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THE SEMICONDUCTOR INDUSTRY IN THE 21st CENTURY: A GLOBAL ANALYSIS USING MICHAEL PORTER'S INDUSTRY RELATED CLUSTERS

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Abstract

The semiconductor industry has attracted considerable attention during the last twenty years as a major high stakes business battlefield between American corporations and Japanese society. Recently, other Asian countries have made inroads into this industry. Consistent with Michael Porter's thesis on the importance of national industry related clusters (Porter, 1990), this paper predicts that between now and the year 2000, the entrepreneurial characteristics of American companies will lead them to significant market share increases and that Japanese businesses will lose market share to other Asian companies, particularly in South Korea. Beyond the year 2000, the industry may evolve to the point where geographic areas concentrate on specific dimensions of the industry with the United States strong in innovation and Asia emphasizing manufacturing efficiencies. It is also possible that later in the 21st century, continued economic growth in Asia could lead to Asian companies taking expanded leadership roles in the industry. This paper

acknowledges the importance of government intervention both in the United States and Japan in the early stages of the industry, but argues that the evolving maturity of the semiconductor industry is reducing the need for government subsidies, even though trade issues, especially with China, continue to be important.

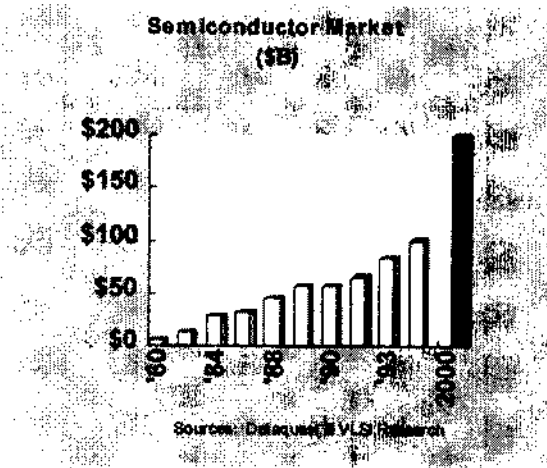
Introduction

The semiconductor industry has attracted considerable attention during the last twenty years as a major high stakes business battlefield between American corporations and Japanese society. Recently, developments in South Korea and Taiwan suggest a global widening of this competition. Consistent with Michael Porter's thesis on the importance of national industry related clusters (Porter, 1990), this paper predicts that between now and the year 2000, the innovative characteristics of American companies will lead to significant increases in their market share for key segments such as FLASH memory, microprocessors and successful niches in specialized Random Access Memory (RAM) segments. Japan will still be strong in commodity memory markets, but will yield market share to other Asian countries, particularly South Korea and Taiwan. Beyond the year 2000, the industry may evolve to the point where geographic areas concentrate on specific dimensions of the industry or perhaps Asia will increase overall leadership responsibilities, including strong partnerships developed with American companies.

Historical Developments

Chart 1, below, shows the explosive growth of semiconductors from 1960 and the projected doubling of industry sales from 1996 to the year 2000. The early stages of the industry in the 1960's and 1970's were characterized by American innovation in all segments of the industry and by aggressive actions of the Japanese government to protect its home market by restricting the activities of American companies and by subsidizing the growth of national companies.

CHART 1

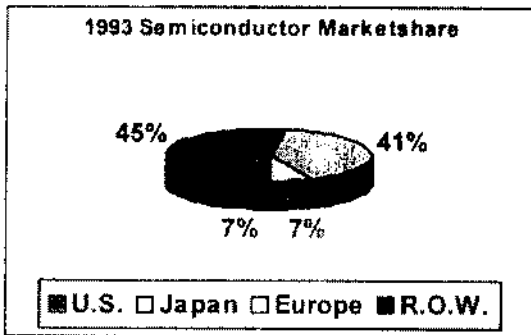


By the late 1970's, American companies began to complain about Japanese dumping practices. The impact of Japanese industrial policy is reflected in the dramatic shift in market share from 1978 to 1986, when the Japanese share in Dynamic Random Access Memory (DRAM) went from only 25% to over 75%. At this time many American companies were forced to withdraw from this segment. To counteract Japanese competition, American semiconductor

companies created the Semiconductor Research Corporation in 1982 to fund cooperative industry research and to enhance curriculum development in American universities. Another part of the response by the American government was the creation of the Defense Advanced Research Agency (DARA) by the Department of Defense. Sematech, a research consortium of fourteen American semiconductor manufacturers was also formed in 1987 and received half of its annual budget from the government. Government funding for Sematech continued until 1994 at which time it was funded solely from industry participants. The battle between the United States and Japan reached a crescendo in 1986 when the Japanese government agreed to a target of 20% foreign market share in Japan by 1991 (Tonelson, 1994).

The semiconductor battlefield expanded globally in 1988 when the South Korean government initiated a five-year program aimed at catching up with the Japanese in memory technology. This effort was funded with \$500 million from Korean companies and \$270 million from the South Korean government. By 1992, South Korea had semiconductor exports of \$6.7 billion (Kim Nak-Hieon, 1993).

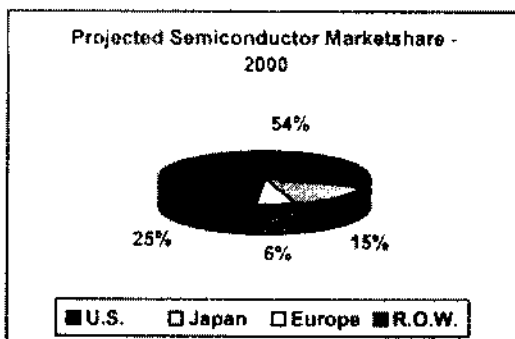
CHART 2



Source: Semiconductor Industry of America

By 1995, as shown above in Chart 2, the efforts of governments and companies around the world led to the United States and Japan both having market shares of approximately 40%, with Europe having only 5% and other Asian countries at 15%. A 1993 forecast for the year 2000 (Hayes, 1993) shown below in Chart 3, projected dramatic declines in market share by Japan, replaced by other Asian companies. Since 1993, Korean companies have doubled their market share at the expense of both American and Japanese companies.

CHART 3



Source: VLSI

An indication of emerging Asian strength is that Samsung of South Korea was the first company in the world to market a 16 megabyte DRAM chip and in 1993, became the world's largest manufacturer of memory chips. The competition between Japan and other Asian countries resulted in major oversupply conditions and severe price cutting for commodity chips hurting the major memory players, while American companies have prospered in the newer, innovative segments of the semiconductor industry.

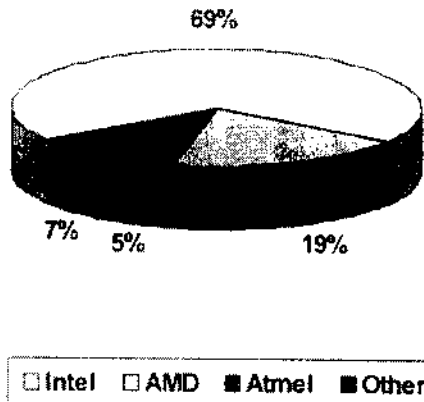
Reasons For American Resurgence

American growth has been fueled by several inter-related factors including advances in the semiconductor equipment manufacturing industry, software innovation and creative design skills involved in developing new chips. This synergistic combination is exemplified by Intel, Microsoft and the many software firms providing user friendly applications. American culture may be a strong competitive force in that "Software is more of an art than effort; the best programs are written by talented individuals not by teams, which is why the U.S. still leads. Meanwhile, Japan spends millions trying to find hidden patterns so as to reduce it from an art to a process." (Herbig and Palumbo, 1994).

American strengths in design are also reflected in the FLASH Memory market as shown in Chart 4.

CHART 4

1994 FLASH Memory World Marketshare



Source: Dataquest (Electronic News, 1994)

FLASH memory does not need power to retain its content and is the major breakthrough in enabling the rapid growth of portable, lap-top computers. Although Toshiba originally developed the technology, Intel and Advanced Micro Devices were the first to aggressively pursue this market, dominating this market in 1994 with a combined market share of 85% (Electronic News, 1994).

Advocates of timely government intervention to serve as a national catalyst for developing successful industry clusters can point to the 1987 formation of Sematech. The American government provided annual funding of \$100 million which was matched by the consortium of fourteen American semiconductor manufacturers. The goal of Sematech was "to bring U.S. semiconductor manufacturing capability to equal or exceed the world's best.

This includes the design for manufacture as much as the manufacturing process."

This occurred at a time when American semiconductor manufacturers found key manufacturing equipment made in Japan was not made available to them in as timely a manner as it was to their Japanese counterparts. From 1987 through 1992, Sematech generated 51 patent applications, 1100 technical documents and perhaps even more importantly, developed more than 300 industry standards. Sematech coordinated university research and provided an industry-wide forum to enhance the American semiconductor industry cluster. The benefits of Sematech were initially made available to all consortium members and eventually to all U.S. companies within this cluster, to help promote overall American competitiveness in this industry. The General Accounting Office of the United States Government published a report on Sematech in 1992, concluding that it was a success and a model for similar consortia in the future (C. Richard Deininger, 1994).

Industry Related Clusters

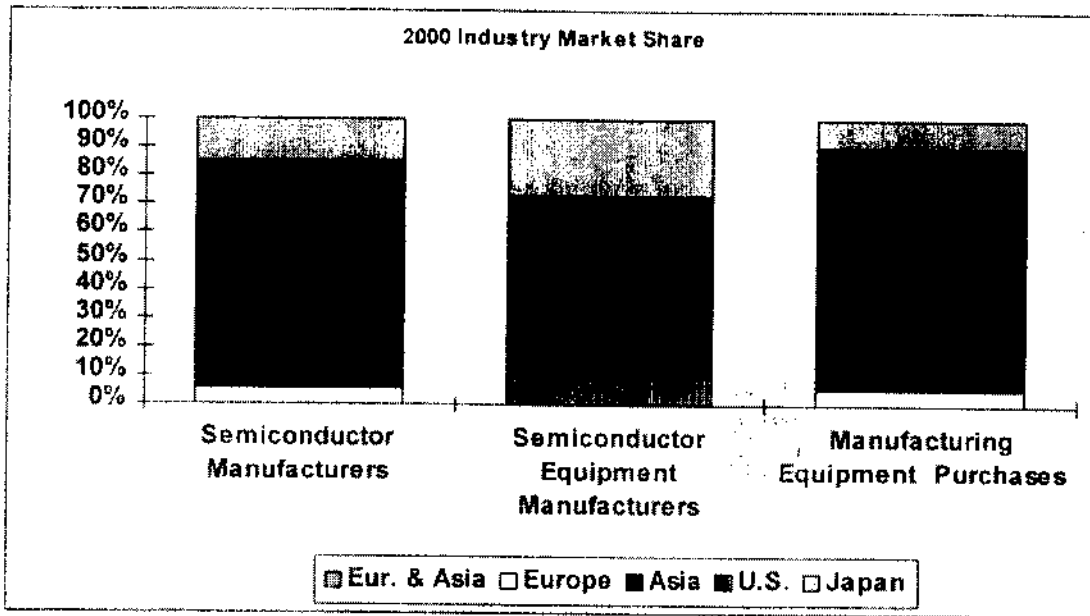
Using Michael Porter's industry clusters as an analytical framework, the United States has several strengths including a diversified group of companies located not only in Silicon Valley, but also in Texas, New Mexico and Arizona. These companies maintain a close relationship with local universities and suppliers. In addition, American software companies are frequently nearby. This proximity facilitates close collaboration, particularly in developing new applications for hardware and software. This synergistic grouping of small and large

companies has created a fertile entrepreneurial environment in contrast to Japan whose efforts are largely concentrated within large bureaucratic companies with strong manufacturing roots and a pattern of incremental process and product improvement. This provides strengths for Japan in large volume markets such as memory chips, but has not been advantageous in entrepreneurial innovation. Though competing for a number of years in this industry, the Europeans have not prospered. A primary reason for this may be the failure on their part to develop full industry clusters, as they lag considerably in the supplier and equipment manufacturing segments of the cluster. Korea has the advantage of lower costs than Japan and the focused concentration of Samsung made it the world market leader in 1994 for memory chips. However, to date South Korea has not developed the full industry clusters prevalent in the U.S. and Japan. They need to do this to prevent the vulnerability the U.S. experienced in the mid 1980's when the Japanese semiconductor equipment manufacturers gave the Japanese semiconductor manufacturers a significant advantage by selling to them first. If the South Koreans correct this vulnerability, then to use a famous Michael Porter phrase, Japan may be stuck in the middle between Korea and the United States; unable to compete in either the price or the innovative segments of the market. Market share data for 1993 is shown in Chart 5 and a forecast for the year 2000 by VLSI Research is shown below in Chart 6 (Hayes, 1993), which reflect the projected increases share for Korea.

Review of Government Intervention

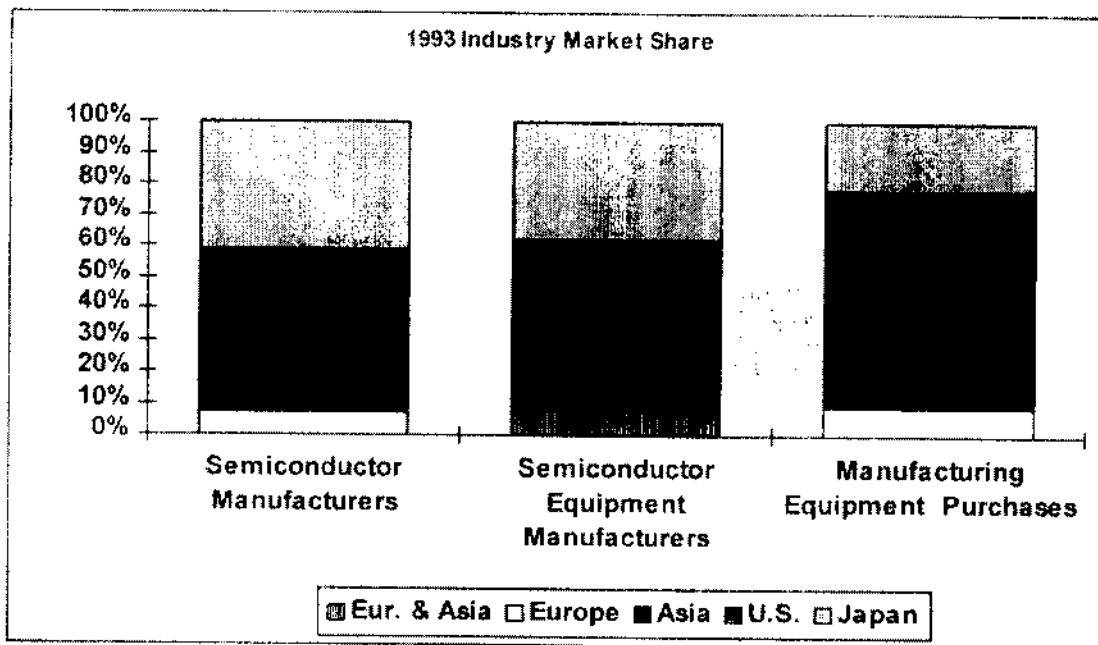
The 1970's and 1980's were decades when both the Japanese and American governments intervened to support national semiconductor efforts. Although American companies were initially savaged by Japanese targeting, the combined private and public restructuring efforts resulted in an industry which is currently very healthy. The American media has emphasized the power of Japan, especially in high technology electronics, but the truth appears to be that the American industry is well positioned for future global competition and does not need major help from the federal government. The powerful Japanese companies have enormous resources and also do not need assistance from their government, which has been weakened by a series of political changes in recent years (Wall Street Journal; July 11, 1995). Additionally, the large trade surplus of Japan has resulted in the appreciation of the yen and decreased global competitiveness for all Japanese products including semiconductors. Despite the admiration for MITI and the Japanese semiconductor cluster expressed by Michael Porter in 1990, the original natural cluster developed in the U.S. now appears to be stronger than the heavily subsidized "artificial" cluster developed in Japan. The implication of this is that countries where clusters originate naturally can effectively compete with less government assistance than those copied and developed through government intervention. The Korean semiconductor industry should be watched carefully by both the United States and Japan to prevent any further dumping incidents similar to those settled between Korea and the U.S. in 1993.

CHART 5



Sources: Dataquest & VLSI Research

CHART 6



Sources: Dataquest & VLSI Research

Recently Created World Semiconductor Council

During 1996, government and industry discussions over semiconductor trade policy evolved beyond bilateral government to government negotiations to the point of creating the World Semiconductor Council which hopes to be a global forum for worldwide semiconductor issues. During 1996, negotiations were conducted between Japan and the United States regarding the renewal of the 1986 agreement that targeted an American market share of 20% in Japan. As a key part of the industry-wide negotiations in Japan and the United States leading up to a broad U.S.-Japan agreement signed in Vancouver, British Columbia in 1996, the World Semiconductor Council was launched with the two founding members being Japan and the United States. One month following the August, 1996 agreement, Korean semiconductor companies sought to join the Council by asking the South Korean government to eliminate all tariffs on imported chips. This action is necessary because the Council requires that all countries seeking membership must abide by free trade principles. Membership in the new council is important because it will serve as a critical forum to discuss common issues of standards, intellectual property rights and environmental concerns. Under previously negotiated trade agreements, Korean tariffs had been scheduled to decline from 8% to 4% in 1998 and then to zero in 1999. To join as soon as possible, the Korean companies are seeking an acceleration of the present schedule. The Executive Director of the Semiconductor Industry Association's (SIA) Tokyo office welcomed the announcement and

said that "South Korea is obviously a major player." European chip makers also want to join, but European Union negotiators want reciprocal reductions in other industries before eliminating semiconductor tariffs. Discussions are continuing among the various parties with the first formal meeting scheduled for 1997 (Shorrock, 1996).

China and The Future Of The Semiconductor Industry

With Japanese, Korean, European and American companies starting to use the World Semiconductor Council as a vehicle for direct industry discussions, the role of government involvement may now shift its focus to China. That issue was the focus of testimony given to the United States House of Representatives at hearings in 1996 regarding the accession of China to the World Trade Organization (WTO). Daryl Hatano, Vice-President of the Semiconductor Industry Association (SIA), testified that the SIA is very concerned that China adhere to WTO policies regarding free trade and the protection of intellectual property rights. In seeking membership to the WTO, China has asked for special industry policy exemptions applicable to developing countries, including the use of high tariffs to protect infant semiconductor operations. This is of particular concern to the SIA because they forecast that China could become the world's largest market for semiconductors in ten to fifteen years, resulting from the combination of local consumer demand and aggressive exports of manufactured goods. Since 1985, the growth in China's semiconductor market has been 24% per year and only 25 to 33% of this demand is satisfied by local production. To increase that

percentage, China is actively pursuing a multi-faceted strategy of encouraging local factories and joint ventures with foreign companies (Hatano, 1996). The SIA is asking the United States Government to actively monitor China to ensure that American companies have fair access to the growing Chinese market.

Globalization of Industry Clusters

Today we are just beginning to evolve to the next phase of this global industry. Over the next five years, the United States will be the major R&D and design center for the industry, while Asia may become the largest fabrication center within the industry. Europe may continue to play a minor role as a fabrication center. Companies such as Texas Instruments, Advanced Micro Devices and Intel have significant Japanese partners and perform substantial amounts of production in Asia. Texas Instruments moved all DRAM production out of the United States years ago. Intel enlisted a Japanese partner to do foundry work for their FLASH memory production. Advanced Micro Devices and NEC built a huge fabrication facility to produce FLASH memory, again in Japan. Additional support for Asia becoming the dominant manufacturing center for semiconductors is the fact that in 1994 there were 47 fabrication facilities under construction throughout the world, with two-thirds of these fabs being built in Asia (Economist, April 1994). Further evidence of the move to geographic specialization is the agreement between Cirrus Logic Inc. and Taiwan Semiconductor Manufacturing Company (TSMC). Cirrus is a design house without manufacturing capabilities,

while TSMC is a fabrication facility without design capability. The deal calls for TSMC to produce chips designed by Cirrus.

In support of the United States becoming the primary R&D and design center we find Asian companies investing heavily in research facilities for college campuses in the United States. Toshiba and the University of California Irvine are an example of this partnering; Toshiba will provide the facility and will gain access to semiconductor technology research results. Samsung also spends heavily on world wide research, with 11 facilities for research around the world, including the United States. (McLeod, 1995).

The United States semiconductor manufacturing equipment industry has long been known for breakthrough technology, but with a relatively poor reliability rate in comparison to their Japanese competition. The combination of U.S. design, coupled with Asian process/manufacturing prowess would benefit this global industry greatly. Beyond the year 2000, the industry clusters may further evolve. Of particular interest is the potential of Korea.

Potential Semiconductor Capability of Korea and Asian In The Year 2005

For many years, most of the attention in the semiconductor industry has focused on the United States and Japan. But recently, media coverage has expanded to include other Asian countries. For example, in July 1995, a cover article in Business Week (July 31, 1995) featured the growing potential of Korea, particularly in high technology fields including the semiconductor industry. These activities raise the issue of future Asian participation in the semiconductor industry. Will Asia in one

form or another aggressively seek to take global leadership in the industry? If so, how? Will Japan, Korea and Taiwan as nations strive to be full-fledged semiconductor industry players or will they concentrate on specific segments within the industry? Will the nations and companies of Asia pursue economic convergence so that an overall Asian industry cluster emerges rather than nation specific clusters?

To gain further insight into these issues, Table 1 has been developed. Six major factors have been identified and ranked by the authors, after review with college professors in Japan and South Korea, on a scale of one to ten for 1995 and 2005. Table 1 is not meant to be a definitive assessment or forecast (that would require more rigorous research and analysis), but has been formulated to use Michael Porter's industry cluster concepts as the basis to explore future Asian possibilities. Table 1 reflects the common assessment that currently the United States is strong in entrepreneurial innovation and the Asians are the leaders in chip manufacturing. Will this pattern continue over the next ten years or will Asia, and Korea in particular, become even more ambitious and seek to create their own intellectual capabilities to become the global leader in developing and manufacturing new breakthrough products?

1995 Semiconductor Industry Speculation

The overall semiconductor industry capability scores in the 1995 Assessment are consistent with the analysis by VLSI Research of 1993 data and their forecast for the year 2000. Their data shows the United States as not only the 1993 market share leader, but they forecast that American strengths will lead to more

business at the expense of Japan. The 1995 assessment also shows Korea as a significant player, particularly in chip fabrication. Europe is weak and Taiwan is a small player, although of growing importance, particularly in wafer manufacturing (Huang, 1995). In terms of evaluating economic competitiveness, the *Business Week* (July 31, 1995) article on Korea mentioned the combination of the strong yen and lower Korean labor costs as enhancing the competitiveness of Korean companies, particularly in market situations that are price sensitive. To take this into account, the exhibit includes a cost adjustment of a negative 15% for Japan and a positive 15% for Korea and Taiwan. The exhibit thus has two overall scores: the first, an overall semiconductor industry *capability* score which shows the United States and Japan as the leaders for the next ten years, and second, an overall semiconductor industry *competitiveness* score including the cost adjustment factor which illustrates the economic potential of Korea.

TABLE 1
SEMICONDUCTOR INDUSTRY CLUSTER ANALYSIS
FUTURE POSSIBILITIES IN THE YEAR 2005

Semiconductor Industry Factor	1995 Assessment				
	<u>U.S.</u>	<u>Japan</u>	<u>Europe</u>	<u>Korea</u>	<u>Taiwan</u>
Breakthrough R&D	10	7	3	7	3
University Resources	10	5	5	7	3
Software Development	10	3	5	2	2
Product & Process Design	10	10	5	6	4
Manufacturing Equipment	10	9	4	2	2
Chip Manufacturing	<u>8</u>	<u>10</u>	<u>5</u>	<u>7</u>	<u>5</u>
Overall Semiconductor Industry Capability	58	54	27	31	19
Cost Adjustment	-8	+5	+4		
Overall Semiconductor Industry Competitiveness	<u>58</u>	<u>46</u>	<u>27</u>	<u>36</u>	<u>23</u>

2005 Possible Industry Competitiveness

	<u>U.S.</u>	<u>Japan</u>	<u>Europe</u>	<u>Korea</u>	<u>Taiwan</u>
Breakthrough R&D	10	6	4	8	4
University Resources	10	6	5	8	3
Software Development	10	5	6	6	3
Product & Process Design	10	10	6	8	7
Manufacturing Equipment	10	9	4	5	3
Chip Manufacturing	<u>7</u>	<u>10</u>	<u>4</u>	<u>9</u>	<u>9</u>
Overall Semiconductor Industry Capability	57	46	29	44	29
Cost Adjustment	—	<u>-6</u>	—	<u>+3</u>	<u>+2</u>
Overall Semiconductor Industry Competitiveness	<u>57</u>	<u>40</u>	<u>29</u>	<u>47</u>	<u>31</u>

2005 Semiconductor Industry Speculation

Forecasting for the next century in the dynamic semiconductor industry is very speculative, but Table 1 attempts to highlight future possibilities, particularly the potential of Korea, who for several reasons may become the strongest competitor to Japan and possibly the United States as well. Korea has an unusual history, with important relationships to Japan and the United States. The Japanese occupation in the first half of this century has fueled strong Korean desires to surpass Japan. The Korean War led to extensive linkages between the United States and the people of South Korea. South Korea has a population of 45 million people with the potential to add 25 million more in North Korea if closer political and economic ties lead to an eventual reunion similar to Germany. Although North Korea could cause short-term burdens, a peaceful, unified Korea has the potential of becoming an economic powerhouse with 70 million people. Compared to Japan, Koreans place more emphasis on the English language and the pursuit of higher education in the United States. Many of the Ph. D.'s in South Korea attended American universities and Korean companies have aggressively hired long-term employees of American firms who want to return to their Korean roots (*Business Week*, July 31, 1995).

The forecast for the year 2005 reflects the potential of Korea, particularly in the industry factor of university resources. Korean schools emphasize math and science skills. Moreover, many top Korean scientists have attended American universities and are familiar with the breakthrough approaches of American research. That strong American connection is the reason for the score of eight in 2005 compared to a six for Japan. As for the other countries in the 2005 forecast, the assumption is

made that the United States will stay relatively the same, Japan will improve slightly in university education, R&D, design and software; Taiwan will also make significant improvements, but may not reach Korean levels because Taiwan has a population of only 20 million and a problematic relationship with China. Although Europe should also improve, they most likely will still be behind the United States and Asia. As for the 2005 cost adjustment factor, the exhibit makes the assumption that a high yen will continue, but that Korean and Taiwanese labor cost advantage will decline. As the exhibit indicates, Japan may still maintain a lead in semiconductor industry capability, but exchange rates and labor cost variables may make Korea more economically competitive.

Another interesting issue for the future is to what extent do the six semiconductor factors interact synergistically within a country to enhance overall competitiveness or will the combination of specific national strengths and market forces lead to specialization in different segments of the market with America being the innovative, entrepreneurial leader and Asia, particularly Korea and Taiwan, being the center for semiconductor equipment manufacturing and chip fabrication.

Applicability of Michael Porter's Industry Related Clusters and The Impact of National Culture

Michael Porter (1990) has argued that the innovative cultural strengths of the United States have led to world leadership in the industry clusters of entertainment, software, and telecommunications. An interesting question to pursue is the extent to which the cultural strengths of Asian countries in mathematics and science education as well as manufacturing engineering could eventually result in the

leadership of the semiconductor industry shifting to Asia. Pertinent to this analysis is whether Asian countries will pursue largely national identities or will Asian companies develop ever-increasing convergent relationships across national boundaries. These corporate alliances could incorporate strong American companies such as Motorola, IBM and Texas Instruments with major Asian operations.

The combination of society-wide educational achievements in math and science and the high savings rate of Asians will enable aggressive investments by Asian companies in high technology industries. As the world economy becomes increasingly global and interdependent, the potential exists for Asian companies led by thousands of Asian and American educated executives to develop creative alliances with American companies and universities. It is possible that powerful cultural forces are underway whereby the huge size of Japanese, Korean and Chinese markets could easily evolve into Asia becoming the geographic center of a global semiconductor industry encompassing world-wide technology and business alliances.

Conclusion

From its embryonic beginnings twenty-five years ago, the semiconductor industry as exemplified by Intel and its symbiotic ally, Microsoft, will arguably become the most strategically important economic force in the 21st Century. The formation and development of national industry clusters were strongly affected by timely government intervention in Japan, the United States, South Korea, and now China. Industry developments for the near future apparently are leading to a global industry cluster with the United States strong in breakthrough technology and Asia leading in

manufacturing production. European companies may be left behind unless they are able to create crucial strategic alliances. This industry evolution appears to be the natural result of market forces. Governments around the world should not subsidize specific companies, but instead should facilitate the market process by working towards a free trade environment. The recently formed World Semiconductor Council has the potential for private companies to create a stronger industry with minimal government participation. To enhance national competitiveness, government involvement should emphasize cluster factor development such as funding university research and development and supporting technical education. Specific subsidies for semiconductor companies do not appear to be necessary or appropriate.

As for the long-term future, deep cultural factors may become the critical determinant. During the 21st Century, a new constellation of economic forces may evolve. Historic American innovativeness, and Asian technical excellence particularly in manufacturing may lead to fascinating global combinations. American and Asian companies are already linked, but largely by American technology guiding Asian manufacturing. As the Asian electronic conglomerates become larger and larger and as their employees become more and more educated, will we see an evolutionary shift similar to what has already occurred in the automobile industry? Asian companies started in low value added products such as economy automobiles, developed their manufacturing processes, and eventually became strong in the high value added products such as luxury automobiles. Asian automobile companies have become major competitors across all market segments alongside American and European manufacturers. Will future economic growth in

China and the rest of Asia fuel the same developments in the semiconductor industry?

In *The End of History*, Francis Fukuyama (1992), an American of Asian descent, argues that the Western idea of market freedom has triumphed around the world thanks to American leadership. It is possible that if Asia moves beyond its tragic 20th Century history, resources previously constrained by military and ideological burdens will now be liberated. Powerful forces such as hard work and respect for education channeled into strong organizations may now become fully unleashed, enabling the huge Asian populations and their ancient cultures to pursue new economic histories.

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