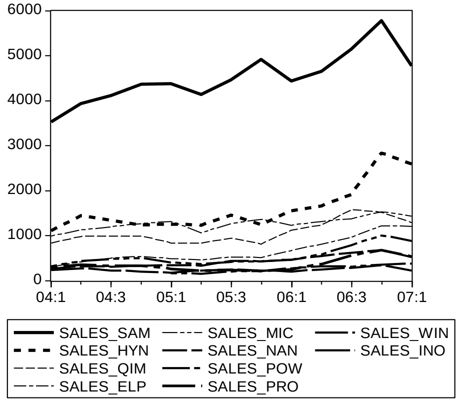

Figure 3: Trend of Sales

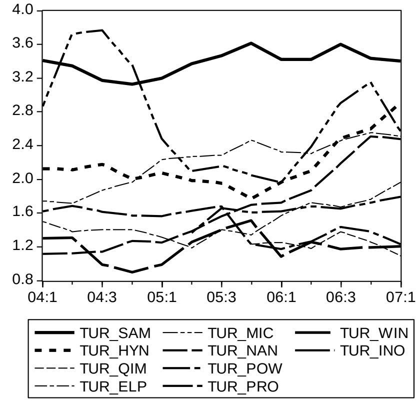

Figure 4: Trend of TUR

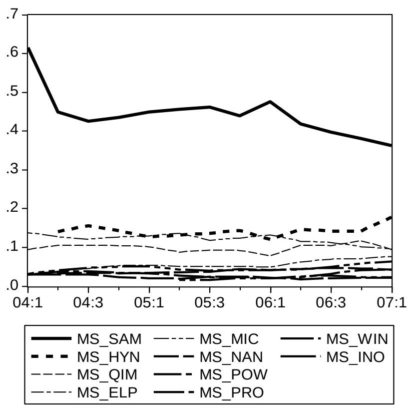

Figure 5: Trend of MS

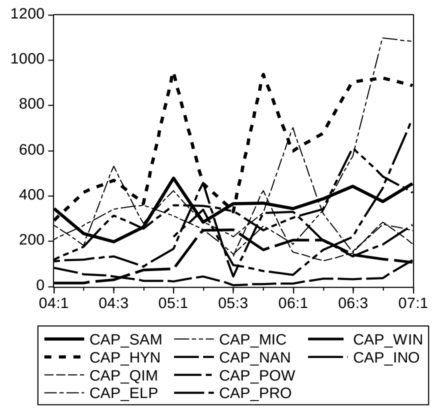

Figure 6: Trend of CAP

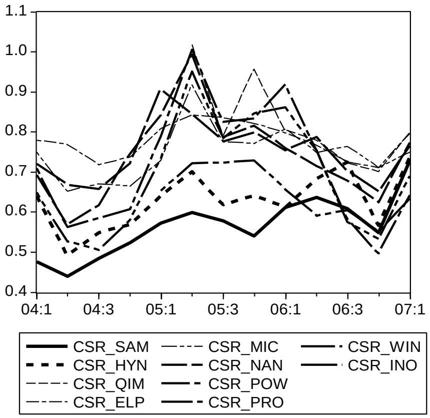

Figure 7: Trend of CSR

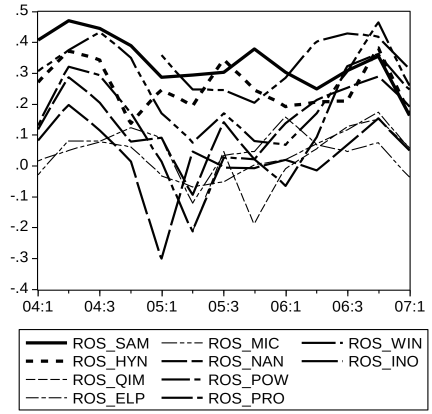

Figure 8: Trend of ROS

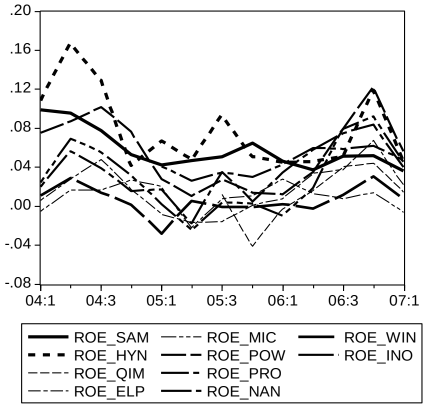

Figure 9: Trend of ROE

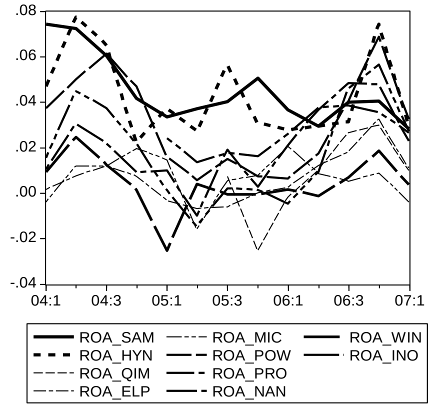

Figure 10: Trend of ROA

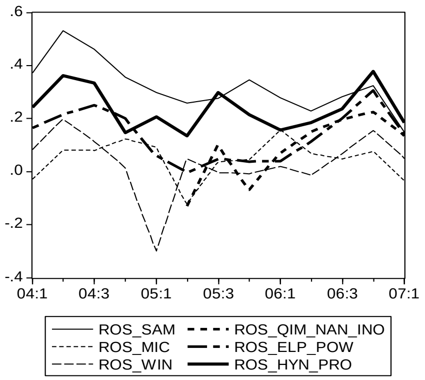

Figure 11: ROS Trend of Alliances

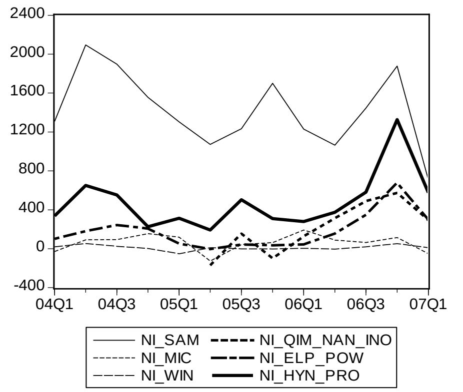

Figure 12: Net Income Trend of Alliances

Note for Figure 11: ROS_QIM_NAN_INO divides the sum of 3 firms' profit by sum of sale. ROS_ELP_POW and ROS_HYN_PRO are calculated in the same way.

There are two main limitations in this study: Firstly, the data of divisional financial statements from certain firms are not complete enough, which affects the representation of the sample data. Secondly, the environmental change in DRAM industry is too fast since the strategic alliance, merger or acquisition between firms is very frequent. Therefore, some large firms newly established such as Elpida and Qimonda can only provide us very limited historical data for empirical verification. Nevertheless, these limitations do not threaten the validity of this study. Since this study only briefly discusses the effect from ΔAPT towards profitability. In fact, the effect of technological change is not limited to the evolution of process technology, which also includes the evolution of product technology (Neto and Fontes 2006). Furthermore, due to the limitation of study scale, this study only briefly discusses the effect from MS towards profitability and has not gone further into the effect from 4 major dimensions towards the DRAM firms' marketing performance (Chen and Li 2006). We believe that these factors are all important directions for future studies.

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