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**Creating First-Mover Advantages:
The Case of Samsung Electronics**

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Abstract

This paper analyzes the sources of first-mover advantages by examining the case of Samsung Electronics, a firm which has maintained and strengthened the technological leadership in the DRAM industry since 1992. The focus is on endogeneity of first-mover advantages under changing technological and competitive environments, part of which are also shaped by the technology leader. The paper also discusses general implications of this case study for strategy and organization for innovation.

Key words

First-mover advantages, innovation, firm growth, Samsung Electronics, semiconductors

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1. Introduction

The history of the dynamic random access memory (DRAM) industry used to be characterized by continual leadership changes: Whenever DRAM technologies moved to next-generation products in every 3-4 years, technological leadership was passed from an incumbent leader to a new challenger. However, this pattern ceased once Samsung Electronics Co. became the world leader in 1992. Samsung has since then strengthened technological leadership for four generations of DRAMs in a row and it is even said that the world DRAM market is currently being run by “1 tiger and 3 cats.” Samsung has emerged as the undisputable leader by a wide margin in competition with previously major competitors like Micron Technologies, Infineon Technologies AG, and Hynix Electronics.

This paper investigates how and why the history of the DRAM industry has been re-written since Samsung’s emergence as the technology leader and discusses its implications to our understanding of first-mover advantages. DRAM production is governed by significant first-mover advantages because it requires heavy investments in research and development (R&D) and facilities and the life cycle of each generation of products is extremely short. Industry leaders can charge high prices during the initial period of a product life cycle and have better chances to recoup their investments, whereas latecomers can only sell their products during later stages of a product cycle when prices fall rapidly and thus have smaller chances to recoup their investments. The history of the DRAM industry before Samsung’s leadership is therefore a story about how the latecomers overcame the disadvantages of late entry with ingenuity and determination. On the other hand, the history after Samsung’s leadership can be understood as a story about how first-mover advantages became

even stronger with latecomers facing increasing difficulties in overcoming their disadvantages.

This paper explores these changing advantages and disadvantages between forerunners and latecomers by investigating the endogeneity of firm growth under changing technological and competitive environments. Overcoming the disadvantages of a latecomer requires the right strategies and organization. First-mover advantages are also not simply preordained but are created in the process of responding to changing technologies and competitive challenges. As a forerunner, Samsung Electronics continued to devise strategies and manage its organization so as to create and maintain first-mover advantages. In this paper, the following factors are highlighted: (1) aggressive and timely investments in R&D and facilities, (2) speedy ramping-up and development, (3) process innovations for reducing production costs, (4) technological choice, deepening and diversification, and (5) governance and organization of the firm.

This study is based largely on authors' interviews and working with Samsung Electronics officials during 2003-2004 and includes various internal sources which have not been made publicly available. While several studies have looked at how Samsung caught up with its forerunners prior to 1992 (Choi 1996; Kim 1997; Choung et al. 2000; Mathews and Cho 2000), to our knowledge this study is the first to analyze how and why Samsung has maintained its leadership in the DRAM industry for over a decade since then.

2. First-mover Advantages and the DRAM Industry

In their seminal survey paper on first-mover advantages, Lieberman and Montgomery (1988: 52-53) argue that prevailing theoretical models “have been designed to articulate one piece of the first-mover puzzle but have failed to embed it within a suitably endogenous system” and, therefore, have not dealt with the “fundamental (and in our view most interesting) question on how first-mover opportunities arise and are pursued by specific firms.” They also insist that “future empirical research needs to be more precise in elucidating specific first-mover mechanisms”, rather than remaining at the level of “general investigations of the merits of pioneer versus follower strategies”.

A plethora of studies has investigated the sources and workings of first-mover advantages, though most of them have been written rather independently and employ different terminology and focus. A large part of research on firm growth, strategic management and innovation deals with the issue one way or another. In particular, the resource-based view of firm growth (Penrose 1959; Wernerfelt 1984; Barney 1996) understands a firm as an entity that possesses productive resources and is engaged in a continuous search and selection process to gain or maintain its competitive advantages. Innovation studies by evolutionary economists are also concerned with first-mover advantages, though not exclusively (Schumpeter 1934; Nelson and Winter 1982; Freeman and Soete 1997; Dosi et al. 1988). Successive innovations result from an interactive process by which forerunners forge ahead with “new combinations” that allow them first-mover advantages as latecomers attempt to catch up with them employing their own new combinations, often utilizing late-comer advantages. Recently, first-mover advantages have been given attention to by those who study network externalities (Katz and Shapiro 1985; Shapiro and Varian 1999; Kristiansen

1998). Positive network externalities are here a major source of first-mover advantages.

However, still wanting are in-depth analyses of “elucidating specific first-mover mechanisms”, as Lieberman and Montgomery (1988) point out. How a firm creates, maintains and exploits its first-mover advantage is not clearly understood or established. It seems to us that this has more to do with the fundamental existence of diversity than the lack of theories or empirical studies. Firms and their competitive environments are diverse and undergo continuous change. There is no universal theory that can adequately explain this diversity in its entirety, as Weber (1949) pointed out more than a century ago. What seems more appropriate for researchers is to build ‘small’ theories to better understand particular events by looking at recurrence of and deviations from what are anticipated by those theories and to employ them to understand configurations in the reality. This process of building theories and understanding the reality is a never-ending one. We need perpetual updating and augmenting of our knowledge. Our understanding of firm behavior can be never complete.

Our study of Samsung Electronics is a small contribution to this pursuit for elucidating first-mover mechanisms, which we hope will be useful for building theories to better understand firm growth and innovation. There have already been quite a few studies of Intel’s maintenance and exploitation of first-mover advantages (Jackson 1997; Burgelman 2002), yet no similar study has traced Samsung’s technological leadership in DRAMs (and memories) over the past decade.

One important characteristic that distinguishes Samsung’s case from Intel’s is that the former had to rely solely on technological leadership with little help from network externalities. DRAMs (and memories) are standardized components which

can be replaced by products made by other companies with little switching cost. Customers of the products are companies that are extremely sensitive to price and quality and that, unlike general consumers, are not easily swayed by brand names or advertisement.

The competition in the semiconductor industry is based on increasing the complexity and decreasing the size of chips, as manifested in Moore's law.¹ Therefore, it is imperative that semiconductor firms continually invest heavily in R&D facilities to maintain their edge. For instance, as Table 1 shows, the average cost of R&D investment for successive generations of DRAM increased from US\$30 million for 1M DRAM to US\$800 million for 256M DRAM, and further to US\$1,500 million for 1G DRAM. The average cost of facility investments also rose from US\$350 million for 1M DRAM to US\$2,500 million for 256M DRAM, and further to US\$5,000 million for 1G DRAM. Samsung maintained its leadership through outspending its rivals in R&D and facilities as well as through starting these major investments earlier than its rivals (section 3.1).

For a success in competition in the DRAM industry, heavy and early investments are only part of it. Equally important is speedy development and ramping-up, i.e., shortening the time taken from developing products to mass-producing them, due to the high volatility of prices and rapid generational changes in the industry. Samsung's technological leadership after 1992, as well as its catch-up prior to 1992, had much to do with its ingenious ways of speedy ramping-up and development (section 3.2).

¹ The observation made in 1965 by Gordon Moore, co-founder of Intel, that the number of transistors per square inch on integrated circuits had doubled every year since the integrated circuit was invented. Moore predicted that this trend would continue for the foreseeable future. In subsequent years, the pace slowed down a bit, but data density has doubled approximately every 18 months, and this is the current definition of Moore's Law.

Semiconductor firms also compete fiercely to reduce production costs through various process innovations. One first-mover advantage Samsung enjoyed was the result of having developed future generation micro-fabrication technologies earlier than its competitors, which enabled it to reduce production costs substantially by applying them to current generation products. Samsung also employed various other methods to reduce production costs (section 3.3).

One challenge that faced DRAM producers from the middle of the 1990s onward was the possibility that the industry might fall into a commodity trap, which meant that the DRAM could become a commonplace product with technological maturity and subject to the vicissitudes of heavy price fluctuations seen in many commodities. Samsung overcame this possibility by developing high-end DRAMs and diversifying into newly-emerging memory products (section 3.4).

This competition for investment and innovation should be also supported by appropriate organization. Samsung maintained a very close integration within the firm. It was also managed by a strong owner-manager, who was instrumental in carrying out timely and aggressive investments. The company's diversified business structure, especially its involvement in mobile communications equipment and the handset business, helped its semiconductor division develop cutting-edge mobile-related memories (section 3.5).

3. Strategy and Organization of Samsung Electronics

3.1. Aggressive and timely investments in R&D and facilities

Samsung's aggressive investment in R&D and facilities was a well-known factor in its successful catching-up with its forerunners before 1992. Its average capital expenditure over revenues in the semiconductor division during 1987-92 was 39.8%, nearly double that of the industry average of 20.5% (Figure 1). Samsung also surpassed its competitors by a wide margin in terms of investment in DRAM. We estimate that Samsung's average annual investment in DRAM was US\$396 million from 1988 to 1991, 2.3 times that of Toshiba, the heaviest investor among Japanese DRAM manufacturers, and 2.8 times the average of the four major Japanese DRAM manufacturers, which includes Toshiba, NEC, Hitachi, and Fujitsu (Figure 2).

The investment in this period was crucial to Samsung's emergence as the number one producer of DRAMs in 1992 and as the number one producer of memories in 1993, and also to its maintaining technological leadership thereafter. One important decision associated with this investment was the shift from 6-inch wafers to 8-inch wafers. The global DRAM market was in a recession between 1990 and 1991. Japanese competitors were reducing their capital investments and hesitant to invest in facilities to support 8-inch wafers. The investments required to setting up the new facilities and the technological uncertainties involved in running them were huge. Yet Samsung bore these risks in order to leap-frog the competition since the move promised to substantially increase productivity. Facilities for 8-inch wafers required 1.4 times more investment than facilities for 6-inch wafers, but the former is 1.8 times more productive than the latter per wafer (Table 2). First among DRAM producers to invest in the 8-inch wafer, Samsung was also second in the whole semiconductor industry to do so, after IBM.

As we will discuss shortly (section 3.2 and 3.3), Samsung's success in 8-inch facilities also had to do with various process innovations and speedy ramping-up. But

one first-mover advantage Samsung gained from this early investment was that it was able to reduce purchasing costs of new equipment as equipment suppliers were willing to offer discounts for trials of new equipment.² Samsung was therefore able to reduce the investment costs in 8-inch facilities from 1.4 to 1.2 times that of 6-inch facilities. Thanks to massive investment in 8 inch facilities, Samsung became the number one in DRAM production in the year when it first mass-produced DRAMs from its 8 inch facilities.

Samsung repeated these successes during the transition from the 8-inch wafer to 12-inch wafer in the late 1990s. As the technological leader in the industry, it set up a task force and ran pilot facilities beginning in 1997, two to four years ahead of its competitors. After maturing the 12-inch wafer production technologies to its satisfaction, Samsung placed a volume purchase order with its equipment suppliers. While 12-inch facilities required 1.7 times more investment than 8-inch ones, the former brought about 2.3 times higher productivity than the latter per wafer. As the first mass-purchaser of equipment, Samsung could get heavy discounts and further reduced the investment costs of 12-inch facilities to 1.3 times that of 8-inch ones per wafer (Table 2). In 2001, it began mass producing DRAMs from the 12-inch facilities and the gap with its competitors further widened.

After becoming the number one producer of DRAMs in 1992, Samsung continued to reinvest heavily compared to other firms in the semiconductor industry, although its ratio of capital expenditure to revenue stabilized at a lower level as relative to its catching-up period. Samsung's capital expenditure-to-revenue ratio was 26.0% on average during 1993-2003 while the semiconductor industry average during

² For a discussion of discounts for trials of machinery, refer to Rosenberg (1976; 1982).

that same period was 23.2% (Figure 1). In terms of total investment in DRAMs, the gap between Samsung and its competitors was even more marked and this gap increased over time. We estimate that, during 1993-2000, Samsung's average annual investment in DRAMs was US\$1,134 million, 4.7 times that of the average of the four major Japanese DRAM producers. In addition, Samsung's total capital expenditure on DRAMs during this period, at US\$9 billion, was also larger than that of the four major Japanese producers combined, at US\$ 7.7 billion (Figure 2).

What is also notable in the investment race during Samsung's leadership period was that it began major investments slightly ahead of its competitors. This is partly reflected in Figure 1. During 1994-1995, it substantially increased its capital expenditure before the peak in 1996. Its earlier investment was most conspicuous during 1999-2000. It again started major investments in 2003 when competitors were actually reducing their investments. The early investments increased its revenues as it could sell its products during earlier phases of their life-cycles. It also decreased its investment costs because the company could get bargains from equipment suppliers who were suffering from recessions. This speedy investment was a reflection of Samsung's first-mover advantages. As the frontrunner equipped with investment funds and technologies, it had more confidence than its competitors to bet heavily on next generation technologies and facilities. Samsung's speedy investment decisions were also partly due to its unique organizational characteristics, as shall be discussed later (section 3.5).

Samsung's continued heavy investments also set in motion a process of innovations through creating "technical imbalances" (Rosenberg, 1976: 113). After a company invests heavily, it often has to solve various technical problems in running new facilities and maintaining a high facility utilization rate. A Samsung official says:

“We agonized over what to do with our expanded facilities and we had to develop new products and find out various other ways to fully utilize them. This impetus also led us to further increase R&D investments”.³ For Samsung, a process of cumulative causation was set in motion between investments and developing new products.

3.2. Speedy ramping-up and development

Competition in the DRAM industry is a war of speed owing to the huge first-mover advantages inherent in the industry. However, the early development of new products does not necessarily guarantee success, since market demand may languish. It is also possible that a forerunner in development may be overtaken by a latecomer with superior ramping-up capabilities in the race to introduce marketable products. The best strategy for a DRAM producer is therefore to wait for the development of the next generation chip closest to the market creation and ramp up production as fast as possible. Among close competitors at similar technological levels, the ramping-up capability is often more important than the development capability.

Samsung’s successful catch-up with its forerunners by 1992 owed greatly to its capability of speedy ramping-up. As a latecomer, it had always started developing next generation chips later than its forerunners, and therefore made concentrated efforts to shorten the time gap between development and mass production. When it began producing 4M DRAM in 1989, Samsung realized that its ramping-up capability rivaled, if not surpassed, that of its Japanese competitors. Once 16M DRAMs were introduced, Samsung’s superiority in ramping-up capability became evident. Although Toshiba developed a 16M DRAM sample slightly earlier than Samsung in

³ Interview in December 2003.

1989—one which also worked at a much faster speed than Samsung’s sample, Toshiba failed in the ramping-up race as Samsung became the first DRAM manufacturer to mass-produce 16M DRAMs in 1991.

Samsung’s ramping-up capability is a competitive advantage about which its “competitors feel most curious and are most inquisitive,” according to a Samsung official.⁴ While many of the details are confidential and cannot be fully reported in this paper, the essence of Samsung’s ramping-up capability is the manner in which the company integrates development and production.

First, Samsung attempted a full integration between development and production by directing engineers from every stage, from design to mass-production, to take part in the entire development process together. This facilitated problem-solving and information-sharing which helped speedy ramping-up. Many engineering problems that may have arisen in production were also detected during the development process, and production-side knowledge contributed to reducing time taken for development (more on this later in this section). This fuller integration between development and production was facilitated by the fact that Samsung was the only major semiconductor manufacturer in the world that had built design and production facilities at one site.

Second, Samsung managed a ‘unique’ task force system, which it calls a “Samsung-style TF”.⁵ This operated like a cobweb of networks in which design, manufacturing, and operating functions are intertwined. One advantage of this system is a quicker problem-solving capability. Samsung mastered a parallel problem-solving capability as against a serial problem-solving capability. When technical problems arise, it is a common practice in other companies that they start to find causes of the

⁴ From an interview with a Samsung official conducted in June 2003.

⁵ According to a Samsung official, this TF system is “definitely different from the Japanese TF system”. Interview conducted in June 2003.

problems from the most probable areas and serially move to the next probable areas. But Samsung developed its own knowhow to ascertain that the causes are within, say, 5 major areas and investigated those areas simultaneously. Samsung's parallel problem-solving proved very effective in facilitating speedy ramping-up.

Third, Samsung developed a system to test yield rates with pilot lines. Companies normally acquire knowledge of their yield rates of new products only after starting mass production. However, Samsung managed to accumulate knowledge and institute a system to get to know yield rates of new products at the stage of development. Therefore, it could solve many of possible production problems at the development stage. Thanks to this new system, Samsung attained a yield rate approaching to 'the golden yield rate (80%)' in the initial mass production of the 12-inch production line in 2001, which until that time had been inconceivable in the industry.

Fourth, Samsung developed an effective intra-firm knowledge transfer system, which is made up of several elements. It maintains a comprehensive database containing detailed information collected from development and production processes. It has an internal practice that about half the engineers working in a new production line also worked in the previous generation production line, which ensures a natural flow of information among engineers from different lines. It has also held a 'Maintenance Prevention (MP) Information Sharing Conference' since 1994, where engineers get together to exchange information gathered from running existing lines before starting to set up new production lines. This knowledge sharing reduces the possibility of repeating mistakes and equips its engineers with knowledge that may be useful for further improvements.

Samsung acquired a substantial part of its ramping-up capability during its catching-up period. And this capability functioned as an important first-mover advantage that enabled Samsung to sustain its technological leadership thereafter. It refined and improved its ramping-up capability through various innovations at the shop floor, a typical case of innovations through “learning-by-doing” (Arrow 1962; Spence 1981).

As Samsung strengthened its ramping-up capability, it also improved its development capability. When it first developed the 64K DRAM in 1984, it lagged behind industry leaders by a four and a half year development gap. Samsung progressively reduced this gap to 6 months with the development of the 4M DRAM in 1988. Samsung developed the 16M DRAM in 1989 at almost the same time as its Japanese competitors, and then outpaced them in development for the next four generations (Table 3).

As explained above (section 3.1), a major factor contributing to Samsung’s leapfrogging of its competitors in the development race was its aggressive R&D investments. Another important factor was its aggressive concurrent or parallel development. Concurrent development is a common practice in the semiconductor industry because of the incongruence between production time and product life-cycles. It normally takes about five years to develop and produce new generation chips, yet their life-cycles span only three to four years. Therefore, it is necessary to begin developing next-generation chips before producing current-generation chips.

When Samsung narrowed the gap with its forerunners during its catching-up period, it employed this common practice aggressively and augmented its development capability. As it moved to the position of technological leader, Samsung

stretched concurrent development to the extreme by developing three generations of DRAMs concurrently. After making progress in developing 16M DRAMs, it started developing the 64M DRAM and soon thereafter the 256M DRAM—all before churning out the first 16M DRAMs from its production lines.

Such concurrent development was possible due to Samsung's close integration of development and production and its unique TF system. The development process benefited greatly from the continuous flow of information from the production process, which helped economize resources and reduce the time required to develop the next-generation product. This, in turn, enabled Samsung to move on to develop the next-next-generation product. Samsung also leveraged concurrent development and the TF system to diversify into other memory products like Flash memories, FRAMs, and so on (see section 3.4).

Samsung's leadership in the development of new products, combined with its mastery of ramping-up technologies, provided it with enormous first-mover advantages. It could charge higher prices during the early stages of a product life cycle and, if followers began producing the product, had the financial capacity and technological edge to aggressively lower prices to make it difficult for followers to stay in the competition. Samsung also utilized various technologies acquired from developing next or next-next generation chips to increase the productivity of existing products, as will be discussed in detail later (section 3.3).

3.3. Process innovations for reducing production costs

Firms are constantly engaged in process innovations to reduce production costs and gain price competitiveness over their competitors. Such competition is

particularly acute in the DRAM industry, and the semiconductor industry in general, because despite heavy investments in R&D and facilities companies face sharp declines in the price of their products within 2-3 years of their initial production. Therefore, it is important to reduce production costs rapidly in order to survive life-cycle downturns. Companies that cannot make profits or accumulate heavy losses during this period will be out of business. Samsung's leadership in the industry was largely based on its ability to reduce production costs by introducing various process innovations.

One of the most important innovations here was the intergenerational application of technologies. As the technology leader, Samsung applied frontier design and micro-fabrication technologies acquired at the development stage of future generation chips to the production of current-generation chips, thereby substantially reducing their production costs. Until the early 1990s, production required a strict match between circuit density and design rule. For instance, 256K DRAMs were produced only by applying the design rule corresponding to a circuit width of $1.1\mu\text{m}$ and 1M DRAMs were produced only by applying the design rule corresponding to a circuit width of $0.7\mu\text{m}$ (Table 3). In developing the 64M DRAM in the early 1990s, Samsung applied the design rule for 64M DRAM, devised for a circuit width of $0.35\mu\text{m}$, to the production of existing 16M DRAMs, for which the $0.42\mu\text{m}$ design rule had previously been required. This inter-generational application of technologies was more widely adopted in subsequent generations of DRAMs. For instance, 64M DRAMs, initially developed with design rules corresponding to a circuit width of $0.35\mu\text{m}$, progressively adopted design rules corresponding to $0.25\mu\text{m}$, $0.18\mu\text{m}$, and $0.13\mu\text{m}$.

The adoption of next-generation design rules brings about substantial cost savings. For instance, the size of the 256M DRAM chip, for which the 0.18 μ m design rule was initially employed, can be cut in half if the 0.13 μ m design rule is adopted. If the 0.11 μ m design rule is applied to a 256M DRAM chip that was originally made using the 0.13 μ m design rule, its size can be reduced to 59% of its original size. Therefore, if the 0.11 μ m design rule is applied to a 256M DRAM chip that used to be made by the 0.18 μ m design rule, its size can be reduced to about 30% of the original size. Shrinking chip sizes considerably reduce production costs because it enables companies to use much fewer wafers. It also increases stability and improves chip quality. Moreover, it helped make DRAMs and other memories available for use in mobile electronic devices, which require much smaller chips than servers or PCs, thus opening a new avenue of expansion for Samsung (details on this in section 3.4).

Samsung utilized its leadership in shrinking technologies to its own advantage. After producing a commercial sample of first-generation 16M DRAMs (chip size 126.7mm²) in 1991, it concentrated efforts to shrink the chip size and successfully mass produced second-generation 16M DRAMs (93 mm²) in 1993, which was critical in solidifying Samsung's position as the market leader in 1995. Samsung also began mass producing third-generation 16M DRAMs (60 mm²) at the end of 1995 by applying design and process technologies from the 256M DRAM and improved its productivity by 60% over the second-generation product. A similar story was repeated for the 64M DRAM. The Japanese competitors were late in producing first-generation 64M DRAMs and attempted to catch up with Samsung with second-generation 64M DRAMs. But Samsung preempted this challenge by churning out second-generation 64M DRAMs, which improved productivity by 40% over the first generation, well ahead of its Japanese competitors.

This successful shrinking of chip sizes and resulting productivity increase was an important part of Samsung's forging ahead in the 1990s. Samsung internally assesses that its competitors were considerably weakened from losses during the 16M DRAM and 64M DRAM life cycles, and had a diminished capacity to compete in 256M DRAMs. Moreover, Samsung's high productivity, which enabled it to reduce prices substantially and maintain positive profits while forcing its competitors to lose money, contributed to preempting the market by discouraging competitors from entering the market even when conditions were favorable.

Among Samsung's various innovations for reducing production costs, its introduction of a method to produce new generation products from old facilities is particularly notable. Until Samsung began producing the second generation of 256M DRAM in April 1998, there was a consensus in the industry that 0.18 μ m technology can only be applied for mass production of 256M DRAMs using 12-inch wafer production lines. Yet Samsung broke through by rolling out 256M DRAMs with the 0.18 μ m design rule from existing 8-inch wafer production lines, which were also producing 64M DRAMs. This provided a boost to Samsung's competitive edge in 256M DRAMs. It reduced the investment costs for production lines substantially. Moreover, by using the same architecture as that of the 64M and 128M DRAMs, Samsung's 256M DRAMs were well-received by system manufacturers because they could simply be plugged into existing systems designed for 64M and 128M DRAMs.

3.4. Technological choice, deepening, and diversification

Along with its decision to switch from the 6-inch wafer to 8-inch wafer (section 3.1), one of the most significant technological decisions that Samsung made during its catch-up period concerned the choice between the trenching method and the stacking method. Shortly after the development of the 4M DRAM in the mid-1980s, it became impossible to house all the cells (capacitors) on a single flat surface of a chip, so DRAM manufacturers had to choose between two new cell structures to further increase the complexity of chips: one was the trench structure, created by trenching, or digging, on the wafer surface to build underground layers, and the other was the stack structure, created by stacking cells on top of one another to build above-ground layers.

The choice was difficult because the two methods had their own advantages and disadvantages, and the leading manufacturers were evenly divided on the issue. Samsung initially explored the two competing technologies in parallel by dividing its research teams into two. The top management later decided in favor of the stacking method on the grounds that the trenching method, while stable in quality, presented difficulties in shrinking the size of chips, which implied lower yields in the future.

This proved to be a wise decision. Toshiba and NEC, then the number one and two DRAM manufacturers, respectively, chose the trenching method but later had to switch to the stacking method in the middle of the development process after experiencing a decline in production yields. This was a costly mistake. Because they were slow to mass produce 4M DRAMs, the market leadership passed to Hitachi, which had adopted the stacking method. Samsung later overtook Hitachi in 16M DRAMs mainly based on its ramping-up capability.

There were certainly elements of luck in this technological decision. As Lee Kun-Hee, Chairman of the Samsung Group, concedes: “I had a feeling that the

stacking method would be a better choice but was not sure 100%. We were lucky in this respect”.⁶ However, there was a noticeable tendency in Samsung’s technological decisions during the catch-up period. First, it tended to explore competing technologies in parallel until uncertainties had been reduced to some extent. Second, when the time came, it tended to choose technologies that had better long-term prospects even though they might pose greater technical challenges to overcome.

Upon becoming the industry’s technological leader in 1992, Samsung strengthened this tendency of technological choice. First, it instituted a ‘comprehensive concurrent development’ system to prepare itself for various possibilities of newly emerging technologies and products. According to a Samsung official, “other companies tended to concentrate on a few technologies and products, but Samsung explored almost all the possibilities and made the most comprehensive investments, particularly in memories”.⁷ As mentioned earlier (section 3.2), concurrent development is a common practice in the semiconductor industry. But what made Samsung unique after it gained technological leadership was that it carried out concurrent development in the broadest possible scope of technologies. Second, it still outperformed its competitors in producing marketable products, even though it was sometimes slower than them in starting development. As a Japanese expert bitterly commented, “Samsung Electronics tends to throw out its hand slightly later than others in the scissors-paper-stone game”.⁸

A major challenge Samsung faced in the 1990s was the possibility that the DRAM industry might fall into a “commodity trap” and therefore be subject to cut-

⁶ Speech at the Seoul National University on 18 November 1999.

⁷ Interview with a Samsung official in December 2003.

⁸ Interview with a Samsung official in March 2004.

throat price competition and wild fluctuations in prices.⁹ One of Samsung's ongoing strategies to meet this challenge was to maintain cost leadership in manufacturing through various process innovations, as discussed earlier (section 3.2 and 3.2). Once Samsung became the industry's technological leader, it adopted another strategy, which was to produce fewer "commodities" so that the company would remain less vulnerable to price fluctuations in the DRAM market. Samsung implemented this strategy by deepening within the DRAM industry, i.e., developing higher-end DRAMs, and aggressively diversifying its product portfolios into other high-end semiconductors. The comprehensive concurrent development effort aspired to develop the necessary technologies to achieve cost reduction, deepening and diversification at the same time.

Samsung became very successful in developing high-end DRAMs. It introduced the 64M synchronous DRAM (SDRAM) in 1996, which was 4 times faster than the normal 64M DRAM. It also introduced the 256M SDRAM in 1999. While other DRAM manufacturers resisted the introduction of the Rambus DRAM with the view that Intel was imposing its standards on DRAM manufacturers,¹⁰ Samsung had the resources and guts to pursue both the Rambus DRAM and DDR (double data rate) DRAM, technical standards of which it proposed separately.¹¹ In 1998, it developed the 64M Rambus DRAM and began mass producing 64M, 72M, and 144M Rambus

⁹ For instance, Ernst (1998) even argues that the financial crisis in 1997 was due to the fact that the Korean economy, which relied heavily on the semiconductor industry, fell into this commodity trap in 1996.

¹⁰ Intel initiated to develop this new DRAM architecture to reduce the growing gap between microprocessors and DRAMs. For instance, Intel's newest CPU ran at a speed of 1GHz while the fastest DRAM architecture operated in the range of 100-133 MHz in 2000. Rambus DRAM architecture promised to increase the speed of DRAM to 800MHz (Chang and Podolny 2001).

¹¹ Hwang Chang-Kyu, President of Samsung Electronics, says: "We ... concluded that Rambus and DDR would constitute rather different markets, and we did not have to choose only one. The high cost and thus high price Rambus chips would be used in high performance PC and gaming machines. DDRs may be preferred by servers, workstations, and low price PCs. We will make both ... Our bet is that both will survive and there will be two separate market for each" (Chang and Podolny 2001).

DRAMs from 1999. It also introduced the 1G DDR SDRAM in 1999, twice as fast as 1G SDRAM and therefore eight times faster than normal 1G DRAM. Since the 1990s the development of almost every higher-end DRAM has been led by Samsung.

As a consequence of successful transition towards high-end DRAM products, Samsung sold its DRAMs at 10-30% higher prices than its major competitors, as Table 4 shows. According to Samsung's internal estimates, the portion of "commodity" DRAMs, which are normally used in personal computers, reached over 90% for its major competitors including Micron, Infineon, and Hynix, while Samsung's figure was about 70% in 2002. Along with its cost competitiveness in production, Samsung's shift to high-end DRAMs was a major reason why it was the only DRAM company in the world to make money during the recession period of 2000 and 2001, while other DRAM manufacturers incurred increasing losses as they increased production.

A new first-mover advantage for Samsung emerged as the technology gap with its DRAM competitors widened: a substantial increase in the number of technology standards in the DRAM industry. In the early 1990s, DRAMs and other memories operated at a speed of 33MHz, for which there were only about 10 technology standards for command and package. However, as the speed of memories increased to 100MHz by the late 1990s, the number of technology standards skyrocketed. For instance, the second generation DDR (DDR2) alone has about 330 technology standards, as Table 5 shows.

As the technology leader, Samsung was able to lead the standard setting. It actively participated in the JEDEC (Joint Electron Device Engineering Council), an industry association setting technology standards for memories. This helped Samsung prepare for new systems and technologies earlier than its competitors and take the

lead in the investment race, though it did not wield monopolistic standard setting power that could be seen in the case of Intel or Microsoft.

Samsung's diversification within memories was heavily focused on mobile-related products. Samsung's top management saw enormous business potential in mobile technologies and considered itself in an advantageous position over its (current and future) competitors because it had already made significant inroads, as a diversified electronics company, into mobile businesses including mobile communication handsets and equipment, and other mobile electronic products (more on this in section 3.5). Getting the company prepared for the emerging mobile era was the mantra of the top management through the 1990s and it became determined to make its semiconductor division grow into a "total mobile solution provider".

Flash memory was the lead item in this diversification drive into the mobile-related businesses.¹² Samsung chose to concentrate on NAND Flash over NOR Flash because the former has faster erase and write times, higher density, lower cost per bit and ten times higher endurance than the latter, while the latter has faster access time. Although Toshiba was the first to develop NAND Flash, Samsung introduced the product to market slightly earlier in 1989.

Samsung successfully developed the 16M Flash in 1993, 64M Flash in 1996, 256M Flash in 1999 and 1G Flash in 2001, in neck-to-neck competition with Toshiba. In 2002, Samsung became the number one producer of NAND Flash and the number two of total Flash memories, only after Intel, which had been the market leader with NOR Flash. The Flash memory market grew explosively from the late 1990s, and, in 2003, about 35% of Samsung's sales of memories came from mobile-related products.

¹² Flash memories retain contents even if electrical power is off, while DRAMs lose all contents once power is off. This retention capability, or non-volatility, is crucial for mobile devices running on battery power without hard disk drives.

Samsung also achieved its aim to become the most comprehensive mobile solution provider in the semiconductor industry, as Table 6 shows.

Samsung also led in mobile-related technologies by pioneering the development of low-voltage DRAMs. For instance, SDRAM previously required at least 3.3V, which was not suitable for mobile products. Samsung developed 2.5V LP (low-power) SDRAM in 2002 and 1.8V DDR in 2004, with plans to develop 1.5V LP DDR2 by 2006. While competition in the DRAM industry used to be based largely on increasing the density of chips, Samsung introduced two new dimensions of competition in the 1990s: competition for speed (high-end DRAMs) and low electricity power (mobile products).

Samsung's foray into mobile-related memories was boosted by its first-mover advantages as a technology standard setter, as in the case of high-end DRAMs mentioned above. Mobile-related memories require numerous technical standards so that interfaces with other new products can be easily established. Samsung played a leading role in standard setting associations like MIPI (Mobile Industry Processor Interface) and MMCA (Multimedia Card Association), and led standard setting in those newly-emerging products. This helped Samsung move more quickly than its competitors in development and investments.

By utilizing its first-mover advantages in individual memory products, Samsung has also been a leader in the development of merged chips, which combine attributes of different chips. For instance, FRAM (Ferroelectric Random Access Memory) combines the easier design and high density of DRAM, high speed of SRAM, and non-volatility of Flash. Ramtron International Corporation, USA, was the first company to develop FRAM in 1996, but Samsung immediately marketed an improved version of FRAMs. Samsung is also currently the forerunner in MML

(Merged Memory with Logic), which includes MDL (Merged DRAM with Logic), MSL (Merged SRAM with Logic) and MFL (Merged Flash memory with Logic).

First-mover advantages from diversification had implications beyond expanding Samsung's businesses into new markets. They also included further cost advantages. Samsung could utilize its expensive production lines more intensively, which would have otherwise become obsolete much sooner. For instance, the sixth production line, which was initially built for 16M DRAM and 64M DRAM in 1995, is utilized for producing Flash memories, graphic memories, and SRAMs which require less density than DRAM products at similar levels of technical sophistication. Newer production lines are also designed similarly to produce various products. The capacity to produce diversified products, in turn, allowed Samsung to invest in larger size facilities.

3.5. Governance and organization

During its catching-up period before 1992, Samsung's unique structure of governance and organization played a crucial role in its catching-up efforts. First, its owner-management system, as part of a *chaebol*, enabled it to make aggressive and long-term investment decisions, and to sustain them through difficult periods. Second, it established and maintained an internal organization that was imbued with a strong sense of togetherness and commitment, which allowed hardworking and flexible re-organization of task forces that were critical in the race against time for development and ramping-up. Third, its diversified business structure provided it with extra financial and non-financial resources that would not have been available if it were an independent firm.

Samsung has maintained basically the same governance and organizational structure even after becoming the industry's technological leader. This continuity seems to have contributed significantly to creating and maintaining its first-mover advantages.

First, the owner-management system still translated into strong leadership in business decisions. Lee Kun-Hee, the current Chairman of the Samsung Group and the son of the group founder, Lee Byung-Chul, has remained at the helm, though his management style is uncharacteristic of *chaebol* owners in Korea because he has devolved most day-to-day decisions to professional managers and only intervened in major decisions on strategy and investments. When it came to investment decisions on 8 inch facilities and the technological choice of the stacking method, crucial points in Samsung's overtaking of its Japanese competitors in the early 1990s, Chairman Lee's intervention was legendary within Samsung.¹³ Samsung's early investment in 12 inch facilities in the late 1990s was also led by Chairman Lee. Lee Yoon-Woo, then the manager-president of the company, emphasized that "both the first investor and last investor in 12 inch lines are idiots and we need to wait for the trigger point to come". But Chairman Lee encouraged him to decide upon early investment after consulting his own information sources. For those on the investment task force, this decision was passed to them "suddenly" at a time when they expected to have much more time to examine the pros and cons of such a move.¹⁴

Another important consequence of having an owner-management system was that it kept the company infused with a "crisis mentality", which promoted aggressive investments and resisted the temptation toward a defensive posture in trying to

¹³ For instance, Chairman Lee chose the stacking method on the ground that "In the long run, it will be easier to build a house by stacking over structures than digging underground, although I am not sure about the efficiencies of the two methods". Interview with a Samsung official in December 2003.

¹⁴ Interview with a Samsung official in June 2004.

maintain its number one position. According to a Samsung official, “there was no time in the 1990s that we did not hear the word of crisis and this mentality was actually shared broadly from the top management to shopfloor engineers”.¹⁵ In Samsung’s case, it seems that this crisis mentality was stronger for the owner-manager than the other professional managers. For Chairman Lee had experienced the vicissitudes of the industry and weathered a series of tough decisions from the beginning of Samsung’s semiconductor business,¹⁶ and had a longer-term view of the company’s future as the “owner”.

Second, the internal organization of close integration between development and production was further strengthened. As discussed before, this organizational character of Samsung contributed to its success in speedy ramping-up and development (section 3.2) as well as to its various process innovations in production lines (section 3.3). The integration within the firm also greatly aided its diversification efforts. TFs brought together managers and engineers from related business divisions within the firm, facilitating the flow of information into new development and production processes, which was critical in making “comprehensive concurrent development” possible (section 3.4).

Third, the firm’s diversified business structure was instrumental in creating its first-mover advantages. During the catching-up period, its semiconductor division received tremendous support from other divisions within the firm and other companies within the Samsung Group. Once it became the profit center of the company and even the whole Group, the semiconductor division no longer needed

¹⁵ Interview conducted in June 2003.

¹⁶ Against prevalent skepticism within the Samsung Group, Chairman Lee decided to acquire Korea Semiconductors in 1974, which was the beginning of Samsung’s involvement in the semiconductor business and initiated heavy investments in the industry in the early 1980s in spite of skepticism from the Korean government and public.

previous intra-firm or intra-group assistance. On the contrary, it began assisting other divisions and sister companies by providing expertise and financial resources.

As Samsung began diversifying its semiconductor businesses into mobile-related products, however, new synergies emerged from the company's diversified business structure. While Samsung already had a strong telecommunication network division which produced both equipment and handsets, other divisions were also rapidly embracing mobile technologies.¹⁷ The Digital Media Division was involved in developing and producing PDAs, MP3 players and so on. The Consumer Electronics Division was moving rapidly into home networking. The Media Division was developing mobile media sets including mobile TFT-LCD. The development of mobile-related semiconductors was greatly facilitated by the flow of information and engineering expertise provided by other divisions, while in return the semiconductor division assisted in the development of mobile technologies and products in other divisions. These intra-firm synergies were important in positioning Samsung as a "total mobile solution provider".

Another synergy that emerged from Samsung's diversified structure was its ability to make accurate market forecasts for mobile-related chips based on its diversified customer base, which was in turn the result of having a diversified business. Samsung internally projected that the size of the NAND Flash market would grow to over US\$2 billion by 2002 and released a forecast that its sales of NAND Flash memories would reach US\$1.1 billion in 2002. At that time, all the international market research companies projected that the size of the NAND Flash market in 2002 would be at most around US\$1.1 billion. Samsung consequently received enquires from analysts and journalists about whether it harbored ambitions to monopolize the

¹⁷ As of January 2005, Samsung Electronics has five major divisions: Digital Media, Telecom Network, Semiconductors, Displays, and Consumer Electronics.

NAND Flash market by 2002. A main reason why Samsung was able to predict the market trend correctly was that it could gather comprehensive information about future demand from its diverse pool of customers.

4. Discussions and Conclusions

Our case study of Samsung Electronics largely fits with Lieberman and Montgomery's (1988: 49) broad assertion that a firm gains first-mover advantages through "some combination of proficiency and luck". Over time, Samsung Electronics continued to strengthen its proficiencies in R&D, production, decision-making, resource management, reading market trends, and so on, and these proficiencies seemed to be assisted by good luck as the newly emerging technologies and markets turned out to be favorable for Samsung.

Table 7 summarizes Samsung's various first-mover advantages, which can be roughly divided into two categories: those that Samsung created endogenously or further strengthened, and those that were newly-emerging. We begin by reviewing the former. First, as the first-mover, Samsung improved its ability to maintain and reinforce aggressive and timely investments. Second, it stayed ahead of its competitors in each successive wave of development of new generation DRAMs. Third, this leadership in development was translated into mastering shrinking technologies through the intergenerational application of process technologies and other process innovations. Fourth, its ramping-up capability was further strengthened and more broadly applied. Fifth, its close integration between development and production was elevated to a "comprehensive concurrent development" system. Sixth,

its capability to read the market trend was further enhanced from its accumulated experience and continuous information flows from its diverse pool of customers.

There were also environmental factors after 1992 that made first-mover advantages stronger than before. First, the explosive increase in new standards in DRAMs and mobile-related memories allowed Samsung to be at the forefront of technology standards setting in the industry, which helped it stay ahead of its competitors in the development of and investment in new products. Second, the coming of the mobile era provided Samsung with a promising new avenue for diversification. Samsung's diversification within the semiconductor industry was particularly successful at tapping into mobile-related memories. Needless to say, Samsung's ability to take advantage of these new opportunities also depended on its various proficiencies to do so.

The process of accumulating "proficiency" in the case of Samsung Electronics can be more generally understood as an elucidation of Chandlerian expansion through "scale and scope" (Chandler 1990) and Penrosian growth through learning, deepening and diversification (Penrose 1959). It is a technological imperative in the DRAM industry that companies should continuously increase the scale of investment, as larger scale investments generally pay off because they come with newer technologies that promise higher productivity per unit cost. Early investments in 8 inch facilities over 6 inch ones and 12 inch facilities over 8 inch ones were carried out for this reason. Scale advantages are also inter-related with economies of scope. The increased scale necessitates intensive and multiple use of given resources. Inter-generational application of process technologies, information sharing through close

integration between development and production, and so on are all about economizing given resources through leveraging their multiple uses.

During its catch-up period, Samsung acquired and accumulated various resources including technological capabilities, financial resources, organizational and management capabilities and so on. As a learning organization, it also became more proficient in using these resources for productive use. Once Samsung emerged as the industry's forerunner, these resources and experiences became stepping stones for new waves of growth. Deepening towards high-end DRAMs and diversification into mobile-related memories were results of applying those resources and experiences for expansion.

A single case study of Samsung Electronics is far from sufficient to elucidate firm growth processes postulated by Chandler and Penrose. However, by adding case studies from other industries with different technological imperatives and market structures, we can hope to make systematic progress on major academic questions concerning firm growth and innovation.

The Samsung case also sheds some light on controversial issues in managerial decision-making and firm structure, as follows.

The first issue has to do with the timing of developing new products as a forerunner. Being a forerunner carries not only advantages but also disadvantages, for instance, that it is liable to "trial and error" because it tries new things earlier than others. So it is critically important for a forerunner to devise ways to minimize those possible errors, especially when large-scale investments are involved. In the DRAM industry, it is generally better to invest earlier than others, as can be seen in Samsung's case by the decision to invest in 12-inch over 8 inch facilities. However, in

developing new products, Samsung often remained slightly behind its competitors yet was faster in producing marketable products using its ramping-up capability. This innovation strategy has a strong affinity to Freeman's (1997: 272-76) "defensive innovation strategy", which can be traced in Matsushita's competitive strategy against Sony, or in General Motors's competitive strategy against Ford. The existence of strong production capabilities, like Samsung's ramping-up capability, and of wide distribution networks is crucial to the success of this strategy. On the other hand, however, the earlier development of micro-fabrication technologies provided Samsung with a tremendous competitive edge by applying them to shrinking the current generation products. The earlier development looks better in this aspect. Further investigations are necessary to assess in which conditions the defensive innovation strategy works better than the offensive innovation strategy, or how to mix two strategies in the actual innovation processes.

The second issue has to do with the degree of integration of various processes or businesses within a firm. It has been a fashionable trend in the semiconductor industry, as well as in other industries, to decouple design and production, most notably in ASICs (application-specific ICs) led by American and Taiwanese chip designing houses and manufacturers (Langlois et al. 1999; Ernst 2000; Sturgeon 2000). In the DRAM industry, Japanese and European producers have formed alliances with the Taiwanese foundries in their attempts to compete with Samsung Electronics. The record so far, however, looks in Samsung's favor as it continues to forge ahead. This is mainly because, as far as DRAMs and memories are concerned, competition involves a race against time, in which timely decisions on technologies and investments and speedy ramping-up through close integration between development and production are crucial to gaining a competitive edge. Samsung

provides an example of the benefits of integration. It would make an interesting further study to analyze the conditions under which integration works better than decoupling and networking, and *vice versa*, and how their relative merits and demerits change across industries and over time.

Samsung also benefited greatly from its diversified business portfolios, especially in moving into mobile-related memories. A perennial controversy in management literature is whether a firm should focus its businesses around its “core competencies” or pursue a more active diversification strategy (For instance, refer to Prahalad and Hamel 1990; Montgomery 1994; Granstrand *et al.* 1997). Samsung’s case indicates that managing diverse businesses is beneficial when new business opportunities arise through convergence across sectors which have been previously related loosely with each other. However, there are also costs in managing diverse businesses. It is still an unresolved question to what extent and in which conditions diversification matters for corporate success. To answer this question, further systematic studies would be required which look into the effects of technological trends, industry characteristics, and stages of corporate growth, on business organization.

The third issue has to do with the relative advantages and disadvantages of the owner management system versus the professional management system. The consensus within Samsung is that much of its phenomenal growth should be credited to the strong leadership of its owner-manager, Chairman Lee. His leadership was instrumental in making quick investment decisions and maintaining the “crisis mentality” throughout the firm. The Samsung case shows that the owner management system can be effective in sustaining firm growth if the owner manager has in-depth knowledge of the industry and is supported by capable professional managers.

However, it is certainly possible that a strong owner manager may make quick but wrong decisions. Further investigations into which combinations of factors allow effective management of owner-managing company over the long run would enrich our understanding of corporate governance and firm growth.

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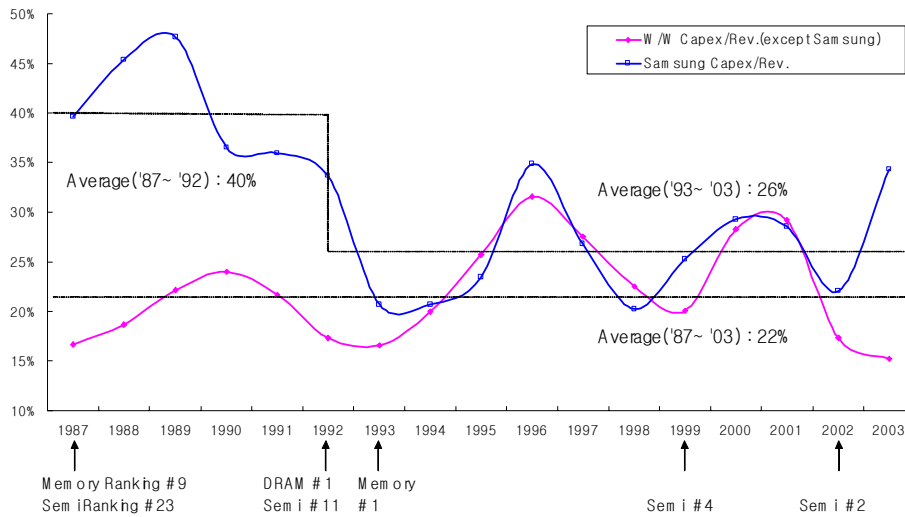
Table 1. Size of Investment by Generations of DRAM
(US\$ million)

	1M	4M	16M	64M	256M	1G
R&D Investment	30	80	150	300	800	1,500
Facility Investment	350	600	1,300	1,500	2,500	5,000

Source: Korea Semiconductor Industry Association

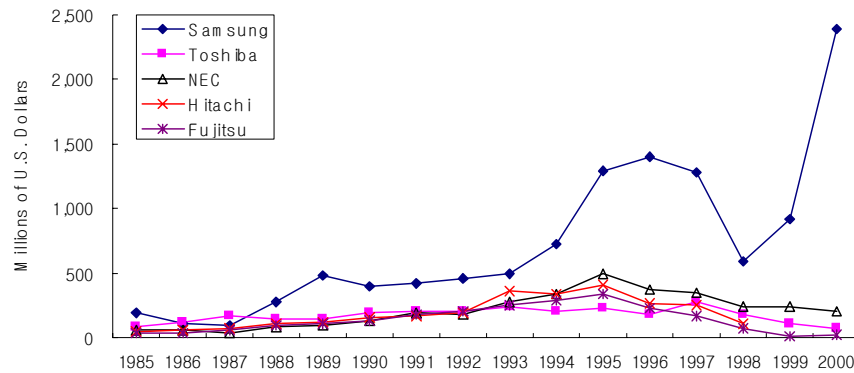
Note: Figure are calculated for an 8" wafer facility which produces 25,000-30,000 chips per month

Figure 1. Trend of Samsung's Capital Expenditure
(%, capital expenditure/revenue)



Source: Samsung Electronics and Dataquest

Figure 2. An Estimate of Major Firms' Investments in DRAMs (US\$ millions)



Source: Authors' own calculation based on Dataquest data, which only provides figures for capital expenditure of individual semiconductor companies without breaking it into different semiconductor products but provides figures for sales by different semiconductor products. We roughly estimated figures for DRAM investments by applying the ratio of sales between DRAMs and non-DRAMs in two years later, with supposition that facility investments would result in mass production in two years on average.

Table 2. Relative Investment Costs and Productivity by Wafer Size (times)

	8 inch over 6 inch	12 inch over 8 inch
Investment costs per wafer	1.4 (1.2)	1.7 (1.3)
Productivity	1.8	2.3

Source: Samsung Electronics

Note: Numbers in parentheses are based on actual costs Samsung incurred, which were below market prices as the company was the forerunner in mass purchasing the equipment

Table 3. Development of DRAM Technologies and Samsung's Milestones

Circuit Density	256K	1M	4M	16M	64M	256M	1 GIGA	4 GIGA
Year Developed	1984	1986	1988	1989	1992	1994	1996	2003
Technology Gap between the First Developer and Samsung	3 years	2 years	1.5 year	Same	First	First	First	First
Design Rule ¹	1.1 μm	0.7 μm	0.5 μm	0.42 μm	0.35 μm	0.25 μm	0.18 μm	0.13 μm
Storage Size (Standard News Paper Pages)	2	8	32	130	520	2,100	8,400	33,600

Source: Samsung Electronics

Note 1: Design rule applied in the initial development.

Table 4. A Comparison of DRAM Average Sales Prices (ASPs) between Samsung and its Competitors (US\$, %)

	1996	1997	1998	1999	2000	2001	2002	2003
Samsung	346.9	152.8	52.3	42.6	38.3	8.9	7.7	5.7
Micron	313.2 (90)	107.2 (70)	39.1 (75)	34.0 (80)	28.8 (75)	5.7 (64)	5.9 (77)	4.9 (87)
Infineon	291.9 (84)	83.0 (54)	40.4 (77)	33.5 (79)	31.6 (83)	6.6 (74)	6.4 (83)	5.1 (89)
Hynix	258.0 (74)	122.2 (80)	36.9 (71)	36.8 (86)	28.9 (75)	6.6 (75)	5.9 (76)	5.0 (88)

Source: Samsung Electronics and Dataquest

Note: Unit prices were calculated at 256M DRAM-equivalent prices. DRAM sales figures are from Dataquest. Numbers in parentheses refer to percentage ratios to Samsung's ASPs.

Table 5. Technology Standards for DDR2

	Major Items	Number of Standards
Function	Circuit, Addressing, Logic, Read/Write, etc.	About 100
Specification	Power, Test, Temperature, etc.	About 200
Package	Pin-out etc.	About 10
Module	UDIMM, RDIMM, SODIMM etc.	About 20

Source: Samsung Electronics

Table 6. A Comparison of Mobile Solution Capability between Samsung and its Competitors

	NAND	NOR	MCP	Mobile AP	Imaging	DDI	Display
Samsung	◎	▲→◎	◎	▲	▲→◎	◎	◎
A	◎	▲	▲	-	◎	▲	◎
B	▲	▲	▲	▲	▲	◎	▲
C	-	▲	▲	▲	-	▲	▲
D	-	-	-	◎	▲	▲	-

Source: Samsung Electronics' internal assessment in 2004

Notes: ◎:Strong, ▲:Weak, -:None. MCP: Multi-Chip Package, Mobile AP: Mobile Access Point, DDI: Display Driver IC. Names of the competitors are not specified for obvious reasons.

Table 7. Summary of First-Mover Advantages of Samsung Electronics

<i>Existing or Strengthened First-Mover Advantages</i>	<i>Newly-Emerging First-Mover Advantages</i>
<ul style="list-style-type: none"> • Capability to make aggressive and timely investment decisions, and to sustain the prolonged investment race • Development capability of DRAMS • Shrinking capability • Ramping-up capability • Capability to integrate development with production • Capability to read the market 	<ul style="list-style-type: none"> • Capability to set technology standards due to explosive increase of new standards in DRAMs and mobile-related memories • Capability to provide comprehensive mobile solutions owing to the combination of the coming of the mobile era and its diversified business structure