

A Study of the DRAM industry

By

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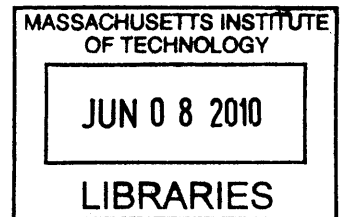
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Submitted to the MIT Sloan School of Management on May 7, 2010 in Partial
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Abstract

Samsung Electronics as a DRAM provider has kept its leadership in the DRAM market with leading technology and production capacity since the 1990s even though there were unpredictable market fluctuations and dramatic changes in competition. Through the depressed market starting from 2006 to 2008, and the financial crisis, Samsung Electronics tightened its leading position in the DRAM market with changes in the dynamics of competition.

But, from the industry wide view, the IT industry is getting complex since its system change from vertical integration to horizontal ecosystem. Also, the shrinkage of optical lithography, the main technical issue in semiconductor industry, is predicted to reach the uppermost limit. In this sense, Samsung Electronics as a DRAM provider should analyze and evaluate its current position in the DRAM market and the IT industry and needs to set a strategic goal and methods for sustaining its current position and also pursue more growth.

I examine the current DRAM market dynamics, diagnose Samsung's current business status and strategy in the DRAM industry, and try to find a way to create value as a complementor in diverse IT industries. Furthermore, I will try to find opportunities where Samsung can sustainably capture value in the DRAM market. For this analysis, I use several frame works and concepts: Value creation and capture, Michael Porter's five forces analysis and Value Chain, Departure from a perfect competitive market, Ecosystem, and Complementor.

Thesis Supervisor: Michael A. Cusumano
Title: SMR Distinguished Professor of Management

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Table of Contents

Chapter 1 Introduction

Chapter 2 Overview of the DRAM Industry

- 2.1 History of DRAM Industry
 - 2-1-1 US Era (1970s)
 - 2-1-2 Japanese Era (Late 1970s ~ 1980s)
 - 2-1-3 Korea and Asia pacific Era (Middle of 1990s ~ present)
- 2.2 The main Industry Features
 - 2-2-1 Short Product Life Cycle
 - 2-2-2 Technology Driven Industry
 - 2-2-3 Equipment Industry

Chapter 3 Analysis of the DRAM Industry

- 3-1 Semiconductor Value Chain
- 3-2 DRAM Industry Analysis
 - 3-2-1 Threat of Entry
 - 3-2-2 Threat of Substitute Products
 - 3-2-3 Bargaining Power of Suppliers
 - 3-2-4 Bargaining Power of Buyers
 - 3-2-5 Rivalry among existing firms
- 3-3 DRAM Market Challenges
 - 3-3-1 Increase of cost in fabrication
 - 3-3-2 Limitation of technology
 - 3-3-3 Change in customer segment
- 3-4 Current DRAM Market Analysis
 - 3-4-1 Recent key factors of market dynamics
 - 3-4-2 Supply Analysis
 - 3-4-3 Demand Analysis
- 3-5 Summary

Chapter 4 Framework from Microeconomics: Departure from perfect competition

- 4-1 Basic concepts of microeconomics
 - 4-1-1 Demand
 - 4-1-2 Supply
 - 4-1-3 Market Equilibrium
 - 4-1-4 Perfect Competition
- 4-2 Framework: Departure from perfect competition
- 4-3 Apply to framework to DRAM Industry

Chapter 5 Case Study with framework: Samsung Semiconductor Division

- 5-1 The factors of Samsung to keep number one position in the DRAM industry

- 5-1-1 Investment for Capability
- 5-1-2 Technology Leadership
- 5-1-3 Cost reduction through process
- 5-1-4 Product Differentiation
- 5-1-5 Organization Advantage
- 5-2 Strategic Points for Samsung from the analysis

Conclusion

List of Tables

Table 2.1	DRAM demand by application
Table 2.2	Market Leadership of 4K DRAM, 1M DRAM and 4M DRAM
Table 2.3	DRAM Market Share in 1987
Table 2.4	iSuppli's Preliminary Q1 2009 DRAM Market Shares
Table 2.5	Investment for Equipment by DRAM product generation
Table 3.1	DRAM demand by application
Table 3.2	Rising cost of building a leading-edge fab, 1983 to 2003
Table 3.3	DRAM industry consolidation: excluding pure foundry players
Table 3.4	DRAM bit demand split by application
Table 5.1	Samsung technology history of new products
Table 5.2	Mixed Line usage of Samsung after 1992

List of Figures

Figure 2.1	Typical Semiconductor Life Cycle
Figure 3.1	Semiconductor Value Chain
Figure 3.2	Porter's Five Forces analysis, applied to the DRAM industry
Figure 3.3	Change in the number of DRAM providers
Figure 3.4	Alliances and Partnership in the DRAM industry in 2008
Figure 3.5	Chip Making R&D Versus Revenues
Figure 3.6	S-Curve for shrinkage of line width
Figure 3.7	Evolution of PC market, 1996 to 2001
Figure 3.8	Operating Profit Margin Of DRAM Chips Based On Contract Price in 2009
Figure 3.9	DRAM industry—relation between average quarterly revenues (US \$m) and operating margin (%), Q102-Q209
Figure 3.10	PC sales and megabyte per set
Figure 3.11	Rate of supply to demand
Figure 4.1	Elasticity in different time frame and industry
Figure 4.2	Market EXIT and Investing by costs and prices
Figure 4.3	Framework from perfect competition of microeconomics
Figure 5.1	DRAM Supplier's Line width generation roadmap
Figure 5.2	framework of departure from perfect competition from Samsung's perspective

Chapter1 Introduction

In 2009, Dynamic Random Access Memory (DRAM) market size is around \$21 billion dollars accounting for 10% of semiconductors after this industry evolved from Intel's mass production of 1-kilobit DRAM based on MOS process technology. DRAM is used for various IT applications but the core application is for the computer.

During the 1970s, Intel led the DRAM market with technology leadership. After the 1980s, Japanese conglomerates such as Hitachi and Mitsubishi took a chance to lead the market with manufacturing efficiency. Lastly, Korean and Taiwan companies are leading the market from mid-1990s to now. With this historical change, severe market fluctuation decreased the DRAM providers from forty to ten. Especially, the world economic depression from recent financial crisis severely affected industry dynamics. At this point, the DRAM providers including Samsung Electronics should consider a new strategy approach to capture market value.

From this view, I analyze the current challenges the DRAM industry is facing and propose a way for DRAM providers to keep capturing value from the DRAM market.

History of the DRAM industry and the main industry features are described in chapter 2. In chapter 3, the overall industry will be analyzed using some frameworks. The value chain of the DRAM industry will be shown and I will check the industry dynamics using Michael Porter's 5 forces. Additionally, I will show current DRAM market analysis and major challenges for the DRAM industry. Chapter 4 introduces Framework from Microeconomics, departure from perfect competition. Chapter 5 will deal with Samsung case.

Chapter2 Overview of the DRAM Industry

DRAM is one of the random access memories which can store the data. It needs continuously to be refreshed to store data. Its data storage capacity called density is measured by kilobit, megabit, or gigabit. The major applications of DRAM are PC and server. As many IT devices are getting diversified, target markets are getting diversified as well.

Table 2-1 DRAM demand by application

Applications	2006	2011E
Desktop	27%	18%
Notebook	15%	29%
Server	8%	8%
Upgrade Module	25%	18%
Graphics	5%	4%
DSC	2%	1%
Game Console	3%	1%
HDTV	2%	5%
Handset	3%	6%
Other	10%	10%

Source: UBS

2-1 History of DRAM Industry

In terms of technology evolution and business strategy, the history of the DRAM industry should be described with the history of semiconductors because the evolution of technology and competitive dynamics in the semiconductor industry has had a huge effect on the DRAM industry. The history of the DRAM industry can be divided by three stages into dominant market

leaders: US, Japan and Korea.

As table 2-2 shows in 1975, US companies dominated with almost 90% market share with 4K DRAM, but no US company was ranked in the top 5 after 1990. After 1992, Samsung started to lead the market with 4M DRAM.

Table 2-2 Market Leadership of 4K DRAM, 1M DRAM and 4M DRAM

1975		1990		1992	
4K DRAM	Market share (%)	1M DRAM	Market share (%)	4M DRAM	Market share (%)
Intel (US)	46	Toshiba (Japan)	23	Samsung (Korean)	13
Texas Instruments (US)	25	Samsung (Korean)	14	NEC (Japan)	12
Mostek (US)	14	NEC (Japan)	10	Hitachi (Japan)	11
NEC (Japan)	4	Mitsubishi (Japan)	10	Toshiba (Japan)	11
National (US)	3	Hitachi (Japan)	8	Fujitsu (Japan)	9

Source: D. Ma¹, J. Yu², Strategy Evolution and Market Leaderships: New Evidences from Semiconductor Memory Industry

This chapter will describe each stage of history and the main factors of change in leadership. Also, it will discuss how technology has changed through its history.

2-1-1 US Era (1970s)

From the invention of transistors by Bell Laboratories in 1947, government subsidies provided for national defense helped the semiconductor industry develop. In the 1970s, Intel and Advanced Memory Systems developed the 1K DRAM product with the mainframe market growing. But, Intel's 1K DRAM became the industry standard due to its cost effectiveness, small size and performance. Following Intel's success, many other US companies such as Advanced Micro Devices (AMD), Motorola, and Texas Instruments (TI) joined the DRAM industry. US companies dominated with almost 90% of market share of 4K DRAM.

At this stage, US companies had a deep relation with the defense industry in terms of R&D expenditure and demand. Therefore, technology leadership and relationship with the government were the competitive advantages for US companies. But, DRAM needs high investment for product development and process, and high capital expenditure needed to be a market leader. This means that investment capability and yield from learning of previous technology is important. Therefore the DRAM industry is significantly related to the national strategy. In this sense, as the memory market was getting large with the growth of digital device, many potential foreign companies entered the market with national support. Also, US companies, especially Intel, needed to efficiently allocate their resources to DRAM or Microprocessors and needed to make strategic corporate decisions.

2-1-2 Japanese Era (Late 1970s ~ 1980s)

Japanese companies such as Hitachi, Matsushita, NEC, Toshiba, Mitsubishi and Fujitsu

challenged the DRAM market dominated by US companies. As shown in table 2-2, Japanese companies took the market leadership from the US companies. There was a semiconductor price war between Japan and the US and the leading US semiconductor makers were forced out of the DRAM Business.¹ As a result of this war, only two US companies – Micron Technology and Texas Instruments – stayed in the DRAM market.

There are several factors behind why the Japanese companies took leadership in the DRAM industry. The first factor was government support. The Japanese government asked foreign companies which wanted to enter the big Japanese market to transfer technology. Also, the government gave a subsidy for research cooperation among Japanese companies. Secondly, Japanese companies had access to easy capital accessibility. The DRAM business is capital intensive and leadership in technology provided a more chances to profit to recover initial investment. Japanese DRAM providers were a vertically integrated division in the large electronics companies. This structure gave Japanese DRAM providers the opportunity to easily get funds from banks and pursue a long-run strategy.

Also, domestic demand for DRAM is one of the sources for business stability. With the above advantages, Japanese providers focused on the process technology for mass production. The best Japanese producers achieved 70 to 80 percent in yield, while yields of the US producers were between 50 to 60 percent². As a result of this, in 1987 seven of the companies among the top ten DRAM providers were Japanese companies as in 1987 shown in table 2-3.

¹ Daw Ma and John Mark, The DRAM Market Structure: The rise and fall in concentration

² Clair Brown and Greg Linden, Chips and Change, The MIT Press, 2009, page 17

Table 2-3 DRAM Market Share in 1987

Rank	Company	Revenue (000)	Market Share
1	Toshiba	\$452,755	17.3%
2	NEC	\$368,800	14.1%
3	Mitsubishi	\$313,780	12.0%
4	Texas Instruments	\$286,575	11.0%
5	Hitachi	\$278,662	10.7%
6	Fujitsu	\$240,431	9.2%
7	Samsung	\$186,275	7.1%
8	Oki Electric	\$122,152	4.7%
9	Micron Technology	\$109,743	4.2%
10	Sharp	\$47,190	1.9%

Source: Dataquest

2-1-3 Korea and Asia Pacific Era (Middle of 1990s ~ present)

While Japan was hit by recession around the early 1990s, Korean Chaebol companies duplicated Japan's strategy to enter the DRAM industry. Three Korean companies – Samsung, Hyundai and Goldstar – invested a lot with government subsidy and a unique Chaebol corporate structure. These three Korean companies invested \$1.2 billion to enter the DRAM industry in 1984 – 1985. In 1995, these three companies earned more than \$ 5 billion dollars with a dramatic growth in demand from the emergence of window 95 at the expense of Japanese company earnings. One of the Korean companies, Samsung, ranked 1st in the DRAM market in 1992 and these three Korean companies took the 32% of market share in 1995³. Many Taiwanese

³ D. Ma1, J. Yu2, Strategy Evolution and Market Leaderships: New Evidences from Semiconductor Memory Industry & In-Stat, Inc.)

companies such as Nan Ya, Promos, Powerchip and Winbond entered the market following the Korean companies' success.

Although Korean companies tried to duplicate Japanese companies' strategy, there were several differences. Firstly, the Korean companies' domestic market for DRAM was small so they needed to focus on the global market. Meanwhile, a significant share of demand in Japanese companies depended on domestic sales and Japanese companies struggled with domestic economic recession. Secondly, Japanese companies had such a high quality standard that they lost their mass production leadership. This is very ironical because Japanese companies had the leadership in the DRAM industry because of production leadership and quality.

After 1992, Samsung kept its number one position in the DRAM market and Korean DRAM providers had 56% of the market share at Q1 2009. Only one Japanese company – Elpida – was ranked in the Top 10 among the DRAM providers.

Table 2-4 iSuppli's Preliminary Q1 2009 DRAM Market Shares

Rank	Company	Revenue (000,000)	Market Share
1	Samsung	\$1,141	34.3%
2	Hynix	\$716	21.6%
3	Micron Technology	\$484	14.6%
4	Elpida	\$471	14.2%
5	Nanya	\$172	5.2%
6	Qimonda	\$160	4.8%
7	ProMOS	\$47	1.4%
8	Powerchip	\$37	1.1%
9	Etron	\$33	1.0%
10	Winbond	\$19	0.6%
	Others	\$42	1.3%
	Total	\$3,322	100.0%

Source: iSuppli

As seen from the history of the DRAM industry, the competitive advantages for firms are fleeting and DRAM providers are always facing the challenges of industry evolution.

2-2 The main Industry Features

There are three crucial industry features for the DRAM industry analysis: short product life cycle, technology driven and equipment based industry

2-2-1 Short Product Life Cycle

The product life cycle of DRAM is very short due to the speed of technology innovation. As the DRAM industry is getting mature and competition for the next generation process is getting tougher, the product life cycle becomes shorter. In this sense, DRAM providers need a specified and speedy strategy from product design to sales.

The average DRAM product life cycle was about two to three years from 4K DRAM in 1974 to 256M DRAM in 2000 and it is accelerating. This short product life cycle implies that DRAM providers who have the leadership in launching a new product can recover their initial investment and enjoy further profits.

The typical semiconductor life cycle shown in figure 2-1 explains how DRAM prices, cost and demand work through the whole DRAM product life cycle.

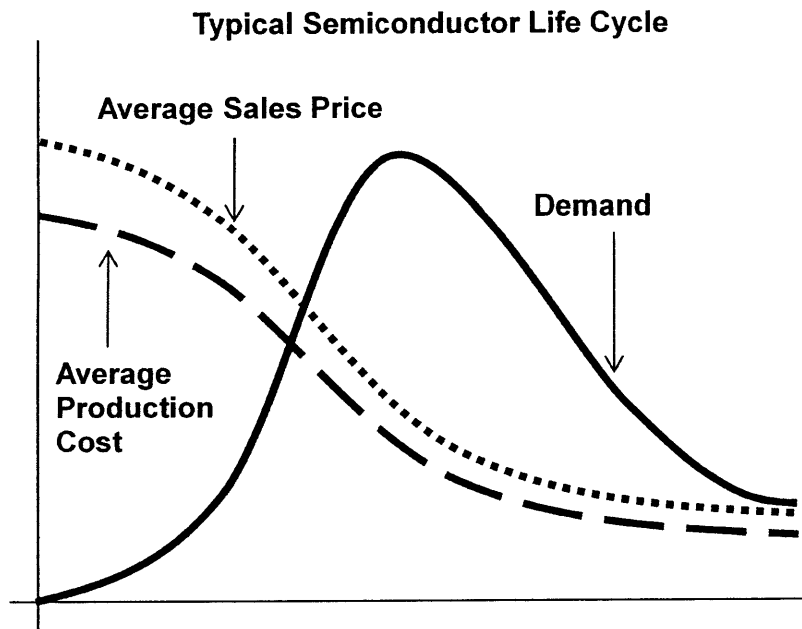


Figure 2-1 Typical Semiconductor Life Cycle (Source: Golding,1972 : Freeman & Soete,1997)

2-2-2 Technology Driven Industry

The DRAM industry is technology driven through its whole process: Product Design, Production, Assembly and Test. Especially, product design and process aspects need a high level of technology and a significant investment is needed at the product and process development stage.

As mentioned before, a company with technology leadership can earn a high premium at the initial stages of a new product and it can maintain a good position to recover its initial investment and enjoy additional profit due to a short product life cycle. Meanwhile, technology followers have difficulty in recovering their initial investment since these companies launch new products at a mature stage where prices decrease dramatically. For example, 4M DRAM sells at \$40 per unit at the initial stage of a product life cycle while prices decrease by \$38 after 4 years from launch. At this point, technology leadership for product design and process are critical factors for a company's competitiveness in the DRAM industry.

2-2-3 Equipment Industry

The last important feature of the DRAM industry is that the dependence on equipment for designing and producing the product is very high. As the density of DRAM and the needs for shrinkage of chip increases, huge capital expenditure for the equipment is needed. As DRAM productivity has a high level of process automation and a close correlation exists between quality of equipment and productivity, the equipment needed for production is more delicate.

Table 2-5 Investment for Equipment by DRAM product generation

1M	4M	16M	64M	256M	1G
350	600	1,300	1,500	2,000	2,500

 (US\$ Millions)

Source: Korea Semiconductor Industry Association

Following the DRAM product generation changes, there was huge increase in investment for equipment as shown in table 2-5. Investment of equipment for 1G DRAM is 2.5 billion dollars that is 7.1 times more than that of equipment for 1M DRAM.

This high tech equipment requires a long lead time and the strategy for procurement is highly related to a company's business strategy because the new product development and mass production cannot be conducted without equipment at each process.

Chapter 3 Analysis of the DRAM Industry

Chapter 3 will first discuss semiconductor value chain and provide an analysis of the DRAM industry and its competitive position within the semiconductor industry using Porter's five forces model

3-1 Semiconductor Value Chain

A Semiconductor product is developed and produced following 4 important steps: design, fabrication, assembly and test. Figure 3-1 shows the semiconductor value chain.

Through the entire value chain, compared to all stages, design and fabrication are the more important stages of value creation. The design stage needs a high level of skilled human resources and expensive EDA software. The fabrication stage requires huge capital investment for equipment set up and a clean environment for production. At these points, technology differentiation can be created from the design stage and cost leadership can be achieved from the fabrication stage.

Although the assembly and test stages require expensive equipment and skilled workers as well, the cost and skill levels needed are much lower than those of the design and fabrication stages. When the semiconductor industry is analyzed, the focus is more on the design and fabrication stages.

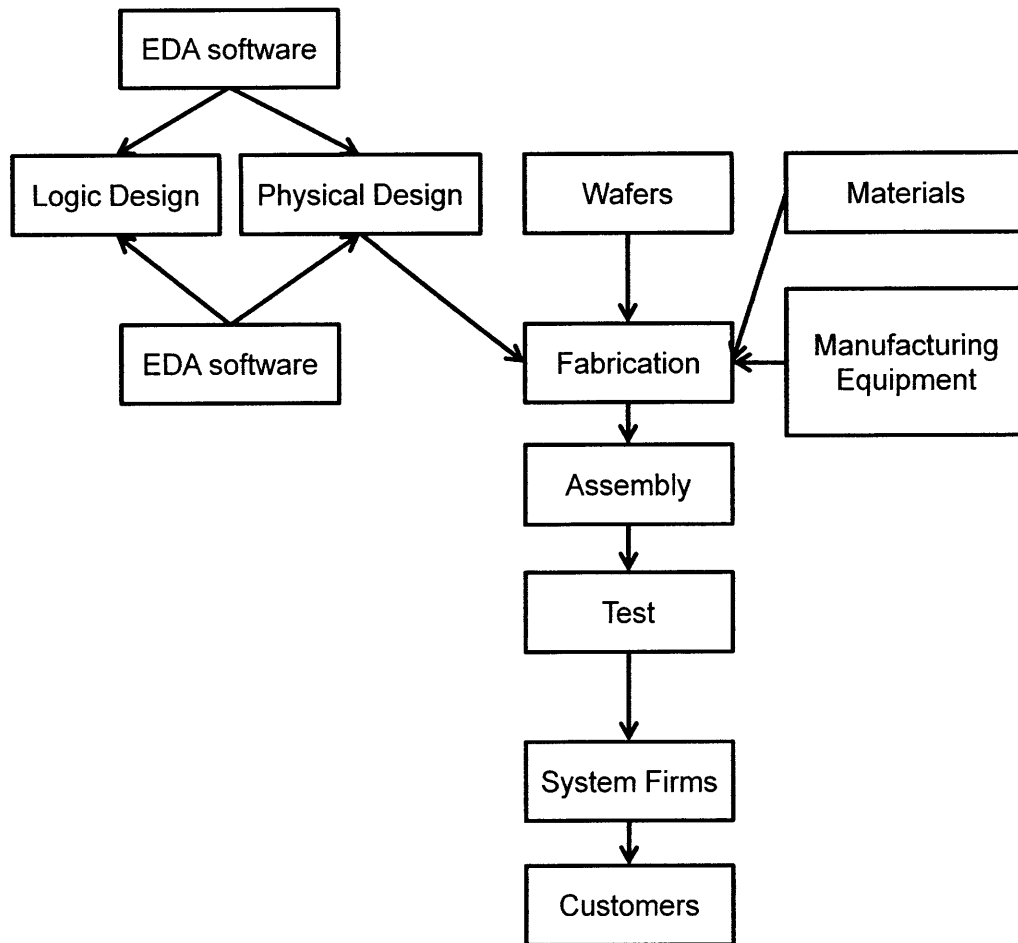


Figure 3-1 Semiconductor Value Chain⁴

⁴ Clair Brown and Greg Linden, Chips and Change, The MIT Press, 2009

3-2 DRAM Industry Analysis

Porter's 5 forces model is used to analyze the DRAM industry. Figure 3-2 gives an overall idea about the DRAM industry.

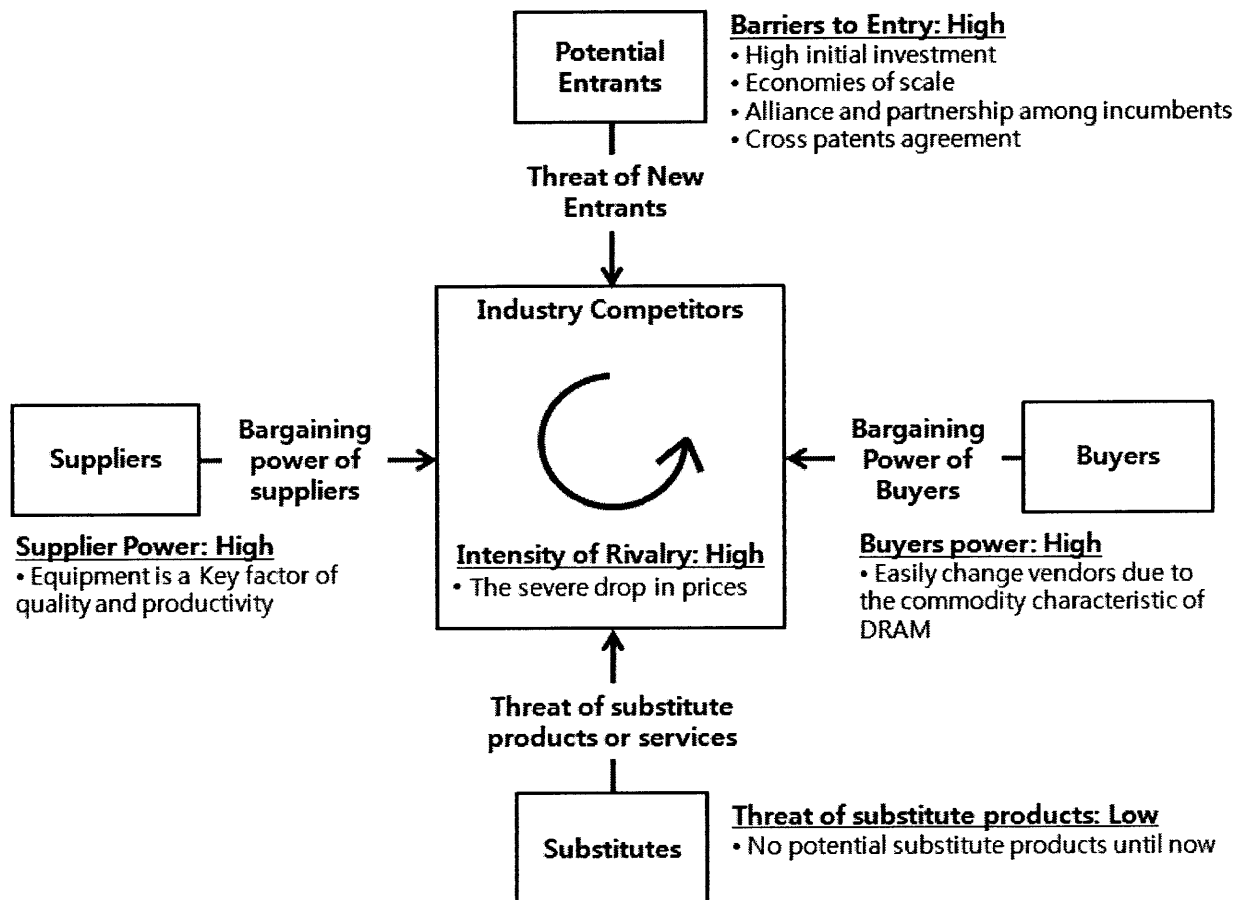


Figure 3-2 Porter's Five Forces analysis, applied to the DRAM industry (Source: Author)

3-2-1 Threat of Entry

The threat of entry in to the market can be measured by current barriers to entry. Barriers to entry into the DRAM industry are quite high with some industry characteristics.

Barriers to entry into the DRAM industry are quite high due to extremely high fixed costs, economies of scale, cross patent and high switching cost.

The design and fabrication stages are crucial to create value from cost leadership and differentiation. In other words, a huge capital is invested in two stages. In the table 2-4, Investment of equipment for 1G DRAM is 2.5 billion dollars which is 7.1 times more than that of equipment for 1M DRAM and it will increase continuously. In addition to the investment for design and fabrication, the investment for human resources is high because of highly skilled human resources for each stage of the value chain. It means that new entrants should take a capital risk premium and it makes barriers to entry high.

Economies of scale in the DRAM industry are another burden to the new entrants. If new entrants enter on a small scale, they should take a cost disadvantage. Also, most of DRAM providers are vertically integrated firms, so they face a cost advantage in procurement and sales.

In the DRAM industry, a significant number of patents are cross licensed because patents can be traded in this market. This cross licensing is another high barrier to a new entrant. As competition is getting tougher, the number of DRAM providers is decreasing from more than 20 in 1986 to around 10 in 2009. Also, partnership and alliance for technology and capacity makes the market power of incumbents bigger.

Considering the above circumstances of the entire industry, the barriers to entry into the DRAM market is increasing.

3-2-2 Threat of Substitute Products

For DRAM, the threat of a substitute is quite low because there are no substitutes which have the exact same function of DRAM until now. Flash memory chips may be potential substitutes for DRAM.

Flash memory is a silicon-based memory, but non-volatile memory chip that is different from DRAM. In 1984 Toshiba invented this technology and Samsung is a leading company with 40% of total market share in the flash memory chip market. Flash memory chips can be electrically written and read and is non-volatile. In contrast to DRAM, flash memory chips can store data without electricity power, but they cannot be a substitute for DRAM. First of all, the times of read and write are the same for DRAM but the write time is longer than the read time. A fast write time requiring system cannot perform with flash memory. Also, flash memory has a write time limitation so it cannot be used for applications which need significant number of write times.

At this point, although one of the substitutes for DRAM with the most potential is flash memory, it is difficult to see flash memory become a substitute for DRAM.

3-2-3 Bargaining Power of Suppliers

The power of the supplier is quite high mainly since the quality of equipment and the timing of supply are critical factors to develop and produce massive new generations of DRAM. The equipment industry was controlled by the US and Japanese companies. As features of DRAM were mentioned in Chapter 2, equipment forms the key factors for cost leadership and differentiation. On account of a high level of process automation and a close correlation between quality of equipment and DRAM productivity, more delicate equipment is needed. Also, the timing of providing equipment can decide the revenue of the DRAM providers since the DRAM market is cyclical. In this sense, the power of a supplier is quite high.

3-2-4 Bargaining Power of Buyers

The main customers of DRAM are computer manufacturing companies covering 70 ~80 percent of the entire market. Also, about 80% of total customers are corporate customers except those that upgrade modules.

Table 3-1 DRAM demand by application

Applications	2006	2011E
Desktop	27%	18%
Notebook	15%	29%
Server	8%	8%
Upgrade Module	25%	18%
Graphics	5%	4%
Computer	80%	77%
DSC	2%	1%
Game Console	3%	1%
HDTV	2%	5%
Handset	3%	6%
Other	10%	10%
Other Applications	20%	23%

Source: UBS

DRAM is a commodity-like product so change their vendors easily. Also, most of the demand comes from corporate so procurement power of these customers is very high. As a result of these facts, the power of the supplier is very high in the DRAM industry.

3-2-5 Rivalry among existing firms

The DRAM Industry has been restructuring through the market recession. US companies controlled the market in the initial stages but Japanese companies led the market during the 1980s. After the 1990s, Korean companies beat the Japanese companies in the DRAM industry and became market leaders. Recently, Qimonda, one of the top five providers, became bankrupt

due to the DRAM market recession in 2007 and financial crisis in 2008. Through these series of events, around ten DRAM providers are competing in the DRAM industry.

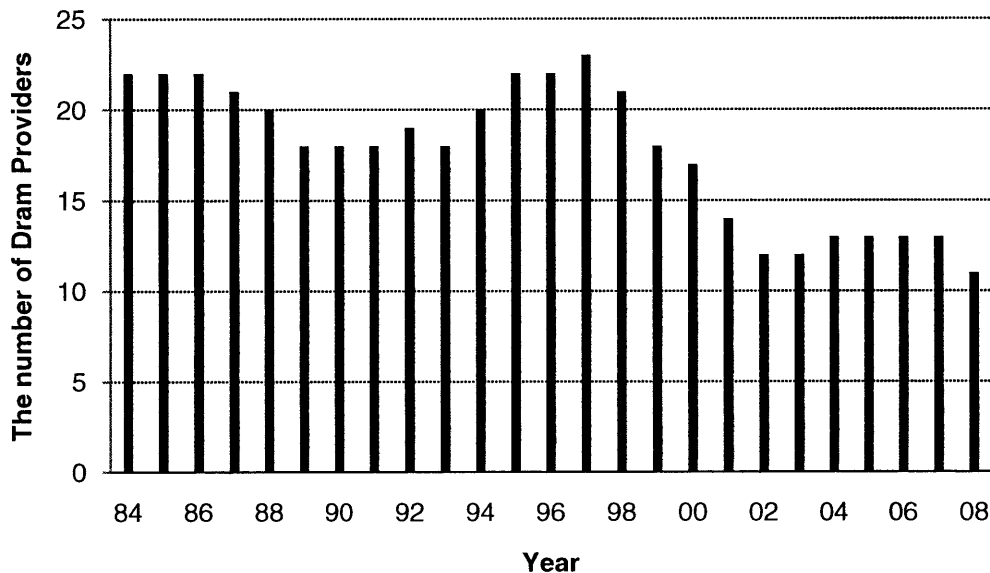


Figure 3-3 Change in the number of DRAM providers (Source: WSTS, IDC, HANADAETOO Securities)

The price fluctuation in the DRAM market is extreme depending on demand and supply. In 2007, the price of 1Gb DDR2 was around \$10 dollars but it dropped to under \$1 in 2008 due to oversupply of DRAM. But, DRAM providers could not stop production due to the high fixed cost and long lead time of fabrication. Also, cost leadership is the core factor for profitability. Therefore the competition for sales and technology development in the DRAM industry is very high.

In sum, the threats from substitutes and new entrants are quite low but the power of

suppliers and customers are very high since DRAM is a high tech commodity. Also, competition among the existing firms is high due to the high fixed cost and the possibility of abnormal price competition.

3-3 DRAM Market Challenges

The DRAM industry has some fundamental challenges regarding costs and technology. The fixed cost for design and fabrication is huge in this industry. For example, the R&D cost of a 1gigabit DRAM was 1.5 billion dollars and equipment cost for that was 2.5 billion. This means the risk on return is increasing. Another challenge is the limitation of circuit integration. The DRAM industry has developed with Moore's law describing "a long-term trend in the history of computing hardware, in which the number of transistors that can be placed inexpensively on an integrated circuit has doubled approximately every two years or three years."⁵ But, there is a physical limitation of integration and it is a critical but fundamental factor affecting the growth of the DRAM industry.

Also, profits are getting squeezed as DRAM customers are now the consumers rather than corporates. Corporate customers are usually more sensitive to quality than to price. But, consumers are very price sensitive and it limits DRAM suppliers' profitability.

This chapter will cover the rising cost of design and fabrication, the limitation of technology and price squeeze resulting from a change in the customer segment.

⁵ http://en.wikipedia.org/wiki/Moore's_law

3-3-1 Increase of cost in fabrication

The increasing cost of fabrication in the value chain of DRAM is the most critical portion when new fabrication for the new generation DRAM is developed. Among the entire fabrication process, photolithograph is the most crucial and the expensive process in terms of equipment cost. To overcome this challenge of fabrication cost, alliances and partnerships among DRAM suppliers has been expanded as shown in figure 3-4. Non-DRAM semiconductor providers such as Qualcomm, Intel and Texas Instruments have increased to the use of foundry services specialized in the fabrication process and this market is extending hugely since foundry services can reduce the risks incurred from huge investment for fixed assets. But, DRAM providers cannot use foundry service due to its typical characteristic of development⁶.

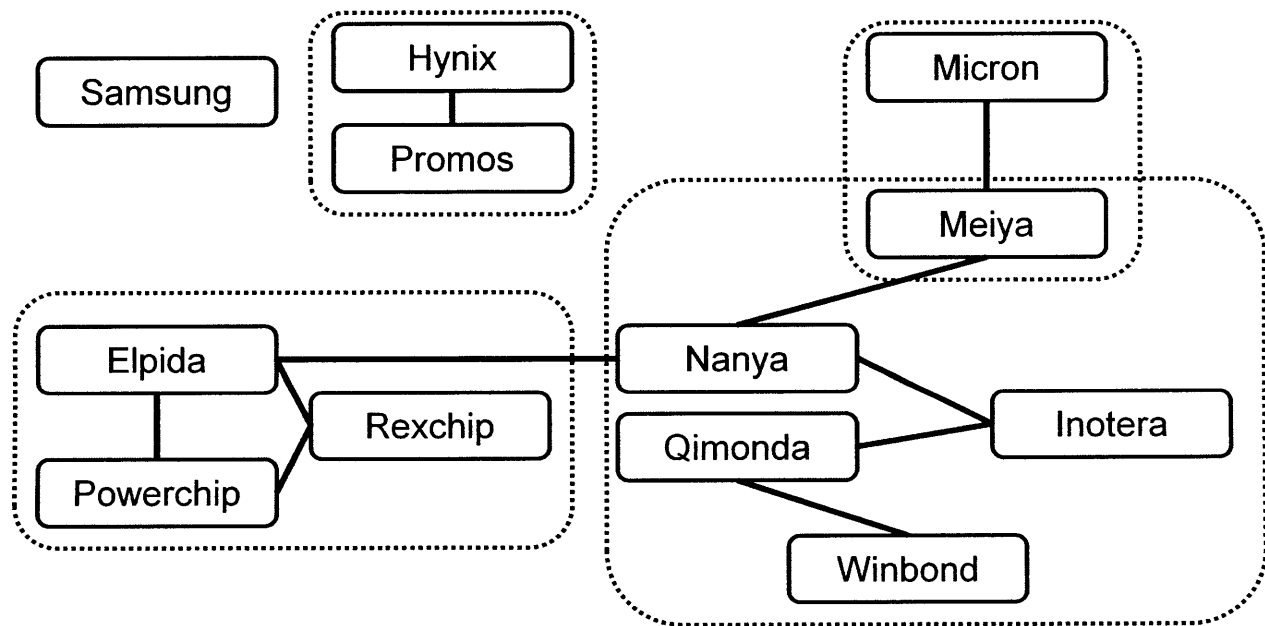


Figure 3-4 Alliances and Partnership in the DRAM industry in 2008 (Source: IBK securities)

⁶ Development of DRAM asks whole processor together from design to fabrication.

The process of fabrication involves the circuit of DRAM being plated on silicon wafer by designed masks. The fabrication of DRAM is conducted through hundreds of detailed process with various equipments. This whole process needs to be conducted in an extremely clean environment.

The critical cost increase of fabrication is investment in the lithography equipment. This equipment is in charge of about 20% of total fabrication facility⁷. For example, the lithograph equipment needed for an eight-inch fab⁸ is valued at 8-9 million dollars and lithograph equipment for a twelve-inch fab is valued at 20 million dollars. Because every new generation of DRAM needs new lithograph equipment, this cost is huge.

Wafer size is an important factor that can enhance productivity in the same generation of product and the same process. Thousands of chips are designed from one wafer⁹. After circuit is plated, a wafer is split into thousands of chips and packaged through the assembly process. Therefore wafer size can determine the productivity among the same product generation since a larger wafer can make more chips. More chips with the same process can reduce the cost of production. From this point of view, productivity is a very critical factor to overcome the rising cost of equipment and fabrication for a larger wafer and is one of the key factors for cost reduction. At this point, DRAM providers have competed to invest and build fabs which can be capable of producing chips with larger wafers. But, the cost of building a leading edge fab has increased as well as shown in table 3-2.

⁷ “Chip makers gripe bitterly, but litho costs keep soaring”, EETIMES, September 1999

⁸ A fab means normally a factory in the semiconductor industry.

⁹ The number of chips is depending on product generation and wafer size.

Table 3-2 Rising cost of building a leading-edge fab, 1983 to 2003

Year	1983	1990	1997	2001	2007
Wafer (inches in diameter)	4	6	8	12	12
Linewidth (microns)	1.200	0.800	0.250	0.130	0.065
Cost (US \$ millions)	\$200	\$400	\$1,250	\$3,000	\$5,000

Source: Adapted from Hurtarte et al., Readapted from Clair Brown and Greg Linden, Chips and Change, 2009, table 2-1

As the costs of fab increase, DRAM providers have invested in new generation technology which shrinks the line width in the chip for profitability. But, the cost of new generation technology has also dramatically increased. The cost of \$1.5 billion dollars for developing 65 nm increased to \$2.4 billion dollars for 45nm¹⁰.

As shown in figure 3-5, these kinds of R&D costs have continuously increased and reduced the revenues gaps. Annual growth rate of revenues will stay at 6.5% but annual growth rate of RD&E¹¹ will be 12.2% between 2004 and 2020 per the following by forecast of VLSI research¹².

¹⁰ G. Dan Hutcheson , The R&D crisis, VLSI Research INC, 2005

¹¹ Research, development and extension

¹² G. Dan Hutcheson , The R&D crisis, VLSI Research INC, 2005, page4

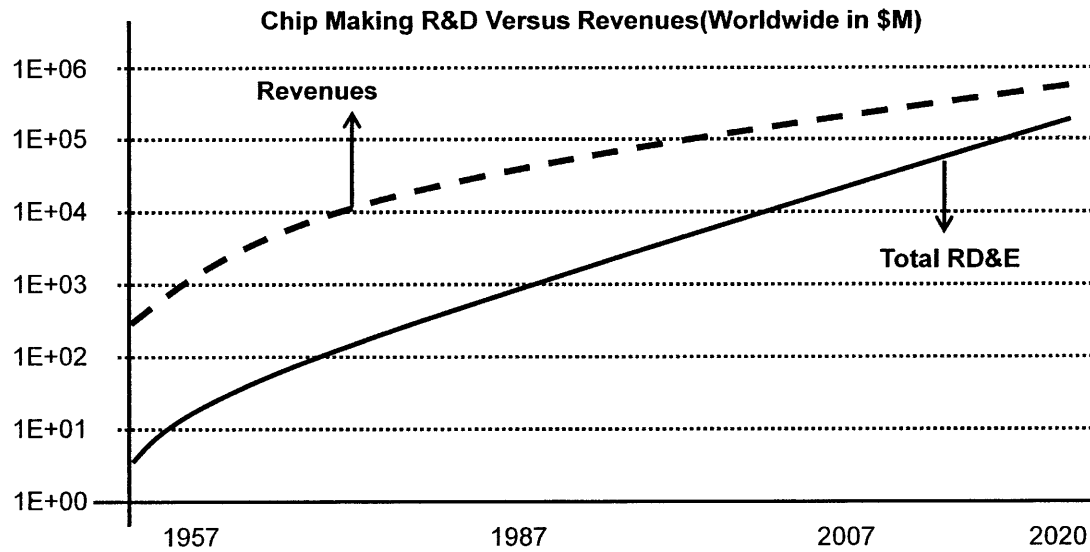


Figure 3-5 Chip Making R&D Versus Revenues (Source: G. Dan Hutcheson, The R&D crisis, VLSI Research INC, 2005, page 4)

The increasing cost of fabrication is a critical issue as discussed but the DRAM providers don't have other options such as foundry services since design and process engineers should work together due to the DRAM process characteristics. In other words, manufacturing process is the competitive point among DRAM providers. It is a critical bottleneck for the industry profitability.

3-3-2 Limitation of technology

As already discussed, the DRAM industry has grown by doubling the density with the same size of chip following Moore's law. The core technology for the new generation of DRAM is the photolithography. Photolithography equipment occupies a huge portion of total DRAM

fabrication costs, i.e., 20% of total fixed cost. The reason why the price of lithography equipment is high is that it is very difficult to enhance its function.

Optical lithography is currently used for photolithograph equipment. This technology is still evolving despite the fact that many experts expect that lithograph technology cannot follow Moore's law due to physical limitations. The micron light beam using wavelengths of 0.436-micron has been used for 20 years and blue-light technology using wavelengths of 0.365-micron was applied to the lithograph equipment. Then the technology using wavelengths of 0.248-micron appeared in 1990s. In 1999 lithograph equipment using 0.193-micron wavelength was shown and is still used for 35-nano meter fabrication process. But, experts insist that more enhancement technology is uncertain. Also, a partnership for technology development among semiconductor providers can be the debatable issue due to the issues of patent and technology roadmap.

Physical limitation of the technology can be explained by S-curve of semiconductor technology shown in figure 3-6.

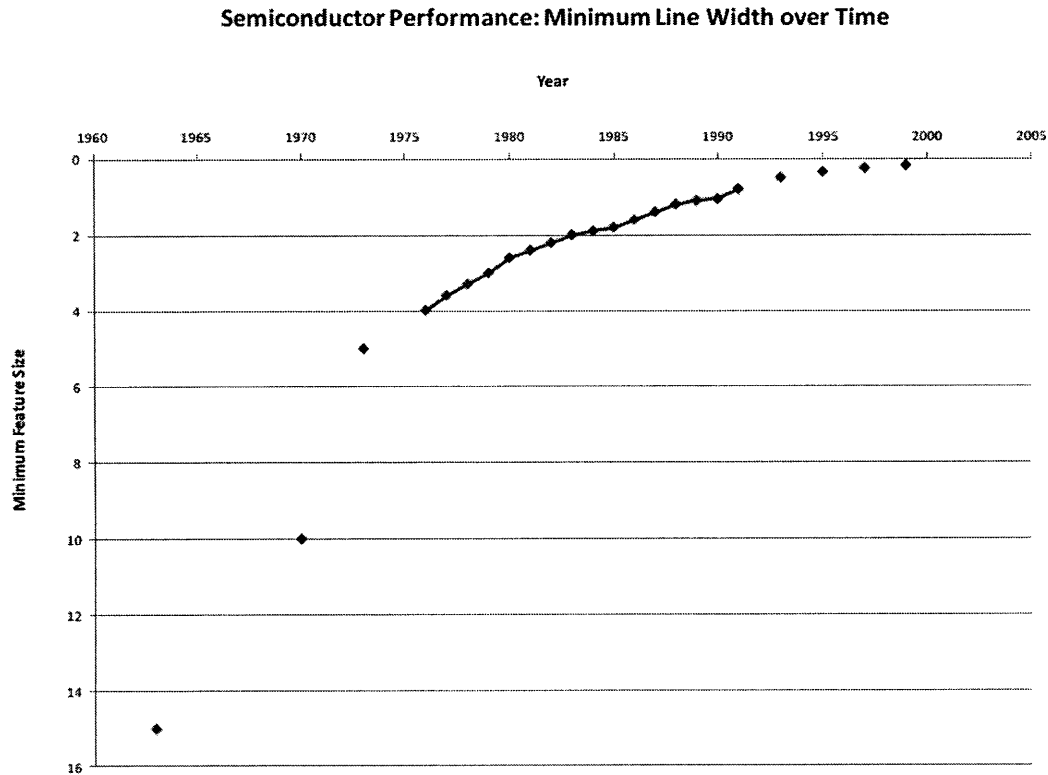


Figure 3-6 S-Curve for shrinkage of line width (Source: Jason Davis, 2009)

This physical limitation of technology is one of critical issues for the DRAM provider to solve, for, shrinkage of the chip size is the main method used for cost reduction.

3-3-3 Change in customer segment

One of big challenges in the DRAM industry is the change in customer segment. Historically, corporate customers focusing on performance and quality of products have grown the DRAM market in terms of market size and technology innovation. But, the consumers segment has grown with the passage of time. This change in the customer segment of the DRAM

market puts pressure on the market to lower prices and it leads to reduction in profit.

The consumer segment in the semiconductor industry was 25% in 1984 but it grew to 55%. With its focusing on the computer market, the consumer segment has increased in the DRAM market from 24% in 1996 to 32% in 2001 mainly due to wide usage of internet.

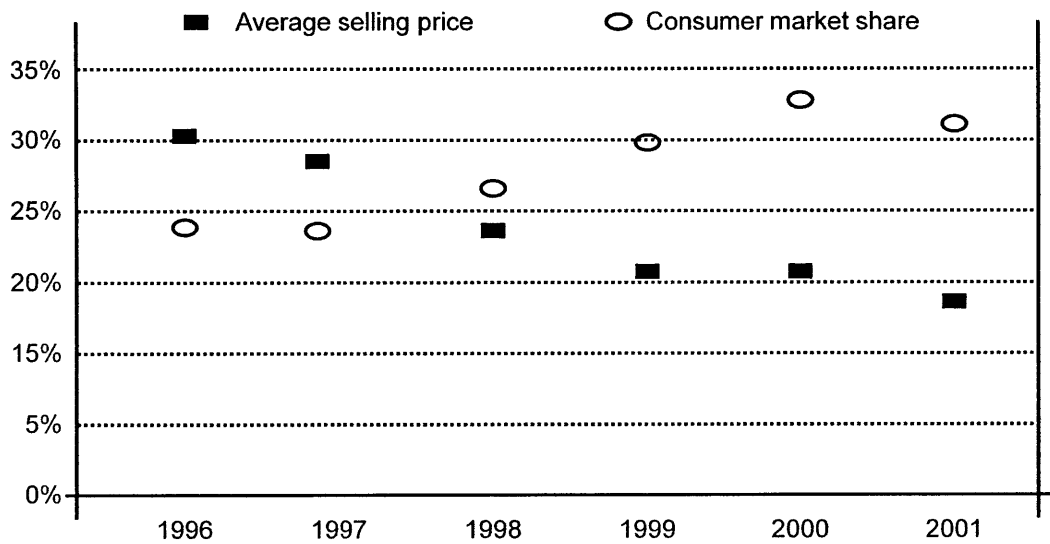


Figure 3-7 Evolution of PC market, 1996 to 2001. (Source: Clair Brown and Greg Linden, Chips and Change, 2009, Figure 4-3)

The growth of the consumer market not only adds pressure to lower prices but also generates efficiency issues in the production since the consumer segment is divided by diverse applications. It is a big challenge to DRAM providers whose mass production is based on standard products.

DRAM providers currently face a big challenge: increasing fabrication costs and uncertain for return on investment. Also, the physical limitation of technology improvement gives rise to an uncertainty of growth in the DRAM industry. Lastly, DRAM providers are

finding it difficult to make a profit due to the growth of the consumer market. From these three challenges, potential risks of cost increase, technology growth and profit is growing.

3-4 Current DRAM Market Analysis

Through the financial crisis of 2008 and the recession in the DRAM industry from 2007 to 2009, the DRAM market has changed on the supply side due to the dynamics of competitors. Also, the demand side of the DRAM market is changing with the appearance of diverse applications and new operating systems of PCs. At this point, Samsung can tap into the DRAM industry again by adopting a business strategy that reflects the current market status.

3-4-1 Recent key factors of market dynamics

There are some major changes in the DRAM industry in terms of the 5 forces analysis as discussed in Chapter3.

Decrease of competition among existing firms

The number of DRAM providers decreased from 11 to 7 through the 21st century. Also, the DRAM market shows characteristics of an oligopoly as the four leading providers have 87% of the market share of which Samsung's market share about 35%. Therefore, DRAM providers pursue more profitability than market share which is

different from the past.

Decrease in the power of buyers

The power of buyers is typically very high in the DRAM industry because the major customers are big PCs makers and customers have bargaining power. Also, major customers can easily change their suppliers since DRAM is one of the commodities. But, as the number of DRAM providers decrease, and with the providers focusing on profit due to the reduction in profitability, the investment and the supply of DRAM decreases in the market. However, new applications and products such as the new operating system Windows 7 (requiring 4 GB DRAM for the system) and many IT devices such as smart phone and net book have appeared all of which require DRAM. In addition, timing of the shipment is getting critical for device makers, and competition among IT devices is getting tougher. As a result of this, the power of DRAM providers is increasing.

3-4-2 Supply Analysis

The supply of DRAM has fluctuated from the beginning of the DRAM market. As mentioned, production capability increase requires a high level of capital and lead time. During the recession between 2007 and 2009, most of the DRAM providers could not invest due to the losses. In 2009 the total capital expenditure in the DRAM industry was 4.9 billion which is the lowest after the start of the 21st century. Therefore bit growth of the DRAM in 2010 will be 44% at most. (IBK securities, 2009)

The most important factor concerning supply comes from DRAM providers. The profits of DRAM providers suffered after the recession in 2007; the operating profit margins of the companies are negative, except for Samsung and Hynix.

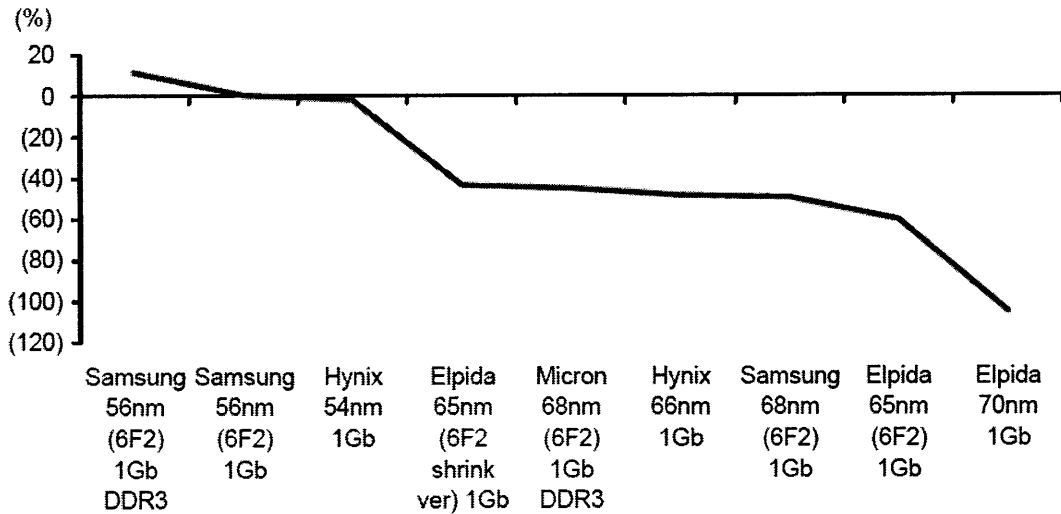


Figure 3-8 Operating Profit Margin Of DRAM Chips Based On Contract Price in 2009

(Source: BNP Paribas estimates, 2010)

As profitability has decreased, the number of providers has reduced from twenty in 1995 to 7 in 2009.

Table 3-3 DRAM industry consolidation: excluding pure foundry players

Rank	1995	1996	1997	1998	1999	2000	2001	2008	2009E
1	Samsung	Samsung	Samsung	Samsung	Samsung	Micron	Samsung	Samsung	Samsung
2	NEC	NEC	NEC	Micron	Hyundai	Hyundai	Micron	Hynix	Hynix
3	Hitachi	Hitachi	Hyundai	Hyundai	Micron	Samsung	Hynix	Elpida	Elpida
4	Hyundai	Hyundai	Hitachi	NEC	NEC	Infineon	Infineon	Micron	Micron
5	Toshiba	LG Semicon	Micron	LG Semicon	Infineon	NEC	Elpida	Qimonda	Nanya
6	TI	Toshiba	LG Semicon	Infineon	Toshiba	Toshiba	Toshiba	Nanya	Powerchip
7	LG Semicon	TI	TI	Mitsubishi	Hitachi	Mitsubishi	Nanya	Powerchip	ProMOS
8	Micron	Micron	Mitsubishi	Hitachi	Mitsubishi	Hitachi	Winbond	ProMOS	
9	Mitsubishi	Mitsubishi	Toshiba	Toshiba	Mosel-Vitelec	Mosel-Vitelec	ProMOS		
10	Fujitsu	Fujitsu	Fujitsu	Fujitsu	Fujitsu	Winbond	Powerchip		
11	IBM	IBM	Infineon	IBM	OKI	Powerchip	Mitsubishi		
12	Infineon	Infineon	IBM	Mosel-Vitelec	IBM	Fujitsu			
13	OKI	Mosel-Vitelec	Vanguard	Vanguard	Nanya	OKI			
14	Motorola	OKI	Matsushita	OKI	Vanguard	Vanguard			
15	Nippon Steel	Motorola	Mosel-Vitelec	Nanya	Powerchip	Nanya			
16	Matsushita	Matsushita	OKI	Matsushita	SANYO	IBM			
17	Mosel-Vitelec	Vanguard	Nippon Steel	Powerchip	Nippon Steel	SANYO			
18	SANYO	Nippon Steel	Motorola	SANYO	Winbond	Alliance			
19	Sharp	SANYO	SANYO	Nippon Steel	Matsushita	Etron			
20	Ramtron	Sharp	Alliance	Winbond	Etron	G-LINK			

Source: UBS, 2009

Even though the exit barrier from the DRAM industry is quite high, DRAM providers could not endure high pressure resulting from loss and highly fluctuating market demand and prices.

To overcome this crisis, DRAM providers, except Samsung and Hynix, the two top rankers in the DRAM market, tried to have a tight partnership establishing Taiwan Memory Company (TMC). In 2008, most of the providers were eager to establish a partnership (TMC) with a subsidy form the Taiwanese government. But, establishing TMC was unsuccessful due to

the complex interests in technology and the difficulty in providing subsidy due to political issues.

As a result, the Taiwanese companies which had a severe loss of profit are in trouble now. It is very difficult for Promos one of the Taiwanese DRAM providers to recover the business since it sold the equipment to Powertech and TSMC. Profitability of Promos was minus 430% in the 1st quarter of 2009. Also, Powerchip faced serious financial loss resulting from debt. Other Taiwanese companies such as Nanya, Winbond, and Innotera have the same kinds of issues. Micron and Elpida also had serious losses in 2009 as shown in figure 3-7.

Economy of scale is the core issue in the DRAM industry due to its high fixed cost. The fact that most of the providers suffer from loss of profitability is closely related to revenue.

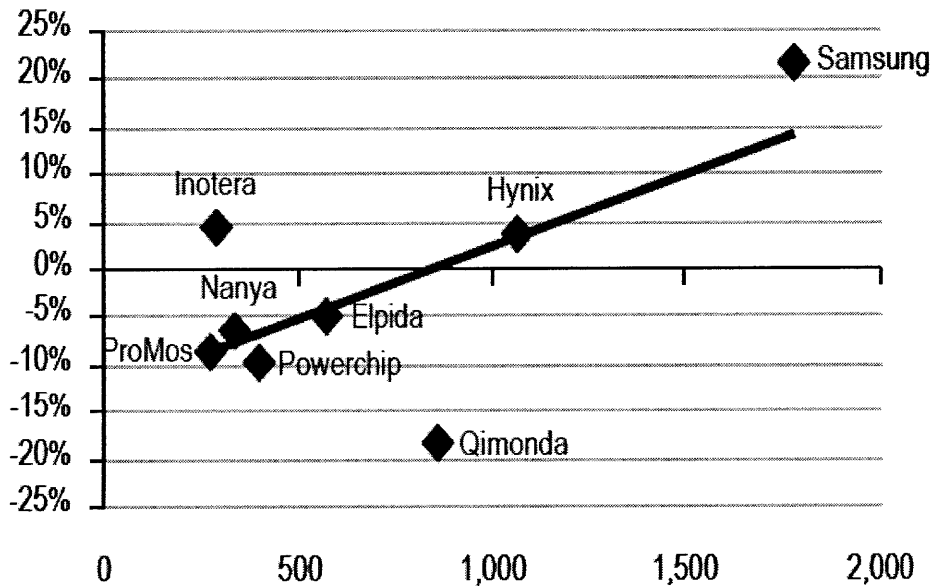


Figure 3-7 DRAM industry—relation between average quarterly revenues (US \$m) and operating margin (%), Q102-Q209 (Source: UBS, 2009)

All things considered, the supply of DRAM will be very limited as a result of decrease in

supply capability in the industry. In addition, the industry will be restricted by M&A.

3-4-3 Demand Analysis

The PC market is the most important factor in deciding DRAM demand since the PC market has almost 80% among total demand. HDTV and Handset are expected to grow to be other important applications in terms of bit demand.

Table 3-4 DRAM bit demand split by application

Application	2006	2011 E	Growth
Desktop	27%	18%	-9%
Notebook	15%	29%	14%
Server	8%	8%	0%
Upgrade Module	25%	18%	-7%
Graphics	5%	4%	-1%
DSC	2%	1%	-1%
Game Console	3%	1%	-2%
HDTV	2%	5%	3%
Handset	3%	6%	3%
Other	10%	10%	0%

Source: UBS, 2009

Even though the segment of new applications which adapts DRAM is growing, the computer is and will be the main driver. Recently, mobile IT products market such as smart phone is growing but DRAM is not mainly used in those applications. Therefore the computer industry is the crucial point to be considered when analyzing DRAM demand.

PC sales and megabyte per PC has been growing even though the growth rate has fluctuated.

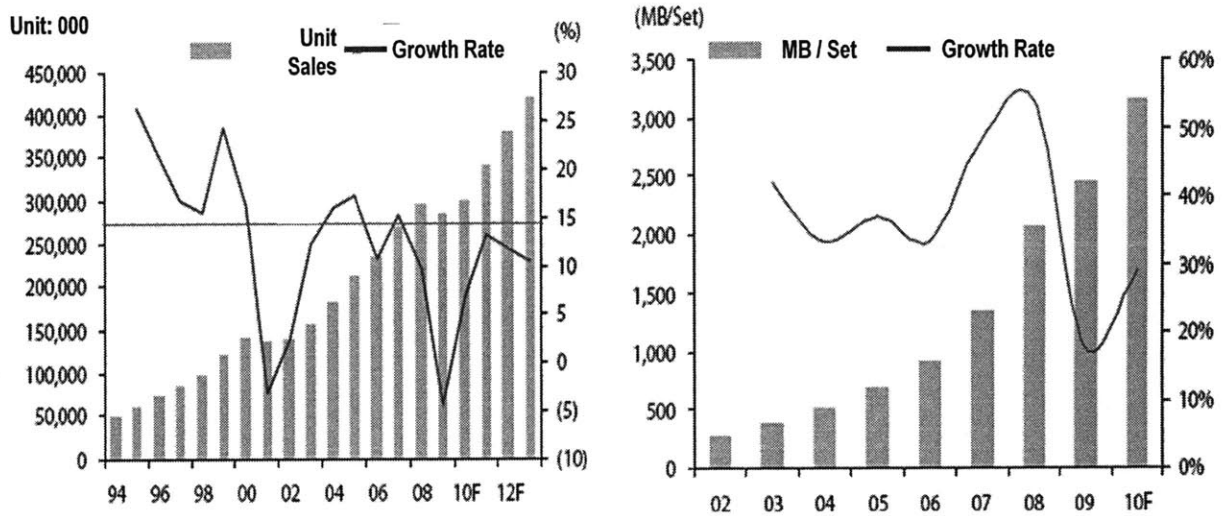


Figure 3-10 PC sales and megabyte per set (Source: IDC, 2009)

As shown in the figure 3-10, PC sales are increasing but PC prices have decreased as well. Also, the decrease in price of DRAM by chip shrinkage offsets the increase in megabyte per set. In 2009, Windows 7 was introduced and it triggers the sales of PC and megabyte per set.

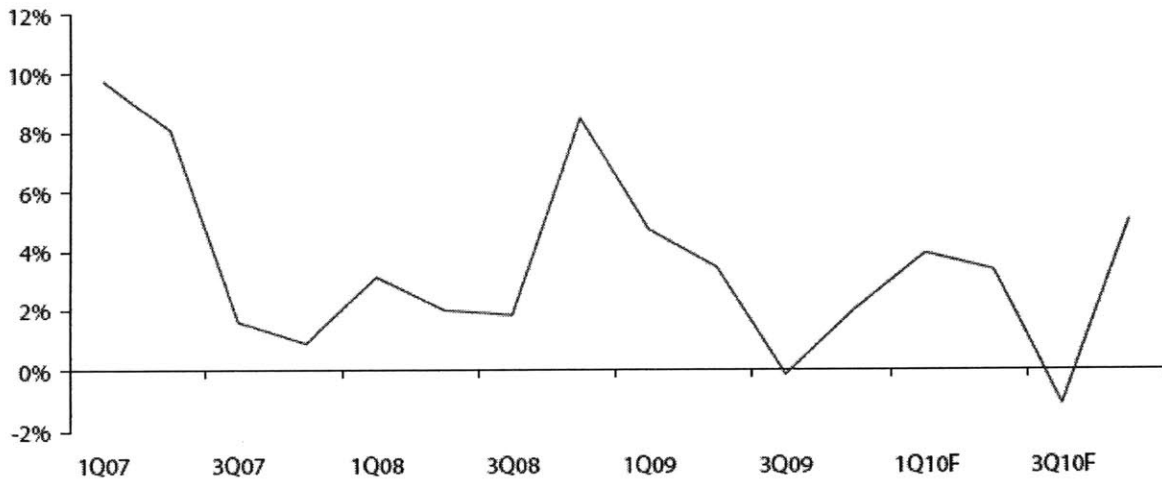


Figure 3-11 Rate of supply to demand (Source: IDC, 2009)

Even though the supply side is weak due to decrease in capital expenditure, market demand does not continue to exceed supply. In other words, the price of DRAM is strong compared to a year ago but it will go downward soon.

3-5 Summary

Analyzing the DRAM industry using Porter's 5 forces model, the DRAM industry is not attractive. The threats from substitutes and new entrants are quite low but bargaining powers of suppliers and buyers are very high and intensity of rivalry is also high.

In addition, the fixed cost for design and fabrication is growing huge in this industry. Also, profits are getting squeezed as DRAM customers are now the consumers rather than corporate customers.

Within these circumstances, the number of DRAM providers decreased from 11 to 7 through the 21st century. This increases the power of suppliers due to the limitation of supply. Even though the segment of new applications which adapts DRAM is growing, the computer is and will be the main driver.

Considering all the dynamic changes of DRAM industry, DRAM providers should consider new strategies for the profitability.

Chapter 4 Framework from Microeconomics: Departure from perfect competition

This chapter explains the framework to be applied to the DRAM industry from a microeconomics perspective. The DRAM industry has many similar characteristics with perfect competition market although the perfect competition from microeconomics is unrealistic. But, strategic points for profitability can be taken by violations of assumptions of perfect competition¹³. Therefore this chapter will describe the basic concepts of microeconomics (demand, supply, equilibrium, and perfect competition) and will point out some strategic points and offer a framework. This framework is generated from A note on Microeconomics for Strategists, Kenneth S. Corts and Jan W. Rivkin, 1999.

4-1 Basic concepts of microeconomics

4-1-1 Demand

Demand is the desire to get any services and products for utility or to attain happiness. From the business perspective, demand is derived from buyers who want to purchase services or products to make a profit by using inputs. Also, willingness to pay can be defined as the price which is indifferent whether buyers do purchase or don't purchase the service or products. This willingness to pay is decided by buyer's tastes, financial capability, availability of substitutes,

¹³ Kenneth S. Corts and Jan W. Rivkin, A note on Microeconomics for Strategists, the president and Fellow of Harvard College, 1999, page 15

and complementary goods. Following the law of diminishing marginal utility, the willingness to pay is decreased by purchasing more units. Therefore the slope of demand curve is normally negative. Aggregating these individual buyers' curves make a market demand curve assume that all products provided are identical. Another important concept is elasticity of demand curve. The price elasticity of demand curve is defined as the responsiveness of the quantity demanded of a good or service to a change in its price¹⁴. The demand of monopolistic products is inelastic to the price change, but the demand of commodity products is very elastic to the price change. Also, the price elasticity of demand curve for short run is usually steep and for long run is quite flat.

From the strategic perspective, this elasticity is very important as related to availability of substitutes, and complementary goods. For example, commoditized mature product manufacturers such as DRAM providers have little power because of elastic demand for price from identical substitutes from other providers. Contrary to this, monopolistic product manufacturers such as Intel have a lot of power affecting the price of complementary products in the PC platform.

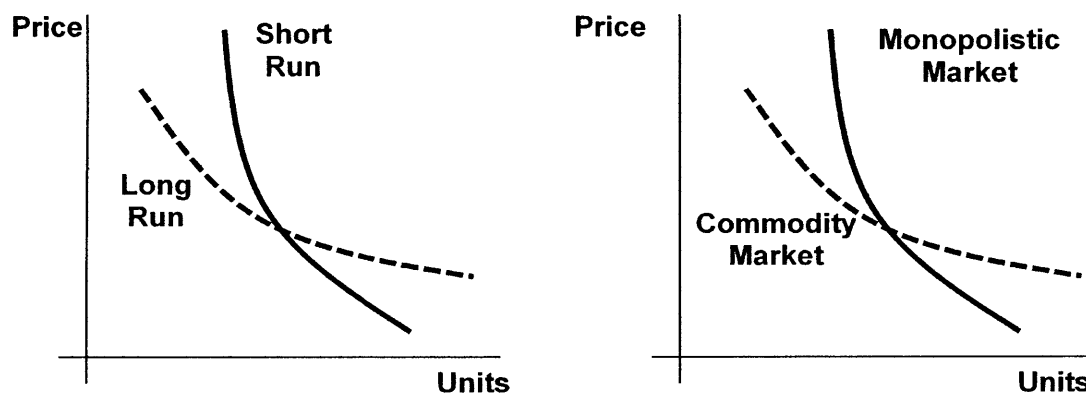


Figure 4-1 Elasticity in different time frame and industry

¹⁴ http://en.wikipedia.org/wiki/Price_elasticity_of_demand

4-1-2 Supply

Supply curve is defined as the amount of goods a supplier will provide at each price¹⁵. A supply curve can provide important points on how individual firms increase their profits. For short run, individual firms focus on production level based on its costs, especially marginal costs. Marginal costs composed of cash costs and opportunity costs affect short run supply. Short run supply curve is the same with positive slope marginal cost curve. In the long run, suppliers should consider average costs including fixed costs and marginal costs as well and firms' exit decisions can be made based on cost analysis. If the market price is higher than a firm's efficient point that marginal costs meet average costs, a firm should increase CAPEX. If the market price is lower than a firm's marginal cost, a firm should shut down theoretically.

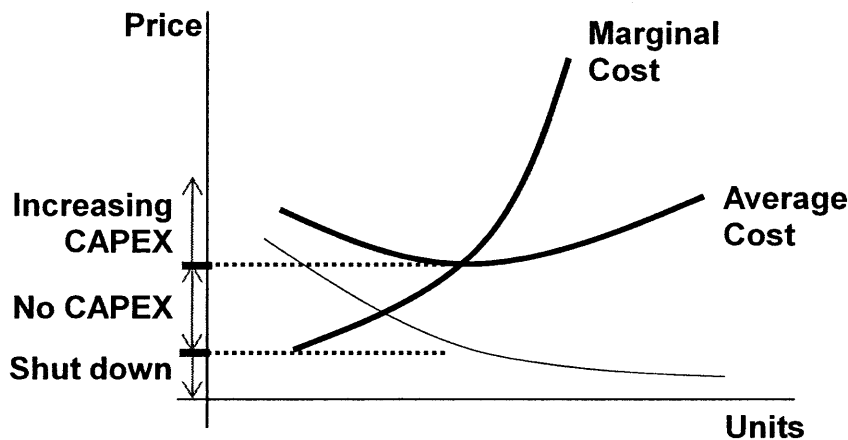


Figure 4-2 Market EXIT and Investing by costs and prices

¹⁵ Kenneth S. Corts and Jan W. Rivkin, A note on Microeconomics for Strategists, the president and Fellow of Harvard College, 1999, page 15

The main factors influencing the supply curve are the costs of inputs and technology. A change of costs makes supply curve move and investing plan change. Disruptive technology increases the efficiency of a firm's operation. Price elasticity of supply is a very important aspect. The supply curve is usually inelastic in the capacity constraints industry or capital intensive industry. Also, supply in the long run is more elastic than in the short run.

From the strategic perspective, the market price and the quantities supplied can be forecasted by concept of elasticity and a firm can cope with the dynamic business situations.

4-1-3 Market Equilibrium

The market equilibrium is the point where demand curve and supply curve meet and market price is decided at this point as well. In the real market, demand and supply, and price do not stay at an exact point of equilibrium due to adjusting time but they move toward the equilibrium. With this equilibrium price, a firm can assess the investment or shut down decisions by comparing with its cost structure.

The market equilibrium is defined with three major assumptions below.

1. Identical Products for aggregating the individual demand and supply curves
2. Many price-taking participants
3. Full information opening to everybody

For a firm's business strategy, market adjustment can provide intuition for decisions. The status of market demand and supply can be detected by market equilibrium price and quantity.

For example, increases in both price and quantity mean industry growth. In addition, price and quantity movement can be forecasted because demand and supply in the long run are elastic. In other words, demand and supply can be easily adjustable in the long run.

4-1-4 Perfect Competition

The model of perfect competition describe that a firm cannot pursue a sustainable profit with the three more assumptions listed below added to those of market equilibrium.

1. Identical sellers: the same technology and inputs are offered to the suppliers
2. Free entry
3. Free exit

From these assumptions, time adjustment is not needed for market equilibrium. If there are any little chances to make a profit, entrants rush in and the price is back to the equilibrium. In other words, firms can earn profits which are exactly the same as the cost of capital. In other words, the competitive advantages from cost leadership and differentiation cannot be achieved in the perfect competition.

4-2 Framework: Departure from perfect competition

A few perfect competition markets do exist in real world industries. But, departures from perfect competition imply strategic points for individual firms pursuing profitability. The strategic framework for industry can be drawn by violating each assumption of perfect competition.

■ Violation of Identical Products Assumption

Buyers can easily change the products depending on prices because all suppliers provide the same products in perfect competition. To violate this assumption, supplier can achieve more profitability when they differentiate their product. To differentiate the product, the firm should have one or more attributes of a product, match their position to customer needs and set an adequate cost which is lower than willingness to pay¹⁶. Also, they use brand image and logistics.

■ Violation of Many Pricing-Taking Participants Assumption

Suppliers and buyers in perfect competition market just follow the market price decided by demand and supply. If there are one or more large suppliers or buyers, this assumption can be violated. In the real world, price-taking assumptions usually happen in the commodity market. Using cost leadership or market control power, a firm can

¹⁶ Krishna G. Palepu, Paul M. Healy, and Victor L. Bernard, Business ANALYSIS & Valuation: Using Financial Statements, South-Western, Thomson, 2004, page 2-8

have price controlling power. Differentiation or cost leadership strategies can be a way to be pricing-makers.

- Violation of Full Information Assumption

This assumption is crucial for market participation. In other words, violation of this assumption can build a barrier to new entrants. Buyers usually have more information for incumbent suppliers and they don't want to take the risk of having a small vendor. Also, incumbents who have a large market share can have more information than a small supplier because they can estimate market information based on their internal data. Therefore new entrants and small suppliers should spend more money on gathering and analyzing market information. An asymmetry in market information can be a big barrier to new entrants.

- Violation of Identical Sellers Assumption

Identical sellers can access the same technology and inputs at the same time. Increasing buying power, cost leadership in process and differentiation are strategies to violate this assumption. For example, Intel which has PC platform leadership with microprocessors, has its own high technology violating this assumption. Contrary to this, many commodity suppliers do not have its identical technology.

■ Violation of Free Entry and Exit

Profit can be eroded under perfect competition since firms can enter and exit the market freely. Suppliers can enjoy high profits by violating free entry. High production experience, huge scale of fixed costs and a strong relationship with the customers can build barrier to entry. But, barriers to exit have another aspect. Even though a supplier suffers a loss because marginal costs are higher than market price, the supplier sometimes does not exit a market due to high exit barrier. Chicken games often happen in high exit barrier industry.

Based on the above discussion, a market under perfect competition is similar to the commodity markets such as DRAM market. Applying this framework to the current industry situation, we can diagnose the industry and see the strategic points for profitability.

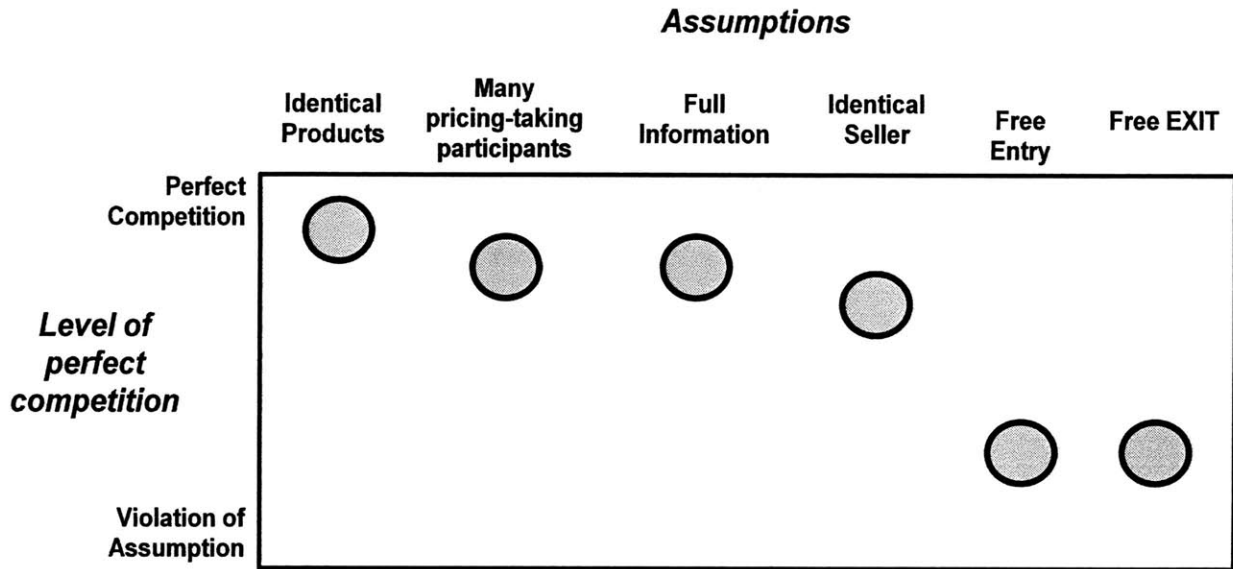


Figure 4-3 Framework from perfect competition of microeconomics

4-3 Apply framework to DRAM Industry

DRAM has the typical characteristics of a commodity: identical products, price taker, full information available and identical sellers. Strategic intuition for DRAM suppliers can be drawn by framework from perfect competition of microeconomics. As DRAM providers try to violate assumptions, DRAM providers can have chances to get profit.

DRAM is almost identical in its functionality because it is one of the commodities. But, DRAM providers can differentiate their products as applications are getting diversified. As the market for mobile products such as smart phones and net book is expanding, low power and long standing battery is a very important function for application. This can be a good opportunity to violate the assumption of identical product.

Also, the timing of shipment is critical to customers of the DRAM providers because DRAM cannot be substituted by other products. Therefore the enhancement of logistics can give a competitive advantage to the suppliers by violating the assumption of identical supplier.

If DRAM providers succeed in violating assumptions of identical product and suppliers, they can pursue price maker.

The framework from perfect competition of microeconomics can provide an opportunity for strategic ways to profitability. Individual DRAM providers apply this framework to their respective businesses by considering its typical business environment. The next chapter will discuss a specific case and try to find a strategy for further growth with this framework.

Chapter 5 Case Study with framework: Samsung Semiconductor

Division

The history of the DRAM industry and its features were described in Chapter 2. Then, Chapter 3 analyzed the DRAM Industry using Michael Porter's value chain and 5 forces model; also, challenges for facing the DRAM industry were summarized in short. Then, a framework from microeconomics for profitability was introduced in Chapter 4.

Next, Chapter 5 will discuss the present status of DRAM focusing on Samsung Semiconductor Division. Firstly, how Samsung Semiconductor Division (Samsung) has helped the number one position for eighteen years is summarized. In addition to this, the situation of the current industry was explained. Finally, some points which Samsung should consider keep the number one position in the DRAM industry.

5-1 The factors of Samsung to keep number one position in the DRAM industry

Samsung has kept the number one position in the DRAM industry after it developed the 64 Megabit memory chip and increased the gap from other competitors in terms of the technology and market share. Also, this gap from the many other institutions in the DRAM industry is expected to increase.

Table 5-1 Samsung technology history of new products

	Developed Time	Developing Duration	Gap
64K	Nov. 1983	6 Month	5.5 years behind
256K	Oct. 1984	8 Month	4.5 years behind
1M	July 1986	11 Month	2 years behind
4M	Feb. 1988	20 Month	6 months behind
16M	Aug. 1990	26 Month	-
64M	Sep. 1992	26 Month	Ahead
256M	Aug. 1994	30 Month	Ahead
1G	Oct. 1996	29 Month	Ahead
4G	Feb. 2001	30 Month	Ahead

Source: Samsung Homepage

As mentioned in Chapter2, companies which were leaders in the DRAM industry had continuously changed from the 1970s to 1990s due to various factors: government subsidy, economic recession and change of core competitiveness. In this section, the strategies which Samsung has taken and other factors for leading the industry are described. Also, what assumptions of perfect competition for profitability Samsung has violated will be mentioned here.

5-1-1 Investment for Capability

One of the ways in which Samsung has succeeded in the DRAM industry is in its bold investment for capability. Samsung's capital expenditure compared to its sales was 39.8 percent twice higher than the average in the world semiconductor industry between 1987 and 1992. Based on this investment, Samsung established a major presence in the market and it kept investing after 1992. This investment was focused on new technology of design and fabrication

process for the next generation product. Investment for capability, especially in wafer size, could increase the competitive advantage in the DRAM industry. But, bold investment for fabrication is highly risky due to uncertainty of technology and a cyclical market situation.

Samsung took a strategic decision to invest in building 8 inch wafer fabrication and it established a major presence in the DRAM market with efficient production capability based on 8 inch wafer fabrication.

Investment for new fabrication includes investment for new equipment, a huge portion of fabrication. Although there is a huge risk in investing in new equipment, investment for new equipment has an advantage in procurement and technology leadership. When equipment suppliers launch new equipment, they also have a quality risk. Therefore, equipment suppliers usually give a price advantage and provide technology support to the first comer. Leveraging these facts, Samsung could secure technology leadership in processing and increase production level to twice that of before 1992. This first mover's strategy was applied to development of 12 inch wafer fabrication in 2001. The reason why Samsung can afford the risk of precedent investment is that Samsung has a diversified portfolio. This is a different competitive advantage of Samsung's compared to other competitors.

5-1-2 Technology Leadership

Technologies of design and process are the core competitive factor in the DRAM industry. At this point, Samsung has kept number one position after 1992.

Vertical integration helped Samsung beat the competitors in technology competition. Samsung has a close internal collaboration from design to mass production. Although this collaboration is the normal phenomenon in the DRAM industry, Samsung uniquely has one site where design, production and sales activity are performed unlike its competitors. This one site strategy can make collaboration among internal processes tighter.

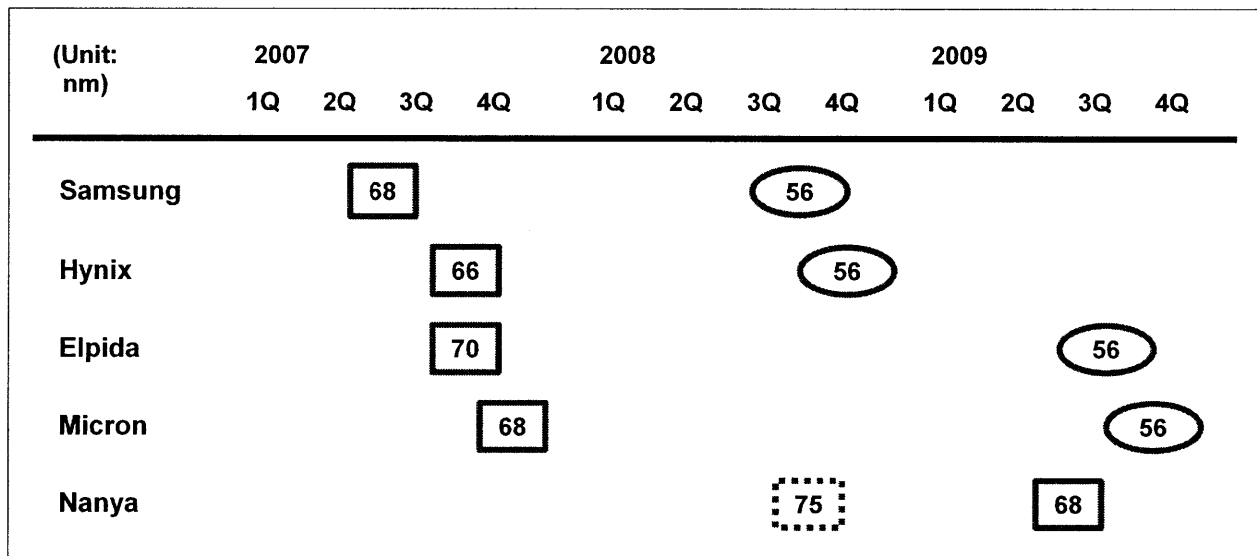


Figure 5-1 DRAM Supplier’s Line width generation roadmap (Source: Samsung)

In addition to this, Samsung has a pre-verifying system which can prove the yield of mass production from the pilot production stages. This pre-verifying system has developed in 2000 and became available due to the vertical integration model. In 2001 Samsung had almost 80% in yield of mass-production at the initial stage of production for the sake of pre-verifying system.

Referring to a typical semiconductor life cycle (figure 2-1), a company with technology leadership can earn a high premium at the initial stages of a new product and it can maintain a good position to recover its initial investment and enjoy additional profit due to a short product

life cycle. Considering this industry feature, technology leadership from internal collaboration and pre-verifying system for accelerating mass production is one of the competitive advantages of Samsung.

5-1-3 Cost reduction through process

As Samsung has enlarged the leadership in capability and technology, it continuously tried to reduce the cost of production by innovation of process.

One-to-one correspondence relationship between circuit density and circuit line width had been maintained in the semiconductor industry by early 1990s. For example, 1.1 micro meter of design rule for line width was only used for 256 kilobit DRAM. Samsung succeeded in applying new line width technology to previous density circuit and dramatically decrease chip size. This process innovation increased productivity of each wafer. In other words, cost of production decreased by increase in productivity.

Also, Samsung utilized old fabrication for developing new product and produce different generations at the same line. This process innovation enhanced the efficiency in usage of product lines. This innovation is getting powerful as the portfolio of products such as flash memory increases.

Table 5-2 Mixed Line usage of Samsung after 1992

Line	Initial Production	Wafer Size	Starting Year
1	64 kilobit DRAM	4 inch	1984
2	256 kilobit DRAM	6 inch	1985
3	1 Megabit DRAM	6 inch	1988
4	4 megabit DRAM	6 inch	1989
5	8 inch wafer processing	8 inch	1992
6	16 megabit DRAM 64 megabit DRAM 64 megabit DRAM Graphic memory Flash Memory	8 inch	1994
7	64 megabit DRAM 128 megabit DRAM Graphic memory	8 inch	1995
8	64 megabit DRAM 128 megabit DRAM 256 megabit DRAM Rambus DRAM	8 inch	1996
9	64 megabit DRAM	8 inch	1999
10	128 megabit DRAM	8 inch	2000
11	128 megabit DRAM 256 megabit DRAM	1, 12 inch	2001
12	256 megabit DRAM 512 megabit DRAM	12	2003
13	512 megabit DRAM	12	2004

(Source: Samsung)

5-1-4 Product Differentiation

Samsung has continuously made an effort to diversify its products for overcoming the

limitation of DRAM product as a commodity as it has maintained the cost leadership by investment in technology and capability and by innovation of process.

The value added features of DRAM are created by improvement in speed, density and power consumption. The issue of power consumption is critical to notebook and mobile product because these are usually wireless products and are used without a plug for the long time. To reflect the needs of these customers', Samsung has developed a low power function for every generation of products. This low power function can create value for the customers and Samsung can enjoy a premium by this product differentiation strategy. Also, Samsung has kept the leadership in density and speed of DRAM and this can be very helpful to capture value in the initial stage of new product market.

Samsung was able to meet the customers' needs by differentiation strategy in product. Also, price premium of differentiated products can be a power for pursuing profitability even during a market depression.

5-1-5 Organization Advantage

One of the factors which allowed Samsung to have leadership in the DRAM industry is diversification in its business portfolio. For example, the semiconductor division of Samsung suffered from two hundred million dollars of cumulative loss in 1986. But, Samsung could overcome a crisis with managerial support from other business units. Also, the fact that Samsung C&T is an expert in building semiconductor fabrication is a competitive advantage in the semiconductor division. In addition, diverse IT products portfolio such as handset, computer and

other electric devices, can give huge advantage of IT market forecast to Samsung. This diversified organization can be a powerful complementary asset to Samsung.

In summary, Samsung has focused on achieving cost leadership and differentiation by investing in capability and technology, innovation of process and product differentiation. From the technology strategy perspective, DRAM is one of the commodity products in the IT industry. There are two important strategic sources to capture value: uniqueness and complementary assets. Samsung wisely used speed of uniqueness and capability of complementary assets.

Reflecting on framework of departure from perfect competition (Chapter 4), Samsung continuously tried to violate assumptions of identical supplier and product even though DRAM is one of the commodities. Samsung tried to violate the identical supplier assumption by investing ahead in capability and technology and innovation of cost reduction of process. Also, Samsung has violated the identical product assumption by differentiating its product.

The DRAM industry dynamics continues to change in competitors, supply and demand through financial crisis in 2008 and deep depression of the DRAM market in 2007. Samsung needs to consider the dynamic change of the industry and come up with a business strategy for facing future challenges.

5-2 Strategic Points for Samsung from the analysis

DRAM is one of the commodities and the DRAM market is almost the same as a market with perfect competition. Any seller cannot make a profit in a market of perfect competition. The DRAM market is not the same as a market of perfect competition but DRAM providers can get the strategic points to increase profit. Especially, Samsung is the number one provider in the DRAM market and can use the advantage from its current position. Considering the analysis of the industry, the current market and the success factors of Samsung, some strategic points for Samsung can come from framework of departure from perfect competition.

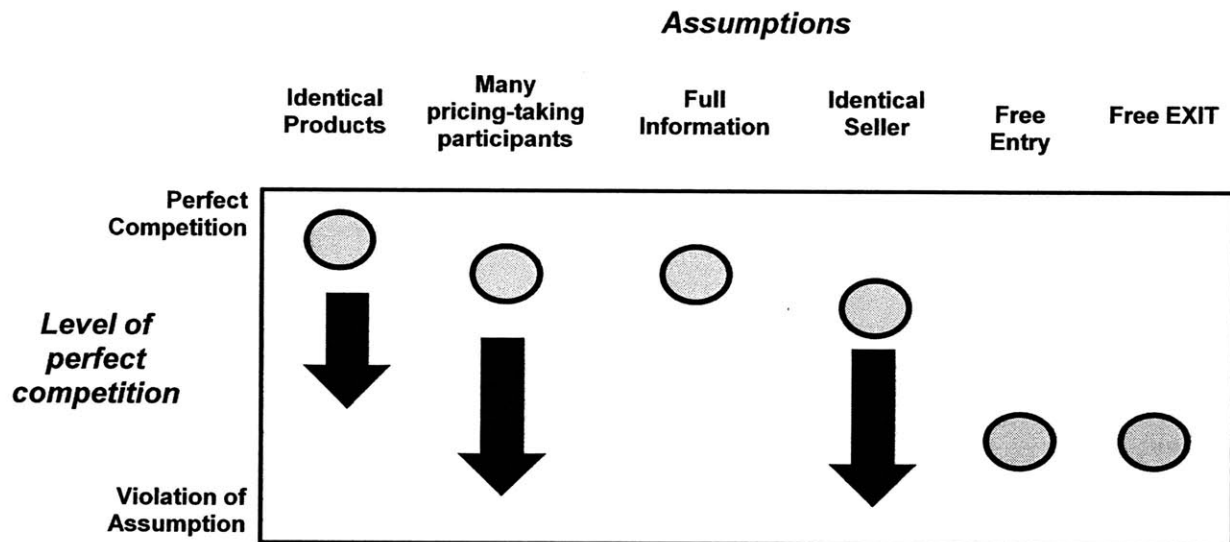


Figure 5-2 framework of departure from perfect competition from Samsung's perspective

(Source: Author)

Assumptions of free entry and exit are not easy to be violated since initial fixed cost is too high to enter and exit the market. Also, information of upstream and downstream is mostly

open to everyone.

Finally, assumptions of identical product, many price-taking participants and identical sellers can be violated for profitability. In terms of product, DRAM is one of the commodities but DRAM providers can make differences not in the products' fundamental function but in the timing of developing and launching the product. As mentioned in Chapter 2, average sales price is very high and Samsung should get the profit and market share in the early stages of a new product. The difference is not in the product itself but Samsung can enjoy the profit by developing every new product by violating assumption of identical product. To violate assumption of many price taking participants, market share is the key to Samsung. Currently, Samsung has around 30% of market share. The DRAM market is mainly controlled by the computer market and the negotiation power of top PC makers is very important. Lastly, violating the assumption of identical seller is the most important point for Samsung. Even though DRAM is a commodity product, Samsung has a quality product and the capability to supply product to customers on time. These strengths come from technology and right investment.

Based on technology advancement and enough capability, market share is the core to violate the above three assumptions. To expand market share, Samsung can focus on current corporate customers or consumers. Although upgrade module market is the only consumer market in the DRAM industry, Samsung did not participate in the upgrade market. Upgrade market occupied 18% of the total DRAM market in 2006 and it is dominated by module makers. Participation in the upgrade market can provide opportunities to not only increase market share but also to enhance brand power.

Conclusion

The DRAM industry has evolved for 35 years in terms of mass production and the industry dynamics has continuously changed. At first, US companies dominated the market with technology, then, Japanese companies grabbed leadership with government support and efficient production process in the 1980s. From the mid 1990s, Samsung took the number one position from Japanese companies.

The change of leadership was the result of various factors such as technology, government support, and economic situations of nations. Just an analysis of the current DRAM industry cannot prescribe the ways to ensure permanent future success. Technology will be continuously enhanced and applications will be more diversified. Therefore no one has the right answer for permanent success and DRAM providers continue to check the industry dynamics and downstream market as well. To do this, departures from perfect competition can provide strategic points to DRAM providers. Analyzing the industry and applying it to the framework can be a way for DRAM providers to pursue sustainable profitability.

In the initial stages of the DRAM industry, US companies had a deep relationship with the defense industry in terms of R&D expenditure and demand. Therefore, US companies had government subsidies. *Technology leadership and relationship* with the government were the competitive advantages for US companies. Following this stage, Japanese companies took the market leadership from the US companies. The Japanese government helped Japanese semiconductor companies obtain technology transfers from foreign companies and provided subsidies for research cooperation. Also, the unique Japanese vertical company structure gave

Japanese companies easy access to huge capital. Japanese DRAM providers were a vertically integrated division in large electronics companies. Lastly, domestic demand for DRAM is one of the sources for business stability.

There is a simple reason why the US companies and Japanese companies lost their leadership in the DRAM industry: their competitive advantages were changed into disadvantages. The US companies focused on design technology and didn't have leadership in the process technology which was an important part of mass production. This led US companies to lose market leadership as the DRAM industry was expanded. In case of Japanese companies, a strong domestic demand basis was a huge competitive advantage. But, high dependence on domestic demand led Japanese companies to lose their market leadership during the recession in Japan.

In the third stage of development, Samsung earned the leadership position with a late-comers advantage. Samsung considered all possible competitive points which the company could use. At the initial stage, government subsidy was provided. Then Samsung invested for capability, design and process development, and cost reduction. Also, it enjoyed a unique corporate organization termed "Chaebol" – which in Korean means a "business family" or "monopoly". Also, the industry competitors have been reduced because of high risk of investment and market fluctuation.

At this point, Samsung meet other kinds of challenges which are different from the previous challenges faced by the US and Japanese companies. As was discussed, physical limit of technology is the critical point for Samsung. Therefore every DRAM provider is trying to develop disruptive products such as MRAM and PRAM. But, these kinds of products still have cost issues to be commercialized. Also, usage of DRAM at each application is not easy to

forecast. Historically, the DRAM market is developed by a growth of the PC market. But, clouding computing has emerged and various applications substitute the PCs which are the main applications for the DRAM. Also, growth of density per PC is limited since OS providers are trying to make their OS lighter than before.

From this perspective, Samsung should forecast future changes in the DRAM industry. Considering all aspects of the industry environment, the DRAM industry can be more commoditized like HDD (Hard Disc Drive). Therefore, the marketing and sales functions of Samsung will become more important than before with continuous technology leadership. Along the same lines, brand power can be the core for Samsung to increase market share in the commodity DRAM market.

From the historic evidence, the DRAM industry has continuously evolved with the IT industry. Currently, the IT industry is changing with new products and a business paradigm such as smart phone and clouding computing. It means that IT ecosystem surrounding the DRAM providers can be changed. Samsung should keep tracking the changes in the industry so as not to experience the same fate of the previous leaders in the DRAM industry.

BIBLIOGRAPHY

- BrownClair, & LindenGreg. (2009). "Chips and Change." The MIT Press.
- Chip makers gripe bitterly, but litho costs keep soaring. (1999, September). *EETIMES* .
- Christensen, C. M. (1997). *The innovator's dilemma*. Harvard Business School Press.
- ChristensenM.Clayton. (2003). "The innovator's solution." Harvard Business School Press.
- Corts, K. S., & Rivkin, J. W. (1999). A note on Microeconomics for Strategists. The president and Fellow of Harvard College.
- (2005). *How to Respond to Changes in the Semiconductor Value Chain*. Gartner.
- Hutcheson, G. D. (2005). *The R&D crisis*. VLSI Research INC.
- Ma, D., & Mark, J. (2003). *The DRAM Market Structure: The rise and fall in concentration*. London.
- Mal, D., & Yu2, J. (2007). Strategy Evolution and Market Leaderships: New Evidences from Semiconductor Memory Industry. (pp. 372-376). IEEE.
- Palepu, K. G., Healy, P. M., & Bernard, V. L. (2004). *Business ANALYSIS & Vlauation: Using Financial Statements*. Thomson.
- Porter, M. E. (1980). *Competitive Strategy – Techniques for Analyzing Industries and Competitors*. New York: The Free Press.
- Siegel, J. I., & Chang, J. J. (2009). Samsung Electronics. Harvard Business School Publishing.