From Strategic Trade Policy to Strategic Alliances in the Global Semiconductor Industry

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Purpose of the case study.

In this case study it will be argued that from its start the semiconductor industry has been considered a strategic industry in the USA receiving government support. However, advantages erode and last only until competitors have duplicated or outmaneuvered them. Observing the excess returns earned in this sector Japanese companies wanted to shift these excessive returns to Japan and the Japanese authorities provided support undermining the initial American competitiveness on the world market by closing the Japanese market both to imports and foreign direct investment.
In order to counteract this the US industry reacted by creating, with government funding, the research consortium SEMATECH and the American authorities responded by concluding in 1986 a bilateral trade agreement with Japan in which Japan agreed to voluntarily restrict its exports of semiconductors and to voluntarily expand the imports of chips.
The present situation in the global semiconductor industry is that due to the exhorbitant high R&D cost of developing new generations of semiconductors the large producers all over the world are forming strategic alliances, implying that according to the Japanese there is no need to renew the semiconductor trade agreement.
The emergence of successful global alliances has the potential to shift competition away from the current, predominantly nationalistic focus to a struggle among competing global partnerships.
If relationships of this sort prosper, then at least one Japanese-American trade sore may have healed itself.
This study starts with demonstrating that globalization is reality in the semiconductor industry. It presents a survey of the events, its backgrounds and an economic evaluation of the policy measures undertaken to support the semiconductor industry.

1. *Introduction*.

Since the birth of the semiconductor industry with the invention of the transistor at Bell laboratories in 1947, the industry has been characterised by a seemingly never-ending chain of product and process innovation. The semiconductor industry is a high-technology industry where firms allocate a large part of their revenue to research and development. Semiconductors have found direct application in almost everything produced and they are believed to have spurred the development of other important industries, such as computers, telecommunications and consumer electronics. They are considered the oil of the next century.

The most significant product and technical advances in microelectronics have been achieved by US companies. Initially, a combination of factor endowments, technological skills and growing demand, all fostered by goverment policies and purchases by the military, gave American companies a competitive edge and first-mover advantages with a steep learning curve.

Semiconductors have been labeled a strategic industry. The reasons and criteria for labeling semiconductors a strategic industry are:

1) the importance of semiconductor components for superior performance in military hardware;

2) the centrality of semiconductor technology for achieving breakthroughs in computers and information-absed technology.

3) the broad range and versality of semiconductor applications for large end user industries, including automobiles and the service sector;

4) the pivotal position of the semiconductor industry in the system of institutions and practices underlying a nation's capacity to innovate, employment, manufacturing infrastructure, R&D, graduate training and so forth.

Therefore, the case for semiconductors rests on their importance in maintaining a nation's capacity to innovate and commercialize technology, and all that this implies for military, industrial, and technological leadership. Hence, as the semiconductor industry is generating externalities and spillover effects for other sectors it is considered to be a strategic sector.

Government promotion of strategic industries is an increasingly common practice because of their connection with the commercial development of critical technologies. The traditional rationale for these policies hinges on the

infant industry argument due to which new industries take a while to get established because of start up problems and because the industry needed to be insulated temporarily from competition.

In high-technology industries, particularly those with high initial R&D costs or those with steep learning curves, the infant industry argument has been supplemented with a new rationale taken from strategic trade theory, arguing that targeting may be desirable under certain circumstances, especially when there are the significant spillover effects between the semiconductor industry and the rest of the economy. These types of industries offer strong advantages to first movers, especially if later entry is quite limited. The firm with the highest cumulative production has the lowest unit costs and hence can underprice all other competitors and still make a profit.

Due to spillover effects in critical sectors, like semiconductors, a country's gain or loss in competitive position can result in a cumulative gain or loss across a whole spectrum of connected industries.

In the presence of such effects in imperfectly competitive markets government targeting of a single sector can have profound enduring effects throughout the economy. Strategic trade theory assumes that competition is imperfect (i.e. oligopolistic or monopolistic) and that there are increasing returns to scale and economies of learning by doing.

Import protection may act as export promotion. Government targeting may shift the outcome of the strategic interaction by shifting the excess returns from the foreign in favor of the domestic firm. Targeting helps national firms grab as large a piece as possible of the international profit pie.

There is nothing new about the conclusion that strategic government intervention can give home firms larger market shares and profits. What is new about strategic trade policies is that this may actually improve the overall welfare of the home country at others countries' expense. Therefore, strategic trade policy aims to shift excess returns from the foreign country to the domestic economy.

Government intervention as a strategic tool can decisively shift competitive advantage from one national economy to another when industrial production is characterized by dynamic economies of scale, imperfect competition and a cumulative and territorially embedded knowledge base. Comparative advantage in this sector is no longer exogenous, it is considered to be endogenous, less a function of factor endowments, but created by strategic government

intervention.

The great danger of strategic trade policy is that retaliation and protectionism may come about, resulting in a decrease of world welfare as a whole and in a situation in which the countries are caught in a Prisoners' dilemma.

In the USA the government directly and indirectly underwrote technology development, both through R&D contracts and through military procurement. While the significance of military markets declined during the 1970s, the initial phase of military procurement during the 1960s helped to secure the technological leadership of US firms in the semiconductor industry.

However, after three decades of technological and commercial domination, US semiconductor firms in the 1980s generally lost market share and technological leadership to Japan. The rise of Japan to market leadership in high-technology industries is a paradigmatic example of the positive growth effects of aggressive government intervention. Through a combination of investment incentives, coordination of R&D and market closure, the Japanese government helped to secure the rise of the Japanese semiconductor industry to market leadership. A classic strategy of infant-industry protection and promotion in Japan worked to create a competitve Japanese industry capable of challenging American supremacy.

The popular view is that Japan's success rests on a combination of government research subsidies, a protected domestic market and dumping of semiconductors at below fair-market-value in the US. The Japanese government intervened strategically in the market, overcoming the technological leadership of US firms and shifting competitive advantage away from the US to Japan. In the face of unfair competition from Japan, US firms were unable to remain profitable and withdrew from key product markets.

However, this account overemphasizes the role of the Japanese government and MITI and underestimates the significance of structural weaknesses in the US semiconductor industry and the superior manufacturing performance of Japanese semiconductor producers.

MITI sponsored research in the precompetitive Very Large Scale Integration (VLSI) production in order to enhance process capability rather than to develop specific product technologies and to improve upon manufacturing equipment bought from US firms.

MITI indeed played a key role in allowing Japanese firms to catch up to the USA, but the subsequent competitive success of Japanese firms had more to do with the internal development efforts of individual firms and the superior manufacturing performance of Japanese producers.

By 1986 Japan had surpassed the US as the largest producer of semiconductors in the world. In 1991, Japanese companies held 46 percent of the $60 billion world market for semiconductors and US companies held 39 percent.

With Japanese producers outspending international competitors in R&D and capital equipment, industry observers warned of a possible domino effect in which US firms would be driven out of profitable segments of the semiconductor industry and other allied high technology sectors of production such as computers and communications systems.

In response, the US semiconductor industry, led by the Semiconductor Industry Association (SIA) conducted a highly effective lobbying campaign for government support. The SIA argued that in the absence of a strong semiconductor industry US defense would become dependent upon foreign sources of supply for leading-edge semiconductor devices. The US government initiated two programs of support for the US semiconductor industry:
1) a semiconductor trade agreement with Japan;
2) multiyear financing for a consortium of US semiconductor firms: SEMATECH.

In the Semiconductor Trade Agreement concluded in 1986 and revised in 1991 the USA and Japan negotiated floor prices for DRAMs and Japan promised to increase purchases of semiconductors from US firms.

In 1987 the US government began a new R&D initiative by providing support to SEMATECH, a consortium of semiconductor firms involved in the development of advanced semiconductor manufacturing technology. The primary goal of SEMATECH has been to restore US competitiveness in semiconductor manufacturing technology.

As a result of these actions, in 1995, US worldwide semiconductor market share out of $155 billion has achieved again 39.8 percent, while that of Japan is 39.5 percent; South Korea and Taiwan have helped to boost the share of Asian producers to 12.1 percent; European producers hold a share of 8.6 percent.

1.1. *Globalization of the semiconductor industry*.

The last decade the semiconductor industry has gone through a period of remarkable and far-reaching change. This $100 billion industry is shifting from a vertically integrated, monolithic, single nation-based business to a horizontally integrated, cooperative industry based on multi-national partnerships and alliances.

In 1995 the world semiconductor industry generated sales of approximately $144 billion. The market is growing rapidly, at about 15% annually, although since the end of 1995 there is a temporary set-back. Sales in 1996 are expected to total some $155 billion and to reach $270 billion by the year 2000. This growth in semiconductor sales and trade is the result of growth in demand for existing products, and the development of new technologies, appplications, products and markets.
The fastest growing supplier and consumer of semiconductors is not the US or Japan, but Asia. By 2010, it will represent above 40% of semiconductor exports. Asia will also sow the biggest growth in demand for semiconductors. 54% of the North American and 61% of Japanese exports of integrated circuits will go to Asia in 2010. Of Asian imports in 2010, almost 47% will be expected to originate within that region.

It is somewhat misleading to talk of a monolithic semiconductor industry, since the industry is composed of many different sectors, from low-end, simple commodity semiconductors, to high-end application specific semiconductors. Each sector has its own demand and business characteristics.

For most world regions, semiconductor trade and sales are driven by the demand for computer applications, which include microprocessors and memories. The Japanese end-use market stands out as somewhat unique, with a strong consumer goods segment which has traditionally challenged computer sales. In other regions of the world, it is the computer market which is the largest user of semiconductors, taking 62% of sales in the US, 41% in Europe and 52% in the Asia/Pacific region. However, recently the Japanes market is moving away from consumer-oriented analog products, towards digital electronics and computer products. The high-end, computer-based segments are the fastest growing segments in all regions.

No single measure of the international semiconductor market tells the whole story. There are different ways of measuring size and shares of markets, none of which is perfect. One measure of total market size is total world exports for semiconductors: $105 billion in 1995. However, this measure excludes the sales of semiconductors within the market in which they are produced. Another commonly used measure is the total value of the industry’s sales, which was $144 billion in 1995. However, this measure does not take into account the captive market for semiconductors, that is the internal use of semiconductors in vertically-integrated companies. Each measure paints a different, but incomplete picture of the marketplace. These simple sets of dats are further complicated by the complex and dispersed organizations of production within each firm and the growing inter-relati-

onships between firms of all nationalities at different stages of production.

Globalization is reality in the international semiconductor industry with a significant shift of production and assembly by US and Japanese firms outside of their respective countries. This globalization trend is reflected in the continued long-term growth in foreign investment and changes in international sourcing and in the extensive formation of alliances. This process is practically irreversible. US firms are more aggressive than other semiconductor companies in moving production facilities offshore in search of lower labour and facility costs, mainly at the finishing stages of production.

Very different conclusions can be drawn based on whether the relative importance of individual countries or regions in the world semiconductor market is measured based on company ownership or based on export shares. Interrelationships between firms have grown to such an extent that it becomes totally irrelevant to use a single measure to assess market share or the contribution of different countries/regions to the global market. In the beginning of the industry’s development, market share measures based on trade or ownership were similar. However, the increased globalization has created a significant gap between these two indicators, as is shown in next table for 1994.

Region	by Ownership	by Exports
North America	32%	18%
Europe	20%	22%
Japan	29%	22%
Asia/Pacific	19%	38%

Source: DRI/McGraw-Hill.

These figures only give a partial view of what is happening. E.g., Europe’s share of world exports mainly reflects the importance of intra-European Union trade. Surprising is the comparatively low US share of world exports which is barely half its market share based on company ownership. This suggests that a very high share of US production is taking place outside the US, mainly in Asia. The two regions with the greatest difference are North America and Asia/Pacific. To a large extent the difference reflects the same phenomenon: Asia/Pacific companies export to the world qua share double of what they own. While this contributes to job creation and economic growth in the offshore region, it may not necessarily affect jobcreation in the country where the owner companies are located. Moreover, the US and Japan are exporting parts for resp. 43% and 20%, which are used in

offshore labour-intensive manufacturing and this again provides a partial explanantion for the ownership/trade data shown above.

International alliances among semiconductor companies have become the norm. The largest portion of these alliances are between Japanese and US firms. They are being formed at all stages of production, i.e. from R&D, to production and distribution. The majority of these are pre-competitive in nature, i.e. formed at the product development stage. The increase in global alliances can be attributed to a few key factors, including a move toward specialization, the growing cost of R&D, changes in the geographic distribution of production linked to different rates of growth of demand across regions, and to companies' search for lower cost production bases. Moreover, semiconductor firms have looked for technological complements in areas where they had limited experience and have sought to gain access to partners' specific strengths in resources, such as products, engineering, technology, finance, customer base, sales forces and/or distribution.

With respect to the movement toward specialization as a key factor leading to industry cooperation, e.g., US companies lead in production of microcomponents and application specific integrated circuits, while Japanese firms are strong in memory devices such as SRAMs and DRAMs and devices geared to consumer-oriented products. Over 60% of alliances by Japanese firms in emerging Asia were for the purpose of production cooperation, while 60% of alliances between Japan - US and Japan - Europe were for development reasons. The majority of US and European partners were chosen for their superior technology and/or products, while Asian partners were chosen for their production capabilities and/or to help share the financial burden of the production facility investment. Japanese companies have more alliances with US firms than with any other economic region, and US companies have more alliances with Japanese companies than any other region. 69% of all alliances between Japanese and foreign companies were between Japan - US, 15% Japan - Europe and 13% Japan - Emerging Asia. The number of alliances with emerging Asia is set to grow as the industry in this region develops further.

As the cost of semiconductor R&D has grown dramatically cooperation and the pooling of financial resources are essential. In the 1970s, total R&D and capital expenditures did not exceed 30% of sales. By 1992, this figure had climbed to 40%, divided equally between R&D and capital expense. Next table illustrates the growing cost of R&D in the development of DRAMs since 1985.

1985	**256 K**	**$ 110 million**

1988	1 M	250
1990	4 M	400
1994	16 M	850
1995	64 - 256 M	1000
< 2000	1 G	> 1000

Source: DRI/MCGraw-Hill.

Another reason for alliances is that in order to maintain market share firms must permanently adjust to changing customer needs. As the main markets for conventional consumer electronic products such as stereos and VCRs have become saturated, consumer electronic firms see their customer base shift to information technology, equipment and multimedia.

In addition to supplier-supplier alliances, the industry is now witnessing an increasing proliferation of global design-in projects between suppliers and users of different nationalities. Design-ins refer to the practice of designing semiconductor devices for specific commercial products.

Another indication of globalization is that instead of doing everything from building processing equipment to manufacturing, packaging and shipping themselves, even huge vertically integrated firms are resorting to outsourcing through buying equipment and services from outside suppliers.

2. *Manufacturing technology*.

Semiconductors are circuits that are built on silicon wafers. A wafer is a thin, highly polished silicon crystal disk of 8-inch.
The technique of production involves etching of circuits on silicon wafers by a combination of photographic techniques ("masking") and chemical baths, followed by baking, cutting into dice, sealing and packaging. Typically it takes from 10 to 30 days to complete the fabrication process. For a chip to work, everything - temperature, timing, density of solutions, vibration levels, dust - must be precisely controlled. The physics of this process is not entirely understood so that manufacturing involves a trial and error process, giving rise to learning by doing.

Technological progress leads to generations with increased information storage capacity (taken as product innovation) and to production processes characterized by smaller design rules (taken as process innovations).
Japan is the leader in process technology and the US in design technology.

The improvement of performance is known as the *Law of Moore*, one of the founders of Intel. Moore has found that every two years microchips show a doubling of achievement. This is due to continuous miniaturisation in producing chips, so that more transistors may be compressed on a small area.

The industry has maintained its growth by achieving a 30 percent per-year per-function reduction in cost over its history. This productivity increase has come through design innovation, device shrinks, wafer size increases, yield improvement, and capital equipment utilization improvements. However, productivity increases resulting from these improvements have been offset by increased complexity, chip sizes, and wafer facility costs.

In future, the production process will be subject to two restrictions.
First, there is the cost problem. A modern chip facility costs around $1 billion and by the end of the decade the cost of state-of-the-art plants will have doubled.
Second, there are two technological problems.

*** First, over 9 to 15 years the Law of Moore might be blocked. The yield curve in microprocessors will probably continue to hold for three generations yet. At this moment the most advanced equipment can etch details of 0.35 micron (a micro metre is one thousand's millimetre). The distance between the transistors on a chip may be further reduced to some 0.25 micron, but thereafter big problems will arise. This has to do with the wave-length of light. Below the 0.10 micron barrier, to be reached by the year 2008, no solutions are in sight.**

*** The second technical problem concerns the formation of heat between the transistors due to the compression on such a small scale that temperature will be increased. Cooling with ventilators might postpone this problem, but it becomes critical when in 2008 the 0.10 micron barrier will be reached.**

Within a few years the generations of microchips will succeed each other less rapidly. An unpleasant consequence is that the development of new applications for PC's such as recognition of speech will be delayed. This means that the increasing development efforts will meet less revenue.

2.1. *DRAMs versus EPROMs*.

The basic breakdown of semiconductors is into integrated circuits, which is the largest product line, discrete devices, and optoelectronic devices. Much of the international trade dispute in semiconductors centred on memory chips, primarily used in computers to store and retrieve

data, which are technology drivers for other more complex semiconductors such as in telecommunications. Memories are divided into volatile and non-volatile devices.

In memory chips a distinction can be made between commodity chips (DRAMs) and specialty memory chips (EPROMs). This distinction fits within the present trend toward commoditization and customization.

DRAMs, (Dynamic Random Access Memories) (so-called "industrial rice") are a volatile device. They temporarily store large amounts of data or instructions; the memory disappears when power is turned off. Any randomly selected location can be accessed and retrieved in the same amount of time; this contrasts with the time required to get information from a tape, which depends on the location of that information. Static RAMs (SRAMs) are faster but hold less information.

The main application of DRAMs is in computer memory boards. The storage capacity of DRAMs quadrupples with each new generation (1K, 4K, 16K, 64K, 256K, 1M, 4M, 16M, etc.), which comes out every 3 years. Their market success depends on low cost of production rather than design.

EPROMs (Erasable Programmable Read-Only Memories) are a non-volatile memory chip. They store data more permanently. In ROMs the memory content is loaded during the manufacturing stage, performing only reading operations, e.g., a fixed program in a pocket calculator. In EPROMs the programmes can be erased and changed occasionally. The main application is in microprocessors. The storage capacity doubles with each new generation (4K, 8K, 16K etc.) which comes out every 18 months. Their market success depends on design and performance more than on low production cost.

The DRAM market is larger than the EPROM market. Price competition is more intense in DRAMs. DRAM costs are mainly determined by current output and age: economies of scale.

The EPROM market offers more scope for product differentiation. EPROM costs are determined mainly by cumulative output: learning by doing. Generally, DRAMS have lower per-bit price than EPROMs.

Due to high switching costs EPROMs of older generations are still in demand even if new generations are already on the market. The demand for DRAMs is biased towards the latest generation.

Both large fixed costs and learning by doing imply that only a few firms can survive. However, continuous innova-

tions offset this and allow small start-up firms to enter the market.

A key transition within DRAMs or EPROMs happens when cost per bit becomes equivalent for adjacent generations. This leads to demise of an old generation.

With respect to the appropriability of technology, the *basic* technique of production qua design cannot be kept secret, while the *details* of production, i.e. gaining experience, are highly appropriable.

For users, access to-state-of-the-art technology is critical to successful competition.

**In general, prices do the adjustment to shocks, while output expands continuously.
This contrasts sharply with, e.g., the automobile sector, where the opposite holds.**

It may be concluded that the large market size, the extended "top-quality status" for the latest generation, and the limited scope for vertical product differentiation, all contribute to making the DRAM market quite different from the EPROM market.

2.2. *Scale economies*.

Several sorts of scale economies are prominent in this production.

1) The cost of building a chip-producing facility; these costs have increased rapidly over the years as chips have become more sophisticated and their production more intricate.

2) The cost of research and development necessary to introduce a new chip.

These scale economies are *static*: the costs are incurred once before production begins and are then averaged over all chips produced, so that the larger the production, the smaller the average costs.

**Another scale economy is *dynamic*, being cumulatively experienced as long as a chip is produced.
When a new chip is introduced, production costs are typically high, largely because many of the chips are faulty and must be thrown away. But as more chips are produced, the firm *learns* how to do it better, failure rates fall and costs decline dramatically. This process has been repeated with the introduction of each new chip and it is fairly predictable.**

Learning by doing takes the form of ever-increasing

yields, that is ever-increasing percentages of usable semiconductor chips, as cumulative output rises.
E.g., early in the product cycle as much as 90% of output is flawed or nonfunctioning; once greater production experience has been acquired, this failure rate can fall under 10%.

Another dynamic scale economy extends *across generations* of chips: producing one type of chip apparently enhances the ability of firms to develop and produce future generations of chips.
Semiconductors are "technology drivers" in that learning by doing lowers costs in subsequent generations of chips: "DRAMs are the bellwether" for the industry.

All these scale economies are *internal* to the individual chip producer: they depend on what that producer does, not on what the whole semiconductor industry does, and they influence the costs of that producer, not the costs of others.

There are also scale economies *external* to the individual chip producer. Semiconductors are intermediate goods, used in the production of computers, consumer electronics, capital goods and a host of other products.
The production process of chips generates valuable knowledge useful to other chip producers and to developers of products that use chips. This knowledge spills over from the chip producer to these other firms that can use it. This spillover occurs due to informal contacts between individuals in the industry, the mobility of engineers and all sorts of other forms of observation.
The problem is that externalities are inherently hard to measure, because by definition they do not leave any trace in market transactions.

These circumstances generate motives for protection, i.e. strategic trade policy.
1) The *internal* economies of scale imply that perfect competition is unlikely to prevail. This means that *profit shifting* could have been a motive: the Europeans and the Japanese have targeted their industries so that oligopolistic profits captured from the sale of semiconductors in their countries would go to their own firms rather than to American firms.

2) The *external* economies imply that *production shifting* may be a motive: due to targeting, knowledge spillovers from the chip production would flow to their own domestic firms. If the externalities are international in nature, e.g., due to direct foreign investments, protection is unnecessary because the spillovers arise anyhow. Moreover, if the spillovers are international, the finding of a spillover does not provide support for policies favoring domestic over foreign firms. Any country that subsi-

dizes its domestic firms in part provides an international public good. However, as there is a strong national component in the externalities production shifting may be a motive.

In an industry characterized by strong learning effects protection of the home market can have a kind of multiplier effect. Privileged access to one market can give firms the assurance of moving further down their learning curves and thus can encourage them to price aggressively in other markets as well. Privileged access to the domestic market was in fact decisive in giving Japanese firms the ability to compete in the world market.

2.3. *Nature of learning economies: empirical evidence.*

DRAMs, SRAMs, and EPROMs share a role as "technology driver", i.e. while the circuit designs themselves differ significantly between these products, they fundamentally involve the same manufacturing technology and process steps.
Multiproduct firms, cet. par., make greater learning investments in technology drivers and capture greater learning economies in each derivative product than firms with a limited product line.

The learning curve may be approximated by specifying that:

$$w(E) = \phi E^{\varepsilon}$$

This gives yielded chips as a function of experience, E, where ϕ equals the wafer fabrication yield, i.e. the learning curve level parameter. Production typically starts at low yields; after a period, yields rise quickly, then flatten out in a pattern close to a logistic curve.

In DRAMs there are several published reports of an empirical 72 percent "learning curve", meaning that current unit cost drops by 28 percent with every doubling of output, corresponding to ε = 0,47.

With a constant wafer-processing cost as the only cost element we have as unit cost:

$$\frac{c}{w} = (\frac{c}{\phi})E^{-\varepsilon}$$

A learning elasticity ε equal to 0.47 is solved from the 72 percent learning curve:
The slope of the learning curve indicates the percentage

$2^{-\epsilon}=0.72$

cost reduction when cumulative output is doubled. E.g., in an 85 percent curve the unit cost falls by 15 percent if cumulative output is doubled. Next figure illustrates this relation between the learning elasticity and the learning curve slope.

Recently, Irwin and Klenow (1994), estimated the learning-by-doing spillovers for 8 DRAM generations over 1974-92 on the basis of some 600 quarterly observations on shipments by merchant firms.

They have tried to disentangle how firm, country and world cumulative production contribute to the experience, so that several hypotheses could be tested: learning purely internal to the firm, external to the firm but internal to the country and learning external to the firm and country.
More concretely, they tested how experience, E_i, has been influenced on the basis of next equation:

$$E_i = Q_i + \alpha(Q_C - Q_i) + \gamma(Q_W - Q_C)$$

where:
Q_i = cumulative output of firm i;
Q_C = cumulative output of firm i's base country;
Q_W = world cumulative output.

This expression nests next hypotheses:
$\alpha = \gamma = 0$: purely internal learning by doing;
$\alpha = 1, \gamma = 0$: learning external to the firm, but internal to the country;
$\alpha = 1, \gamma = 1$: learning external to firm and country.
where:
α = within-country spillover;
γ = cross-country spillover.

Spillover coefficients may represent market (joint ventures or labour mobility) or nonmarket (quid pro quo communication among engineers) exchanges between firms.

Irwin and Klenow found learning rates varying from 10 to 27 per cent, averaging 20% across 8 generations. This result is somewhat below the widely reported figure of 28 per cent learning, according to which unit production costs fall by 28% every time cumulative output doubles.

The average spillover coefficients were: α = .28 and γ = .32. These low spillover coefficients imply largely internal learning so that firms learn over three times more from each additional unit of own cumulative production than from additional units of another firm's cumulative production.

The small value of α - γ, i.e. 0.04, implies that within-country spillovers appear no stronger than international spillovers. Learning spills over just as much between firms in different countries as between firms within a given country.

Although it is often emphasized that various "intrinsic" learning advantages of Japanese firms have contributed importantly to their new positions as dominant suppliers in this market (Japanese engineers and production workers have greater attachment to their employers so that with the lower turnover and continuity in workforce learning processes are more effective), according to Irwin and Klenow there is no empirical basis for believing that Japanese firms are systematically better at learning from production experience than other firms. Japanese firms are indistinguishable from others in learning speeds.

Intergenerational spillovers are weak, being marginally significant in only two of seven DRAM generations. Therefore, Japanese industrial targeting does not permanently affect production and trade in semiconductors.
The absence of important intergenerational spillovers diminishes the potential advantage of industrial policies designed to promote the semiconductor industry because with short (3-5) product cycles, any gains from such policies are likely to be extremely short-lived.

It may be noted that these results were sensitive to variations in demand elasticity. The more steeply sloped the demand curve, the less learning and spillovers are required to explain sharp declines in price.

With respect to the learning curve at the industry level Gruber (1994) has found that:

1) For EPROMs cumulative output is the only significant variable explaining the cost of producing EPROMs. The learning curve is of 79 per cent type, i.e. doubling output of EPROMs reduces average cost by 21 per cent.

2) For DRAMs economies of scale i.e. current output and generation age seem to account for lower costs. In DRAMs the evolution of prices is better explained by current output than by the learning curve.
3) For SRAMs generation age is the only significant explanatory variable.

At the firm level, for EPROMs, the learning curve obtained is not very different from that estimated at the industry level.

Gruber found some evidence for the transferability of learning within the firm. This implies that an incumbent firm has an advantage in adopting a new technology compared with a new entrant. Thus leap-frogging in innovation would be a very costly strategy, although in the DRAM market it actually occurred.

Since economies associated with learning-by-doing are important and largely internalized (no spillovers), increased market concentration is a natural result.
In this respect the Hirschman-Herfindahl concentration index declines from an initially high level, then to nearly 0.1 and at the end of the cycle it rises sharply as producers drop the product line. The U-shaped time profile reaches the mimimum after about 5 years.

2.4. *Intel's persisting leadership*.

One of the often cited explanations for Intels' persisting leadership is based on the company's superior technological competence. Learning by doing, at least if fully appropriable, seems to play a dominant role thereby, although learning spillovers diminish the importance of the leadership advantage and typically generate the "leap-frogging" result in which firms alternate in innovating first.

However, in the semiconductor industry product performance and the cost of manufacturing equipment are nonlinear and this may thwart Intel's efforts to persist its leadership.
The reason is that relatively large infusions of capital must be periodically bestowed on equipment and research, with each infusion exponentially larger than the one before. Moreover, investments in research and new equipment must generate a healthy rate of profit.

At present, semiconductor companies have no way of determining precisely the proportion of their financial returns that comes from their technology investments. Not only must increases in capacity be constantly anticipated, but also great advances in the manufacturing technology itself must be foreseen and planned for.

To account for this technology-drag effect the ratio of cash generated during any given year may be compared with investments made in new technology, consisting of both new manufacturing equipment and research and development, the year before.
What this ratio indicates are incremental profits per incremental investment, one year removed. It shows how high a company is keeping its head above water with respect to profits, thanks to its investment in ever more costly technology.

Next chart, borrowed from Hutcheson and Hutcheson (1996), shows the relation between Intel’s profits and investments in technology throughout the company’s history. Plotted points trace loops that each correspond to roughly a six-year cycle.
During each of them, Intel moves from a period of unprofitable operations caused by heavy investment to an interval of very good cash generation stemming from much lighter investment. Arrows indicate the year in each cycle when Intel made the most money and spent lightly on equipment.
Each loop’s lower portion is lower than the one that preceded it. This means that Intel’s profits, relative to the capital expenditure generating them, are declining with each successive cycle.
From the chart, it is clear that Intel is now entering another period of heavy capital investment.

3. Characteristics of the industry.

3.1. *Captive versus merchant firms.*

A basic distinction is between captive and merchant firms. Captive firms, (IBM), are vertically integrated and consume the chips they produce, and have little influence on prices. As purchasers on the market they desire low prices. Merchant firms (Motorola) produce for sale. They reap gains from protection and from maintaining high prices.

A distinguishing feature of the US semiconductor industry is the large number of specialized small producers; in Europe and Japan, semiconductor manufacturing is dominated by large electronics conglomerates. The US industry is largely composed of merchants, while Japanese producers are largely vertically integrated.

Another widely used classification differentiates between firms manufacturing standard products sold to many different users and customer-specific devices manufactured for one end-user only, providing the latter firm with a proprietary component technology. In the standard products or commodity devices Japanese expertise has been of greatest significance and in these markets the competitive difficulties of US merchant firms have been most severe.

The focus of semiconductor manufacturing has been shifting away from the standard components and toward the custom designing of high-integration application specific integrated circuits (ASIC) and application specific standard products (ASSP) devices for particular market segments. Generic expertise is giving way to specialized expertise in particular product technologies and markets. The shift away from standard components has occurred with a form of market fragmentation with firms developing specialized design expertise.

Although the market share of standard components such as DRAMs remains large, the highest rates of return are obtained on investments in design intensive products.

The increased emphasis on design expertise has provided new openings for start-up firms. These are small design houses that do not have in-house wafer fabrication capability; they subcontract out the production and assembly stages of the manufacturing process to external subcontractors. Unlike the smaller start-up firms, the larger firms have not narrowed their product lines. They produce a greater variety of products than in the past. However, the variety of product markets and geographical market areas has increased rapidly, leaving the large firms with competency in only a few markets.

The small firms are usually start-up ventures set up to exploit new technologies. They are mostly on the leading edge of new product-technology development and are growing rapidly. Large producers often license technologies from these start-up firms to complement and extend their in-house technological capability.

Two elements of this industrial structure stand out as being of central importance:
1) The key role of start-up firms as agents of technological change. The majority of start-up firms were founded as spin-offs from established producers and they provided technological opportunities considered too risky by the parent firms.
2) The tendency toward an "open" technology environment, that is toward an accelerated flow of knowledge and information among firms within the US semiconductor industry.

Barriers-to-entry to semiconductor manufacturing initially were relatively low because of the open technology-environment in which technological knowledge and information flew rapidly among firms, encouraged by liberal licensing practices and by the movement of engineering personnel among firms.
Product licensing gave firms the right to manufacture semiconductors and interfirm worker mobility supplied the skills and knowledge necessary to manufacture devices, thereby alleviating the major barrier-to-entry to the emerging semiconductor industry.

The open environment in the semiconductor industry and the accelerated flow of technology among firms suggest that the consequent leakage of technology from one firm to another will lead to underinvestment in R&D.
Under-investment in R&D is a serious problem in US high-

technology industries. The rate of investment in R&D by US firms is less than that of firms in Japan, Germany and other international rivals. Throughout the 1970s and early 1980s, the US industry failed to keep pace with the investment rates of Japanese firms, (16% versus 28% of sales), especially because of bank ties of Japanese firms in the face of slack demand.

Japanese producers invested heavily in highly automated capacity expansion during recessions based on stable access to cheap capital afforded by the Japanese financial structure combined with rapid tax write offs, while US firms delayed or cut back their expansion plans during rough economic times.

However, on balance the open environment has brought positive benefits.
*** First, this has helped to avoid the "locking-in" of suboptimal technologies.**
*** Second, the flow of information among firms has supported a process of collective and cumulative learning in the industry that allowed individual companies to build on the successes and failures of the industry as a whole. Thus semiconductor firms have been able to avoid unnecessary repetition or research carried out by other firms.**

3.2. *Strategic subsidization through vertical interaction.*

A basic problem on the structure of the semiconductor industry concerns the long-term relative strengths and weaknesses of vertically integrated chip makers in comparison with small entrepreneurial technology driven firms.

Vertical integration has become attractive due to need to transfer proprietary information from designers and producers of systems to component makers. This lessens potential competition from others in the upstream or downstream markets.

Japanese microelectronics firms have managed their integrated businesses strategically in the sense that some activities in the vertical chain are undertaken principally as "drivers" for other activities. In Japan some varieties of integrated circuits are manufactured and internally transferred at below cost as a means of creating an advantage for the corporation's downstream system products.

When these firms use internal sources of factor supply and provide sizeable discounts in factor prices relative to market prices, market share and corporate profits are increased by such discounts. Therefore, the integrated firm's overall corporate profits are increased when it acts strategically and employs a positive internal inte-

grated circuit (IC) price discount.

The profits forgone by the IC manufacturing division, a strategic subsidization, leads the downstream division to greater market share and profits than its non-integrated rival. The interactive firm as a whole has greater profits.

According to Krouse (1995) two conditions require special attention:
1) When the downstream products are weak substitutes, the gains to vertical interaction and strategic subsidization are large.
2) The vertical integrated firm must not organize its divisions as uncoordinated profit centers because this may lead to a myopia which does not allow it to recognize the value in strategic behaviour.

When all Japanese firms act in this strategic way a prisoner's dillemma develops, but each is at an advantage relative to foreign American firms which do not follow this strategy on the whole.

The conclusion is that purchases of DRAMs at spot prices finally places American computer manufacturers at a market disadvantage relative to strategically-minded vertically interactive Japanese competitors.

The exercise of monopoly power by the vertically integrated Japanese chip suppliers has created an economic argument for coordinated defensive action by user industries in the USA by subsidizing high-cost domestic production.

It can be illustrated that such a subsidy of high-cost domestic production is superior to passive acceptance of uncontested cartelized imports. It saves monopoly profits that otherwise would have been paid to the Japanese cartel and as output increases, consumer surplus in the USA is gained. This analysis may have some relevance for European semiconductor policy too.

The essentials of this argument can be illustrated in next figure. The assumed constant cost of Japan are represented by J-J'. Foreign firms have a higher cost schedule given by line U-U'. Foreign demand is given by curve D-D' and marginal revenue by line MR-MR'. If Japanese producers act as a profit maximizing cartel, they produce output Q_0, charge price P_0 and collect monopoly profits P_0AEJ.

If foreign producers effectively contest the market with costless entry in the industry and are subsidized at cost level FF' with output at Q_1, monopoly profits, equal to P_jABF that otherwise would have been paid to the cartel

are saved, and consumers surplus equal to ABC is gained. The conclusion is that subsidy of high-cost domestic production is superior to passive acceptance of unconte-sted cartelized imports.

3.3. Agglomeration economies of Silicon Valley.

In the US semiconductor industry most major merchant semiconductor firms are clustered in Silicon Valley. The close proximity of many specialized manufacturers, sup-pliers and users of semiconductor devices facilitated communication among firms. As the number of suppliers, customers and subcontractors in Silicon Valley increased during the 1960s and 1970s, semiconductor firms were able to secure substantial economies of agglomeration in their manufacturing operations.

Most of the semiconductor firms located in Silicon Valley were founded as "spin-offs" from existing semiconductor "parent" producers, like Fairchild. Employees left Fair-child in frustration at the financial policies of the parent which used much of the profits to feed into other less successful divisions of the company rather than reinvesting in new product and process technologies.

The advantages of locating in Silicon Valley took two basic forms, namely, enhanced access to, and communicati-on with customers and suppliers, and efficiencies in hiring and recruitment within the local labour market. Lacking extensive in-house training programs, start-firms in Silicon Valley were able rapidly to assemble research teams by hiring skilled and experienced engineers from the external local labour market, thereby avoiding the need to develop requisite skills and experience in-house.

Local access to customers and suppliers is especially important at the product-development stage of the manu-facturing process for small start-up firms that lack the global manufacturing and marketing capabilities of esta-blished producers. The ability to fill job vacancies by hiring experienced workers from the local labour market is one of the major advantages attracting start-up semi-conductor firms to Silicon valley. Semiconductor engi-neers in Silicon Valley have a higher level of interfirm worker mobility than do engineers employed elsewhere in the USA.

Semiconductor firms in Silicon Valley have also benefit-ted from the influx of immigrant labour to the region, that has helped to alleviate upward pressure on wages in low-skilled production jobs. During the 1960s and 1970s Asian and Hispanic women replaced white women as the predominant production workers in Silicon Valley.

Summarizing, Silicon valley became a major center for the computer and communications industries and provided semiconductor firms with local access to key equipmemt and materials suppliers. The clustering of semiconductor firms in Silicon Valley has allowed the realisation of significant economies of agglomeration in labour-market processes.

Recentely, Audretsch and Feldman (1996) have shown that in the semiconductor industry 84 of the 172 innovations recorded, or 48.8%, are concentrated in California and an additional 10% are recorded in Massachusetts. Thus, these two states account for over one half of all the innovations in the semiconductor industry. At the same time, innovations in the semiconductor industry account for 8.6% of all the innovations in California, while in Massachusetts this was nearly 4.7%.

With respect to the reason why innovations tend to cluster spatially more in some industries than in other industries, both authors argue that innovative activity will be more geographically concentrated in industries where production is also geographically concentrated. The key determinant of the extent to which the location of production is geographically concentrated is the relative importance of new economic knowledge in the industry. Industries in which knowledge spillovers are more prevalent, that is where industry R&D, university research and skilled labour are the most important, have a greater propensity for innovative activity to cluster than industries where knowledge externalities are less important.

3.4. *Bifurcated system of production in the USA*.

Although US semiconductor firms are "technology driven" focusing their best resources and expertise on the development of new technologies, they were less successful in addressing problems within the domain of production which became increasingly important since the mid-1960s.

The basic reason was that US semiconductor firms adopted a classic bifurcated manufacturing form, with one segment oriented toward innovation and new product development, the other focused on reducing the production costs of existing products.

The drive to lower production costs centered on two key strategies:
1) The exploitation of product-specific economies of scale through high-volume production of standard products. Firms seek to establish a stable and routine production procedure that minimizes product and process variation in order to preserve a high-yield production process.

2) In an attempt to reduce labour costs by relocating assembly and other routinized activities to selected low-wage sites, firms adopted a classic tripartite spatial and international division of labour comprising:
a) centers of innovation and product development located within major high-technology complexes, like Silicon Valley;
b) routinized high-volume fabrication facilities located at dispersed low-wage sites outside the major metropolitan areas in the USA, and
c) labour-intensive assembly operations at low-wage locations offshore, especially in Southeast Asia.

The locational dispersal of routinized assembly activities was in part a response to rising land and labour costs and to associated labour shortages in Silicon Valley. Semiconductor firms were drawn to supplies of nonunion labour outside of the established centers of the Manufacturing Belt. New immigrants and ethnic minorities were the primary source of production workers.

This emergent spatial and international division of labour adopted by the US semiconductor industry was borrowed from the best practice in other sectors of mass production, such as automobiles, consumer appliances and textiles.

However, the commitment to standardized production and the organizational separation of production and innovation generated persistent problems of low production yields and fluctuating levels of capacity utilization. The rapid pace of technological change intensified these problems.

The knowledge and technology to compete in ASIC and ASSP markets is now rapidly diffusing throughout the world. To remain competitive in the long run US firms must attain international standards of production performance and accelerate their rate of product and process technology development. The challenge is to establish production forms that permit high-quality production under continuous innovation.

At present the general tendency among US firms is to deemphasize commodity products on which competition from Japan and South Korea is strongest, in favor of high-integration, design-intensive products produced with advanced design tools and flexible manufacturing technologies.

This shift away from commodity products has provided some immediate relief from intense price competition and has helped to bolster the profitability of US merchant firms. However, design-intensive products do not provide a place to hide from global competition.

Another recent trend in the industry is that expensive wafer fabrication ("front-end") is increasingly performed by foundries for another microchip supplier.
"Back-end" assembly and test operations are also outsourced. A new type of advanced chip supplier is the design-focused fabless house which does not produce wafers.

3.5. *Market strategies*.

In the semiconductor industry firms qua time profile of market shares follow one of three distinct strategies in respect of their timing of entry into each new generation of products:
(1) to enter early and the market share begins from unity and falls monotonically;
(2) to follow the leader after some lapse of time and the share profile first falls and then rises;
(3) to enter late with a monotonically rising share profile.

Due to successive entry by other firms the market share of the leader declines steadily for a given product and eventually becomes zero because he switches to a higher quality. This strategy has been called *cream-skimming*.

Intel has used a "cream-skimming" rather than a forward pricing strategy, whereby it introduces a product early but at a high price and withdraws the product after other firms begin marketing the product at lower prices.

Texas Instruments is a highly efficient producer and is known for its marketing strategy of undercutting competitors' prices to capture a greater market share.

Advanced Micro Devices (AMD) is known as second source producer or imitator and enters late into a given generation and tries to stay until the end.

***3.6. Cost-price relation*.**

Technological progress in the production of memory chips leads to generations with increased information storage capacity (taken as product innovation) and to production processes characterized by smaller design rules (taken as process innovations).

A remarkable characteristic of chips in general is the strong and regular price reduction for chips of a given generation ascribed to learning by doing.

At the beginning of the product cycle of a given generation the price is very high, but it quickly falls to the level where it becomes competitive with the previous generation in terms of per bit price.
E.g., for a 16K EPROM to compete effectively with a 8K

EPROM it is sufficient for the price not to be higher than twice that of the 8K device.

Learning in semiconductors takes the form of increasing yields, meaning rising output, as experience accumulates. Average costs fall at about the rate that output rises. However, prices fall at the rate that output increases times the inverse demand elasticity (which is approximately -1.5).
With average costs falling faster than prices, the price path in a competitive market must involve prices below average cost in the early part of the product life, with prices above average cost in the latter part.

With respect to the evolution of the per-bit cost, initially higher capacity devices may have a higher per-bit cost because of their lower initial yield, but once the firm has learned, higher capacity devices have a lower per-bit cost. Thereafter, the only way to reduce the per-bit cost is to increase memory capacity.

The per-bit cost of a chip, after the firm has learned, depends basically on the design rule. The design rule is a rough measure of the state of the art in Metal Oxide on Silicon (MOS) process technology. It indicates the typical size of the lithographic patterns of the chip.

Firms may not immediately adopt the newest process available because of the substantial cost of re-equiping production facilities.
Competition among firms pushes them to adopt processes with smaller and smaller design rules.

Firms without sufficient experience with an old process should not immediately adopt the smallest design rule available because a rather low initial yield would be achieved and learning would take a very long time.

Flamm (1990) mentions that there is widespread speculation that memory pricing in the future would follow the "bai-rule" rather than the "pi-rule".

The pi-rule refers to the fact that historically DRAM prices for each generation of chip had tended to decline asymptotically toward the $3 level (pi = 3.14) as mass production of that generation peaked.

A new generation of chip was introduced every 3 years which quadruppled the number of bits on a chip, resulting in 1/4 of the initial cost.
This amounted to a 75% cost reduction every 3 years, or annually to a decline of 36%, estimated on the basis of actual historical data.

The bai-rule (meaning doubling) suggests that every new

**generation of chips (quadruppling the number of bits) will double in price as mass production peaks.
This means a 50% cost reduction in bits every 3 years, for an annual decline of about 20%, or about 50% less than under the pi-rule.**

**This change in pricing rules would have implications for the downstream computerindustry. As computer demand is quite sensitive to computer price, a change from the pi-rule to the bai-rule for chips will result in diminished growth of computer demand.
It has been estimated by Flamm that the *reduced* long-run rate of *decline* in memory cost could *reduce* the demand growth for computers due solely to computing power from 5.5% a year under the pi-rule to 3% a year under the bai-rule, with obvious deleterious effects for computer hardware and software producers.**

**Note that the elasticity of computer demand with respect to semiconductor prices is approximately equal to the product of the elasticity of computer demand with respect to computer price (-1,5), times the cost share of semiconductors in computer cost (0,1).
Therefore: -0,15 times -36% results in 5.5% for the pi-rule and -0,15 times -20% results in 3% for the bai-rule.**

However, diminished industry growth is not the worst possible scenario for downstream users. They may be left disadvantaged relative to their vertically integrated competitors by the possibility of differential access to chips; they may have difficulties in obtaining the very latest high-performance chips from their Japanese suppliers.

3.7. *Technical versus economic barriers.*

**It has been difficult to predict when - or if - the stream of creative improvements will dry up.
Nevertheless, the economic consequences of approaching technical barriers will be felt before the barriers themselves are reached. E.g., the costs or achieving higher levels of chip performance rise very rapidly as the limits of a manufacturing technology are approached and then surpassed. Next figure illustrates this point.**

Technology barriers, T_1 and T_2, are where minute increases in chip performance can be achieved only at a huge cost. Economic barriers are encountered well before the technological ones. These occur where increasing costs may drive prices beyond the maximum price buyers are willing to pay, (at E_1 and E_2), causing the market to stagnate before the actual barriers are encountered.

Eventually, as a new manufacturing technology takes hold, the costs of fabricating chips begin to decline. At this

point, the industry has jumped from a cost-performance curve associated with the old technology to a new curve for the new process.
In effect, the breakthrough from one manufacturing technology to another forces the cost curve to bend downward, pushing technical limits farther out.
When this happens, higher levels of performance are obtainable, shifting the barriers to E_2 and T_2, without an increase in cost prompting buyers to replace older equipment.

This is important in the electronics industry, because products seldom wear out before becoming obsolete.
The barriers now being approaced are so high that getting beyond them will probably cause more far-reaching changes than did previous cycles of this kind.

The fact that factories cost so much as $1 billion is one piece of evidence that formidable technical barriers are close. However, the fear that the barriers might be unsurmountable, bringing the industry to a halt, seems to be unfounded. Rather the prices of semiconductors may increase and the rate of change in the industry may slow.

3.8. *Recessions.*

The semiconductor industry seems to go through a recession roughly every four years: in 1977, 1981, 1985, 1990-91 and 1995-1996.

With each cyclical downturn, semiconductor companies have been forced to make painful adjustments.
US companies dealt with downturns by cutting variable costs through laying off workers and cutting back on new capital investments.
In Japan the established practice of lifetime employment precluded lay-offs of large segments of the work force.
Thanks to deep financial pockets Japanese corporations were able to continue to invest heavily in new plant facilities.
Thus differences in labour and capital markets led to different corporate responses to recession in the US and Japan.

Moreover, vertically integrated, diversified Japanese companies utilized the built-in advantages of cross-subsidization out of profits earned by the sale of downstream consumer electronics products, such as video cassette recorders, which had a natural stabilizing effect during demand downturns.

A lesson learned by both the Americans and the Japanese during recessions was that the products embodying older technology tend to be the most vulnerable. Wherever possible, they tried to roll back manufacturing capacity in older products and to push aggressively ahead in products incorporating newer technology.

To make this move, attention turned to the advantages of joining forces with well-chosen corporate partners. American and Japanese firms began to see strategic alliances as a practical, countercyclical option. Below in par. 8 this phenomenon will be discussed more deeply.

4. Causes of decline in US competitiveness.

Of great importance in achieving technology and market leadership by Japan were differences in the structure of manufacturing systems in the USA and Japan.

Much of the loss of market share experienced by US high-technology firms during the 1980s derived not from a shortage of innovative capability, but from notoriously poor production yields, low production quality and fluctuating production capacity. These production problems arose in part from a fundamental tension between the drive to reduce costs on existing products and pressures to introduce new products and production processes.

Throughout the 1960s and 1970s, as explained above, US semiconductor firms maintained a bifurcated manufacturing system: one segment was oriented toward technological development and problems of innovation, whereas the other segment was focused on production and problems of production cost.

At the root of the problem lay a narrow conception of technological change. There was a tendency to view rapid technological change as almost exclusively a problem of innovation, i.e., to develop the next generation, while the actual production was carried out with little regard to the rapid technological change. Production and assembly functions were optimized for the low-cost manufacture of existing products rather than for manufacturing under conditions of rapid technological change.

As the design of new devices proceeded with insufficient input from production engineers concerning the possibility of achieving high yields on different product technologies, the organizational separation of technology development and production generated serious problems of "manufacturability".

Moreover, in response to rising land and labour costs and to associated labour shortages in Silicon Valley, a locational dispersal of routinized assembly activities took place. Routinized high-volume fabrication facilities were located at dispersed low-wage sites outside the major metropolitan areas in the USA, and labour-intensive assembly operations at low-wage locations offshore. While R&D and innovation remained clustered in core locations,

production and assembly tasks were shifted to dispersed low-cost locations in the US and offshore. However, under conditions of rapid technological change, the geographical separation of production and innovation generated serious difficulties in transferring new technologies from the laboratory to the factory floor.

Therefore, the organizational and geographical separation of technology development and production undermined the ability of US firms to codevelop both new products and new production capability.
Hence, during the 1960s and 1970s US semiconductor firms experienced high levels of instability in production, the cost of which were also passed on to equipment and material suppliers, thereby undermining the ability of suppliers to finance the development of next-generation manufacturing technologies.
As long as US firms maintained a technological advantage over their international rivals, these production difficulties primarily affected profit margins rather than market share.

The Japanese challenge was aimed at the weakest link in the US semiconductor industry, namely, production. Japan's rapid penetration of advanced integrated-circuit product markets was the result of a complex of factors, including low capital costs, a protected domestic market, and a willingness at times to sell below production cost in order to capture market share.
Underlying much of the success of Japanese firms was a close integration of technology development and production activities.
Japanese firms were committed to production as opposed to the tendency in the USA to accord higher priority to product technology.

Japanese firms tended to break with the bifurcated manufacturing forms typical in the USA. The Japanese commitment to device performance and technological sophistication was balanced by a concern for the manufacturability of products and the development of product and process technologies that allowed for high yields in production.

This involved the use of conservative circuit designs, scaling up from existing technology wherever possible to minimize device failure. Most US producers employed more complex circuit designs encountering serious yield problems.

Japanese firms captured important first-mover advantages in 64K, 256K and 1M DRAM devices. They were further down the learning curve and had fine-tuned the fabrication line to eliminate many sources of device-failure. The high yields by Japanese firms reflected quality control and the investment in production automation.

Throughout the 1980s, Japanese producers made substantial investments in automated production and assembly equipment, chemical purification, clean-room technology, process control and the development of work practices to eliminate device failure.

Close relations between semiconductor firms and equipment suppliers were another characteristic of semiconductor manufacturing in Japan that contributed to the Japanese success in DRAMs.

Relations between US semiconductor firms and equipment suppliers were often strained. Rather than developing long-term partnership agreements with equipment suppliers, US semiconductor firms switched among many competing firms in a search for the most advanced technology.

In addition, they transferred much of the cost of fluctuating demand to their equipment suppliers in the form of canceled or reduced orders for capital equipment. Quick to double orders in boom times, device makers moved even faster to cancel during the bust.

By contrast, Japanese producers formed strong partnerships with equipment suppliers, thereby facilitating investments in new equipment technologies and supporting the emergence of a strong equipment industry.

As the costs of new equipment technology increased, it became increasingly difficult for small US equipment manufacturers to compete, resulting in increasing Japanese dominance in equipment manufacturing.

Between 1983 and 1989, the US share of the worldwide market for wafer fabrication equipment declined from 62% to 41%, while Japanese firms increased their market share from 28% to 48%. In 1979, 9 of the top 10 semiconductor equipment manufacturers in the world were US firms; in 1989, only 4 US firms ranked in the top 10.

Two sets of additional events helped to secure greater market share for Japanese firms.

First, the large integrated organizational structure of Japanese semiconductor firms placed them in a stronger position for dealing with the recession of the mid 1980s. During this period of declining sales and rapid price reductions, both US and Japanese firms were selling below manufacturing cost.

It is estimated that during this period Japanese semiconductor firms suffered operating losses of approximately $4 billion. They were willing to do so in order to achieve the long-term goal of increasing market share within the USA. From 1983 onward, investments in new equipment

and facilities by Japanese firms exceeded those of US merchant producers, i.e. as a percentage of semiconductor sales twice those of US merchant firms.

Second, Japanese firms sold within a relatively protected domestic market and at higher prices than in the USA. Throughout the 1960s and 1970s, US firms were prevented from establishing wholly owned subsidiaries in Japan and this has limited the ability of the latter to gain substantial market share. While dominating their domestic market, Japanese firms have expanded their capability to manufacture advanced semiconductors in the USA. During the mid-1980s, all of the major Japanese semiconductor firms opened fabrication facilities in the USA, primarily for the production of DRAM devices.

In 1991 US firms supply approximately 14% of the Japanese market, while Japanese firms hold 22% of the US market. The low levels of sales of US firms in Japan are especially significant as the Japanese market for DRAMs and other advanced integrated-circuit devices has experienced rapid growth. By 1991 Japanese firms are the largest consumers of integrated circuits in the world; that is 38% of the worldwide market.

Due to a slump in semiconductor sales in 1974-75, US firms reduced dramatically their capital investment in new production facilities. When demand for semiconductors began to increase in 1977-78, shortages of production capacity rapidly emerged. Facing lengthy delivery delays, many US customers turned to Japanese firms as a source of supply.

The principal lesson for US merchant semiconductor producers to be learnt from the events of the late 1970s was the need to avoid a shortage of fabrication capacity. By investing in new production capacity US firms expected to recapture in 64K and 256K DRAMs the market share they had lost in 16k devices.

In response to competition from Japan, from the mid-1980s onward, the majority of US semiconductor firms initiated a major restructuring of their manufacturing operations in order to increase yields and improve production quality.

Much of the attention of US semiconductor firms is now focused not in the research laboratory but on the factory floor; the ability to stabilize new technologies in production and then to ramp up rapidly to high-yield production is central to the process of continuous innovation. Increased emphasis is placed on sources of innovation within the manufacturing system, that is, on the development of new technologies, work practices, and product ideas.

It is realised in the US semiconductor industry that the dynamics of innovation is not simply a matter of technology development. Innovation also involves the simultaneous development of new work practices, new markets and new uses for these technologies.

The present attempts of US semiconductor firms to reintegrate and recentralize manufacturing systems around a core of ongoing innovation have an important implication for the geography of production: locational decisions are now driven not by factor input costs but by issues of communication and learning.
At the same time, this restructuring has involved closer and more collaborative relations between semiconductor firms and their customers, subcontractors, and equipment suppliers.

These actions have substantially improved manufacturing performance in the USA. While the yields of Japanese semiconductor firms remain somewhat higher than those of their US competitors, the gap has substantially narrowed. Product defects in the US declined from an average of 170-190 parts-per-million in 1986 to an average of 50-60 parts-per-million in 1990. Probe yields of US firms increased from 60% in 1986 to 84% in 1991. During the same period, yields achieved by Japanese firms increased from 75% to 93%, thus narrowing the difference in yields from 15% in 1986 to 9% in 1991.
This reduction in the yield differential enhanced the ability of US firms to compete with Japanese producers during the late 1980s.

***5. Global competition*.**

The DRAM market has become the battlefield for the product development of commodity chips. This market has seen a dramatic change is its structure starting at the end of the 1970s.

The US firms have dominated the market since its inception at the beginning of 1970, in particular through INTEL, the inventor of the DRAM. Intel had the leadership in product innovation for the first three generations.

In the early 1970s the US enjoyed a 70% share in the world market, which was less than $5 billion.
Once large Japanese companies had acquired the necessary process technology and production experience, they entered into DRAM production and invested heavily in capacity. In the late 1970s the US was losing its lead and were overtaken by Japanese firms in 1986.
Because of the intensity of price competition most of the US firms (including INTEL) abandoned the DRAM production. Since then the DRAM market has been dominated by Japanese companies.

Summarizing, two key intersecting dimensions of economic globalisation triggered far-reaching changes in the US semiconductor industry:
1) The erosion of US technological and market leadership and the emergence of advanced semiconductor-manufacturing capability in Japan, South Korea and several Western European countries.
2) A rapid expansion of non-US markets for semiconductor products.

A critical factor in the manufacture of leading-edge circuits is the timely availability of the best process *equipment*. The SME (Semiconductor Manufacturing Equip-ment) industry emerged in the 1970s and was also at first US dominated.

Parallel to the declining competitiveness in chips have been concerns about the health of the US semiconductor manufacturing *equipment* industry, which saw its world market share decline from 75% in 1980 to 50% in 1992, while the Japanese share rose from 18% in 1980 to 43% in 1992. Today the equipment business is about $10 billion annually.

US chip makers feared to become dependent on Japanese suppliers of chip-making equipment. Such concerns were heightened by Japanese acquisitions of US chip-making firms and by withholding state-of-the-art technology by Japanese firms. In reality, the decline of the US share in this market was due to the decline of the US as a location of chip production and the exit of US firms from high-volume DRAM production.

Because Japanese chip producers were part of larger systems houses they were getting access to leading-edge products before their foreign competitors. This has put US and other foreign systems houses at a competitive disadvantage.

In 1980, Japan accounted for about 30% of the memory market. By 1989 they accounted for more than 80%. Thus, during this period, the US moved from being the dominant producer in both memory and more sophisticated chips to being dominant only in the latter.

The rapid emergence of the Japanse industry as a world-class competitor was a planned result of a concerted policy effort of the Japanese government employing a variety of policy tools. Without the active government policy in the 1970s the Japanese industry could not have climbed to international prominence.

The Japanese government principally through MITI pursued two sets of policies:

* Controlled access, i.e. controlling the links between the Japanese market and international markets by limiting foreign competition in the domestic market through a closure of domestic markets to imports, reinforcing "buy Japan" policies, acquiring foreign technology and know-how in the form of patents, licenses and expertise, and initiating barriers to foreign direct investment.
* Manipulating the domestic firms to stimulate expansion. The government reduced the cost of the riskiest and least predictable phase of the R&D process through support of a joint research venture, the Very Large Scale Integration (VSLI) project which encouraged the diffusion of the generic technologies with wide application and common product techniques.

Therefore, a classic strategy of infant-industry protection and promotion in Japan created a competitive Japanese industry. The Japanese government provided R&D subsides and home-market protection encouraging predatory low export pricing. Barriers to both imports and foreign direct investment by American companies were a key ingredient of Japan’s policy. The existence of dynamic economies of scale has made import protection a policy of export promotion.

It was expected that in the long run, with the exit of foreign competitors and taking the lion’s share of the market, prices could be increased so that rents could be collected to offset the initial costs of predation by collusion whereby Japanese companies are cooperating to cut back supply on foreign markets.

With the growth of the protected Japanese market and the "success" of the Japanese challenge began a 15-year struggle by the USA to open the Japanese market and to counteract predatory Japanese pricing. In this respect Baldwin and Krugman contend that this "success" was actually a net loss to the Japanese economy. It raised Japanese prices, hurting consumers, without generating compensating producer gains. The policy was thus not a successful beggar-my-neighbor one, or more accurately it beggared Japan’s neighbor only at the cost of beggaring Japan as well.

Captive producers in the USA were cautious about initiating any trade dispute with Japan. Not only did IBM have substantial investments in Japan, but as a net purchaser it had little interest in policies that might result in higher prices.
Merchant firms like Motorola wanted to diminish Japanese competition and to raise the price of their output.

For years, the Europeans worried about American domination of the computer industry.
Throughout the 1970s European systems companies grew

increasingly dependent on chips produced by US companies. However, this posed no threat to the European companies because the intense competition among US merchant semiconductor manufacturers meant a continuous stream of new leading-edge products with prices dropping rapidly.
Today Europe must also reckon with Japan (and Asia more generally). Europe has fallen into third place in the global electronics competition, suffering dependency on not just one but two competitive regions.

In the last few years since 1992 the US has recovered overall market share and took back the lead in terms of where chips are produced with 43% share versus 41% for Japan.

6. *The Semiconductor Trade Agreements.*

6.1. *Events leading up to the Trade Agreement (SCTA) of 1986*.

In 1977 several merchant firms formed together the Semiconductor Industry Association (SIA) to promote common interests. The SIA's primary function is to provide a forum for industry leaders to reach a consensus on issues of joint concern and to oversee any political action based on whatever consensus emerged, and coordinates the industry's political strategy.

Initially the SIA lacked the stature to accomplish policy actions. In 1982 the SIA broadened its membership to include vertically-integrated captive producers, and this exerted a moderating influence on trade policy.

Although the semiconductor consumers were organized in the American Electronics Association (AEA), they felt that their interests were not being met by the AEA. Therefore, early 1989 three major computer systems firms formed the Computer Systems Policy Project (CSPP) to function as a counterpart to the SIA and to facilitate and coordinate the industry's positions on public policy and to develop policy recommendations relating to the competitive position of the computer manufacturers.

As a result of this coalition of semiconductor consumers, US trade negotiators no longer faced the single voice of the SIA on what should determine US semiconductor trade policy.

The demands by US semiconductor producers for trade relief were strongly associated with the industry recessions.
During the 1974-75 recession, there was no significant pressure to limit imports or take other trade-related actions in the US. But in the early 1980s competition entered a new phase as Japanese companies attacked the

international market.
During the 1981 recession steeply falling prices for semiconductors along with the early Japanese capture of 70% of the market for 64K DRAMs, triggered a political response by US industry.

However, the regular trips by representatives of the semiconductor industry to Washington got a cool reception there.
This may be traced to several things:
*** The Reagan administration had a rhetorical commitment to free trade and confronting US producers with a rude shock of foreign competition and a healthy dose of competition was no cause for alarm.**
*** The US semiconductor industry was hardly on its deathbed: the merchant industry was still profitable.**

In 1985 the market situation changed dramatically as the electronics industry throughout the world entered a deep recession that lasted until the middle of 1987. In an effort to maintain sales volume, both US and Japanese producers cut prices which for 64 DRAMs fell from $4.00 in 1984 to $1.00 in 1985.

The industry recession in 1985 was extremely severe and concentrated on the memory chip market. It pushed virtually every US producer out of the DRAM market. Only TI and Micron remained in the merchant DRAM market, although IBM and AT&T continued captive production. In the face of huge operating losses many US merchant semiconductor firms withdrew from the DRAM market in 1985.

The root cause of the contraction of the DRAM market in 1985 was a rapid price decline in the face of slumping demand with unprecedented losses for US merchant semiconductor firms.
Imports were not a direct cause of the industry recession: Japanese penetration actually fell in the two years after 1984.

US firms faced several obstacles beyond their control and these factors contributed to an exodus of US firms from the DRAM market:
1) high cost of capital compared with Japan;
2) substantial appreciation of the US dollar in the early 1980s;
3) the US industry was unprepared for a change in process technology away from the standard N-channel metal oxide semiconductor to complementary metal oxide semiconductor favored by Japan;
4) with respect to quality, Japanese chips showed fewer defects. Although US producers heatedly denied this, the perception of a quality gap shifted demand to Japanese firms.

In 1985 the famous cross-over occurred: the global share of the Japanese companies in the semiconductor market jumped ahead of that of the US companies. The trending down of the American market share and the going up of Japan's may be called the X-curve. By the end of the decade, Japanese firms held in excess of 70% of the world market for DRAM integrated circuits.

In 1985 the descent of the semiconductor industry to Washington received a much warmer welcome than in 1982. In 1982, the industry was split on filing an antidumping petition and faced resistance by the Administration on any Section 301 action; in 1985, its course of action has been largely welcomed by the government, having to do with the appreciation of the US dollar and the large trade deficit.

US firms complained about two issues: dumping by Japanese firms and a lack of access to the Japanese market.
US semiconductor firms claimed that Japanese firms should be penalized for their unfair practices of dumping 64K DRAMs at less than fair value, with fair value being defined as the price required to gain a normal rate of return from the production and sale of DRAM devices. The US blamed the lack of real market access squarely on the Japanese government, so that a Section 301 action of the Trade Act of 1974 against Japan was prepared in order to open the Japanese market in such a way that "the cash registers ring".

The administration formulated a two-pronged policy:
*** An exchange rate policy aimed at reducing the foreign exchange value of the dollar;**
*** Market-opening initiatives aimed at diverting protectionist pressures by focusing on measures to open up the Japanese market rather than closing the US market.**
Between June and December 1985 a series of antidumping and unfair trade practice suits have been filed in the US, charging Japanese firms with dumping 64K DRAM chips in mid-1986.

The SIA based its demands on the now familiar "market share shuffle", in which Washington cites low share in Japan as proof of a rigged economy. The argument worked out this way: the US industry had 83% of sales in its home market, 55% in the European market, 47% in the rest of the world, but only 11% in Japan. This would be a strong suggestion that market barriers exist in Japan, although no specific impediment to imports could be identified.

There was a lot wrong with this argument. The 11% figure was a deliberate distortion. If captive production (that is chips produced by semiconductor firms for own use) was excluded from the count, American firms already had about

a 20% share of the Japanese market in 1985. This was about the same as the Japanese share of the American market at the time. When captive production was not excluded from the US calculation, Japanes firms had a 12.3% share of the American market in 1984, 10.6% share in 1985 and only a 9.8% share in 1986.

Another problem with the SIA's position was its assertion that the Japanese government "unfairly" subsidized its semiconductor firms, while in actuality US government assistance for private semiconductor research and development was about 10 times Japan's in 1986. There were also severe quality and delivery problems with many of the American chip products. The failure rate of American chips was six times the rate of Japanese semiconductors.

The conflict between the US and Japanese industries came to a head in June 1985, when the SIA submitted a Section 301 petition against unfair Japanese trading practices. Shortly thereafter, a US firm, Micron Technology, charged the Japanese with dumping 64K DRAMs. In August 1985, the Justice Department opened an antitrust investigation into possible predatory pricing by Hitachi. In September 1985, three more American firms filed dumping complaints against Japanese producers of EPROMs. In December 1985, the Commerce Department in an extraordinary move initiated a dumping case in 256K DRAMS.

The ITC found substantial evidence of sales of DRAMS and EPROMs at below Fair Market Value and tariffs were recommended on Japanese imports equal to the margin of dumping ranging from 10.9% to 35.3%. In June 1986 the ITC found that Japanese firms were selling DRAMs at a weighted average of 20.75% less than fair value.
As a result, tariffs equal to the calculated difference between the market price and costs could be imposed on Japanese imports.

However, in fact this should be an empty victory, due to the speed at which this industry evolves. The ruling should come into effect after the industry would have moved on to the next generation (256K). Therefore, there would be few imports on which to impose the dumping margins.

Although the Electronic Industry Association of Japan (EIAJ) and the SIA kept the international trade lawyers busy by filing counterbriefs to each other's briefs, in the end the pressures to move forward with a significant market-opening initiative against Japan triumphed.

In order to short-cut subsequent legal actions Japan moved to reach a bilateral settlement. The actual imposition of tariff penalties was avoided with the signing of the SemiConductor Trade Agreement (SCTA) on September 2,

1986. As the dumping complaints have been settled by the SCTA, later dumping cases involving 256K DRAM chips and EPROMs have been suspended.

Since 1985 the anticipated collapse of the US industry did not occur. In fact, the manufacturing performance of US firms has improved dramatically in the 1990s. Market share has stabilized and cycle-time for the development of new products and processes has been substantially reduced.

6.2. The contents of the SCTA.

The 1986 SCTA was a response to the US perception of unfair competition from Japan. It contained eight provisions.

1) The Japanese government would monitor costs and prices of chip exports from Japan to the US and other markets.

2) Japanese firms would submit cost and price data to MITI.

3) If dumping appeared to be occurring, the two governments would have two weeks to pursue consultations before proceeding with the case.

4) The Japanese government would try to prevent dumping by Japanese firms.

These four provisions effectively created a firm-specific price floor for semiconductors.

The other four provisions were aimed at increasing foreign firms’ access to the Japanese market.

5) The Japanese government would encourage Japanese producers and consumers to purchase more foreign chips. A secret side-letter to the Agreement called for increasing the foreign share to 20 percent.

6) The Japanese government would establish an organization in Japan to help foreign producers increase sales in Japan.

7) The Japanese government would promote long-term relationships between Japanese and foreign firms.

8) The Japanese government would ensure full and equitable access for foreign firms to patents generated by government-sponsored R&D.

Summarizing, the SCTA contained two main components:
1) It establishes an explict price floor for semiconductors intended to promote competition by halting predatory

pricing: this amounted to a voluntary export restraint (a VER) by Japan. Japan would provide the US with cost information necessary to calculate price floors for DRAMs and agreed not to sell products at prices below these values.
2) It contains provisions aimed at doubling the US market share in Japan by 1991 to counter the alleged market closure: this amounted to a voluntary import expansion by Japan (a VIE). Japan agreed to facilitate increased sales by US firms in Japan toward a 20% US share of the Japanese market by 1992.

Although its contents were widely known at the time, the letter remained officially secret. This secrecy allowed both sides to deny that they had carved up markets in a managed trade agreement, but the effect was asymmetric: Japan denied there was any explicit commitment about guaranteeing a market share, while the US held Japan accountable for such a commitment though it could not produce the text in public to support its position.

US negotiators interpreted the accord as a guarantee that Japan would increase its consumption of US semiconductors to the 20% level, while Japanese negotiators interpreted the figure as a goal that might or might not be met, depending on the demand for US semiconductors in Japan. Therefore, there was a fundamental misunderstanding about what was involved. Japan regarded the 20 percent figure as a target at which to aim, while the US considered it a firm commitment - and a minimum one - which the Japanese had promised to fulfill.

6.3. *Subsequent events.*
There were almost immediately problems. While the artifical controls drove up chip prices sharply in the US, some two to eight times in the initial months after the agreement before abating somewhat, the market distortions created an arbitrageur’s dream. Some of the arbitrageurs (more commonly known as smugglers) took advantage of the bargain basement prices in Japan, where the average chip cost at least $2 less than elsewhere, and flew hither and yon with satchels and suitcases stuffed with semiconductors. One bag of smuggled chips might save a savvy buyer from the US or Europe tens of thousands of dollars.

To implement the Agreement MITI did the only thing it could, (recall that no specific impediment to imports could be identifed so that Tokyo had no effective means of rectifying the situation) and established a production cartel issuing quarterly forecasts of chip demand and production. Amazingly, that was greeted by screams from the SIA that MITI was trying to create "artificial shortages".

However, initially, prices remained low and the US warned

Japan that it was not adhering to the Agreement.
In 1987 US firms accused Japan of violating the agreement by selling DRAMs at below fair value in third markets (primarily Taiwan and other Southeast Asian countries). The USA responded by imposing punitive duties on $300 million of Japanese exports to the USA.

In February 1987, MITI began issuing "requests" for production cutbacks which were met by the following month. But then it was too late. Oki Electric was lured into documenting sales at less than fair market value in Hong Kong.

The American Congress voted to retaliate for violations of the price floor agreement and the Reagan administration announced the imposition of 100 percent tariffs on $300 million on Japanese exports of power tools, computers, and TV sets to the US. Tariffs were deliberately not set on semiconductors themselves because they were essential to so many American businesses.

The retaliation had two apparent effects.
1) The US share of the Japanese market began to rise;
2) The prices of chips began to rise, probably related to anticipated trade policy actions by the US government. As a result, Japanese chips cost American computer manufacturers 30% to 40% more than before the SCTA. Personel computer prices shot up drastically in the late 1980s, almost destroying America’s competitiveness in this high-tech product area.

By the fall of 1987 the price increases were beginning to seriously hurt chip users, particularly the computer firms. The US government reversed course and asked MITI to abandon the price production controls and in November 1987 it partially removed the spring sanctions.

MITI complied but continued to impose strict restrictions under COCOM (the international agreement aimed at controlling the diffusion of sensitive technologies to the Soviet bloc). This had the effect of maintaining the system of administered prices. MITI continued to provide "opinions" to the Japanese firms as to their investment plans.

Even after MITI ended its guidance and the chip market began to weaken in 1989, Japanese producers implemented cutbacks in DRAM production to boost prices and they made excessive profits on global sales. These rents further improved the Japanese firms’ competitive position, not only in chips but potentially in downstream products such as computers and telecommunications equipment, through cross-subsidies. R&D expenditures in chips in Japan exceeded those in the US by $2 billion in 1988.

Coincident with the SCTA was increased activity by US firms to penetrate the Japanese market. This was accompanied by a plethora of tieups and joint activities between Japanese and US firms.
It is difficult to say how many of these were due to the SCTA and how many would have occurred anyway in response to business conditions.

By the SCTA's deadline in 1991, the market access target of 20% had not been met, so that in the summer of 1991, US and Japan entered a new round of negotiations on semiconductor trade. The US government was under mounting pressure from domestic producers to take a more aggressive stance in trade negotiations.

From the past it had become evident that when threatened with retaliatory tariffs, Japanese manufacturers are inclined to take steps to increase marginally imports of US semiconductors. However, at the same time there was little evidence of a fundamental restructuring of industrial practice among Japanese electronics firms, the majority of which continued to source semiconductors from domestic suppliers.

In August 1991 a second five-year agreement was signed between the USA and Japan, which endorsed the existing target of a 20% market share for USA producers by the end of 1992.
The agreement abandoned the flawed policy of price floors. However, Japanese firms were still required to collect production cost information to be provided to the US government on occasion of future dumping charges.

With price floors removed, the price of DRAMS fell substantially during 1991-92, driven down in large part by emergent South Korean producers.

In reaction to both trade agreements US semiconductor firms increased their share of the Japanese market from 8.6% in 1986 to 14.4% in the third quarter of 1991.
At the end of 1992 US market share reached 20.2%, resulting from a modest rise in the purchase of foreign semiconductors and from a shrinkage in the total market for semiconductors in Japan. US and Japanese firms were virtually tied for the lead in worldwide chip sales, with each accounting for 43% of the total.

The trade agreements were actually quite narrow in scope. While the market access provisions were generic, the antidumping provisions of the first SCTA affected only one segment of the entire semiconductor industry, i.e., DRAMs and to a lesser extent EPROMs.
The dumping provisions secured their immediate goal of forcing Japanese firms to raise prices on DRAMs. However, the consequences of this price increase were largely

negative for US firms.

There is widespread consensus that the price floor part of the SCTA was a mistake: it harmed non-Japanese downstream users, while transferring large rents to Japanese firms.
Since the imposed price floor did not take account of the learning-curve nature of this industry, this part of the Agreement almost surely did more harm to US industrial interests than it did to Japanese industrial interests. By the time prices began to rise, all of the major US manufacturers had already withdrawn from DRAM production. Rather than benefiting US firms, therefore, the high prices created windfall profits (estimated at $5 billion) for Japanese producers. Much of these profits were deployed to support an expanded program of R&D and capital investment that further undermined the competitive position of US firms.

Both antidumping and the market access issues illustrate how trade policy can be driven by a coalition of a few vocal firms. The bargaining stance taken by the US Trade representative (USTR) was the position held by the SIA and then the SIA & Computer Systems Policy Project (CSPP), which had effective veto power over any agreement. The trade negotiators themselves proved incapable of any independent conception of what sorts of policies would best serve the interests of the economy overall.

MITI played a key role in facilitating the reductions in output by Japanese semiconductor firms by closely monitoring demand and production conditions. Thus, one effect of the price floor provision of the SCTA was to increase MITI’s control over the Japanese economy. The revival of MITI is one of the unintended consequences of the US movement toward a system of managed trade.
In this respect US policy seems caught in a contradictory position, at one time during the mid-1970s asking for less involvement by MITI, and on another occasion in 1986 asking for more.

The agreement created a breathing space within which US firms could address their underlying problems of production quality, yields, and turnaround time on new products. Japan’s success in producing homogeneous DRAMs pushed US firms into product differentiated markets where they enjoy greater markups and face less direct competition.

In the 1990s US firms were positioned for further recovery. By emphasizing the rapid development and deployment of advanced design-intensive devices, US firms have avoided much of the intense price competition in high-volume commodity markets and have managed to

establish a leadership position in emerging product-lines such as mixed-signal devices and RISC microprocessors.

The stabilization of market share reflected a fundamental restructuring of the US semiconductor industry.
The first theme emerging is the increasing "Japanization" of US manufacturing systems, involving much closer cooperative ties among customers, producers and equipment suppliers and the creation of multidimensional product teams. The result has been a convergence of the manufacturing performance of US and Japanese firms.
The second change is the increasing integration and physical combination of technology development and production within US semiconductor firms allowing a more rapid deployment of new technologies and the achievement of enhanced yields in production.

For much of the 1980s, the restructuring of the US semiconductor industry was dominated less by changes in manufacturing practice than by the redeployment of resources away from DRAMs and other devices (where Japan is dominant) into value-added, more design-intensive product markets, such as microprocessors, mixed-signal devices and very fast logic devices.
This implies a search for markets in which the innovative capability of US firms in product design offsets Japanese leadership in high-volme manufacturing and process technology.

Much of the apparent improvement of US semiconductor and equipment firms in the past two years may be traced to the declining fortunes of the Japanese semiconductor producers. Domestic competition in Japan and entry by other Asia/Pacific producers have reduced the profitability of semiconductor memory chips, the Japanese strongest area.

According to reports in the US mass media, American chip manufacturers had lost interest in gaining a 20 percent share in Japan even before the semiconductor talks in 1986 opened. Due to the enormous amount of money being poured into research and development, more and more, Japanese and US chip makers were putting aside their past rivalry and forming cooperative alliances for self-defense, such as:
- **AT&T with NEC;**
- **Texas Instruments with Hitachi;**
- **Motorola with Toshiba;**
- **Sanyo with LSI Logic;**
- **Intel and Matsushita;**
- **Advanced micro devices and Sony.**

If relationships of this sort prosper, then at least one Japanese-American trade sore may have healed itself.
Few American chip companies want to jeopardise the

collaboration that they have established with Japan's electronic giants. The SIA quietly says that they will not press for reprisals if Japan fails to hit its 20% target.

Today the US semiconductor industry is more competitive and prosperous than it was before the SCTA. It now is the world's largest producer of semiconductors. America's renewed success in Japan has occurred because of private sector initiatives by US and Japanese companies to work together in strategic alliances and joint ventures and despite the US government's managed trade policies. In 1991 there were fewer than a dozen such partnerships between US and Japanese companies. In 1994, there were more than three dozen. US - Japanese joint ventures and strategic alliances are the principal reason not only for America regaining its role as the largest producer of semiconductors in the world, but also for America's increased market share in Japan.
In this sense it is ironic that Japanese and American businesses are seeking ways to co-exist and cooperate in high technology, despite the ups and downs in Japan-US political relations.

6.4. *Renewal of the SCTA?*

Until this very moment (mid July 1996) the achievements of the semiconductor trade policy of the USA have been limited according to the Americans. The 20% target represented a relatively modest market share. Even though this immediate goal has been met, there is little evidence of a structural change in trading relations according to the US. Therefore, additional aggressive intervention, ("cautious activism") by the US government is not unlikely.

In contrast to the Bush administration, which tried to win trade concessions by demanding reciprocity, the Clinton administration uses the principle of comparable access with market share as the yardstick by which the efficacy of its trading partners' market opening efforts are measured.

Since March 1995, US Ambassador to Japan Walter Mondale, US Trade Representative Mickey Kantor, Commerce Secretary Ronald Brown, (who was killed in a plain accident in April 1996 and has been succeeded by Kantor, while Kantor in his turn has been succeeded by Charlene Barshefsky), Vice Presicent Al Gore, Secretary of State Warren Christopher, and Presicent Clinton have all issued statements supporting extension of the SCTA. The Presisent said that "the current agreement held great potential for further progress and that the US would continue to actively pursue its renewal."

The Clinton Administration believes that the recent success of America’s semiconductor industry is the result of the SCTA. However, it is not. The US semiconductor industry is successful today because it sought joint ventures with Japanese firms which gave American firms access to the Japanese market.

It is hard to picture a US industry less in need of government assistance. The US semiconductor industry is made up of companies with strong earnings and a bright future, not companies that are in need of assistance from the federal government in the form of an affirmative action program to help them sell products to Japan. Given the last decade’s massive changes, US producers would seem to have little to complain about regarding access to Japan or, indeed, any other country in the world. With high prices and record profits, the American companies would seem to have nothing to complain about regarding dumping. These two facts alone remove the entire raison d’être for the renewal of the semiconductor agreement. The best rationale supporters of renewal offer is that an extension is somehow necessary to preserve and consolidate past gains by the US industry, what might be dubbed the "chicken soup" argument (as in: it could not hurt).

In 1996 the USTR is replaying the old 1986 mantra. In calling for renewal of the SCTA the Clinton Administration and the SIA point out there is a gap between the US market share in Japan and the US market share in the rest of the world outside Japan. The US has nearly 50% of the world market outside of Japan (48% to be exact) and only 17.9% of the market inside Japan. This gap, the SIA argues, shows that the USA market share in Japan is less than what it should be if the Japanese market were fully open. Therefore, the SCTA which is set to expire on July 31, 1996, should be extended to address the continuing barriers in the Japanese semiconductor market.

However, the Japanese argue that this market share gap is misleading, showing nothing about the openness of the Japanese semiconductor market. The relative high percentage of 48% results form the fact that the US industry has a very large share of the US market. American chip manufacfurers are the dominant suppliers to semiconductor users in the US, which causes the US share of the world outside of Japan to increase significantly. Not surprisingly, Japan has a virtually identical share of the world market outside the US, 47%, again, principally because Japanese chipmakers have a large share of their home market. And the Japanese share in the US, 23%, is roughly comparable to the US market share in Japan, 17.9%. Thus, the infamous market share gap is basically the same for both countries.

A variation on the market share gap argument is that the SIA looks to the neutral markets outside Japan, i.e., Asia and Europe. There, taken together, the US has approximately 40% market share and the SIA compares this to its 17.9% market share in Japan to conclude that the Japanese market is not fully open.

Again this argument is misleading because Europe is not a neutral market. In the 1960s and 1970s, the Europeans focused on the systems end of the marekt and left much of the manufacturing of semiconductors to others, inviting American chipmakers to set up production facilities in Europe while setting up high tariff walls against foreign imported chips. For this historical reason, American semiconductor firms have long held a high market share in Europe. Americans have a 45% market share in Europe, while Japanese companies have a 20% share.

The US position suggests fixing the current 30% level as the floor and measuring ongoing "progress" to infinitely expand foreign market share in Japan.

Moreover, at this moment, the SIA ignores its earlier assertion, made in 1990, that the 20% market share contained in the SCTA was a threshold after which market forces should be permitted to take over and operate. But now, with foreign market share at nearly 30%, the SIA wants even more, arguing that its market share would be much higher.

Therefore, Japanese trade negotiators strongly resist market share goals as a measure of trade performance. Especially in conditions of recession they do not want to be confronted with import obligations. They seek to shift attention to less tangible indicators of the trading relationships, such as the strength of partnerships between US and Japanese firms.

Moreover, it is widely believed in Japan that Japan had overtaken the US in advanced technology. It was so difficult to increase the share of US computer chips in the Japanese market to 20 percent because Japanese companies did not like to be forced to buy "second-rate" US semiconductors instead of "first-rate" Japanese products.

Now the government of Japan proposes a new multilateral forum to replace the current US-Japan arrangement, which will expire on 31 July 1996. The Japanese market is now fully open; the foreign market share in Japan for semiconductors has more than tripled over the past ten years from 9% in 1986 to more than 30% today. The market for semiconductors has become global. There has been dramatic growth in international business partnerships and a tremendous expansion of the Asian semiconductor

industry. Japanese firms now work side by side with their foreign partners in all aspects of semiconductor development, production and marketing. Given the borderless nature of many operations in this industry, the era in which it made sense to distinguish the "nationality" of a semiconductor chip, has long since passed.
A multilateral approach is essential, as a bilateral agreement can no longer adequately address the evolving requirements of a dynamic, rapidly changing global industry. The Japanese government is proposing the formation of a "Global Governmental Forum on the Semiconductor Industry", with the US, Japan and the European Union as founding members.

The overall conclusion is that it is an unfortunate fact of life that legislation often requires one step backward for every two steps forward. The Amercian insistence on renewal of the SCTA is one such instance, and free traders should accept that political reality and not allow the best to be the enemy of the better.

Rather than rely on managing and regulating international trade from Washington and Tokyo, the Clinton Administration would do well to step aside and allow the SCTA to expire on its own accord. In its place is a solid foundation of private business partnerships that have made American companies more competitive and more profitable.

6.5. Evaluation of the SCTA: the VIE as a new form of managed trade.

Given the innovative nature of the SCTA and the obvious interest in applying this approach to other sectoral disputes, a careful evaluation is warranted.

1) Considerable dispute arose over the extent to which price floors were to be applied to sales in third-country markets. The SCTA was the first bilateral deal to explicitly involve monitoring of third-party markets. The USA announced sanctions against third-country dumping applied to Japan.
In reaction, the Japanese government through MITI kept pressure ("provided guidance") on firms to hold production and investment in new capacity down and this brought third-country prices up to US levels.

2) A point overlooked by the Americans was that Japanese suppliers choose to cooperate rather than compete. Since the SCTA Japanese DRAM manufacturers moved from competing for market share to market sharing. Japanese chip producers were collectively cutting back production to achieve high price stabilization. In the DRAM market they established a temporary price floor benefiting all

Japanese suppliers which earned bubble profits of $4 billion between 1987 and 1991. Whether cause or effect of the SCTA, at the very least the SCTA played a catalytic role in this move toward production coordination.
In contrast, in the EPROM market, where non-Japanese suppliers held 40% of het market, there was no effective cooperation among the Japanese suppliers.

Although there is no direct evidence to examine the credibility of allegations of this collusive behavior, fact is that in early 1988 spot prices for DRAMs in the US soared to historically unprecedented levels and the US computer industry was plunged into crisis; producers scrambled for supplies of critical memory chips.

3) In the SCTA's antidumping provisions the Japanese agreed to increase their prices, in return of which the USA dropped their dumping charges.
However, the American computer industry strongly opposed the antidumping provisions because it had been harmed by the sharp runup in DRAM prices. Therefore, in DRAMs de SCTA's antidumping provisions actually made matters worse, by creating a price floor policy which made the US a high-cost production location. The SCTA has put downstream users of semiconductors at a competitive disadvantage.

Unfortunately a similar pattern of development appears to be occurring in liquid crystal displays (LCDs), a type of flat panel display.

In EPROMs the antidumping provisions were applied early enough to deter dumping and to encourage competition, while in the DRAM market they were applied late with the anticompetitive effect of encouraging cooperation among Japanese suppliers.

An alternative to antidumping duties could have been a countervailing US subsidy to offset the injury to US DRAM producers. But this was a nonstarter given the ideological and budgetary climate prevailing in the US in 1986.

4) The market access provisions are more controversial. The original SCTA was a departure in US trade policy. It sought to expand US access to a foreign high-technology product market, rather than reduce foreign access to the US market. It became the first US example of a voluntary import expansion (VIE) measure.

VIEs are designed to increase trade and competition in countries in which structural impediments limit access for foreign suppliers.

There is opposition to VIEs because they result in the

cartelization of markets; they increase prices by limiting competition; they are subject to capture by producer interests in the importing or exporting country; they increase the risks of retaliation if the targets are not met; they can create dangerous precedents that could come back to haunt the demandeur and they violate the principle of non-discrimination.

VIEs are second-best policy remedies because unimpeded market competition is the first-best approach, but may be superior to doing nothing.

Whether a VIE is globally welfare-enhancing comes down to whether the initial situation is distorted or not, and if it is, how.
i) If the foreign market is protected and a VIE is implemented on a nonpreferential basis among foreign suppliers, the VIE may be globally welfare-enhancing, although producers in the protected country will lose.
If one considers the pre-SCTA situation as a distorted one in which large Japanese firms used rents to cross-subsidize the chip production, the VIE is welfare enhancing from both a US and global standpoint, as well as for Japanese consumers.
ii) If the market is protected and the VIE is administered preferentially, it is possible that both the importing and the exporting countries as a whole may gain at the expense of third-country producers.
iii) If the market is initially undistorted, the VIE will reduce importing-country welfare and increase exporting-country welfare. In an undistorted market the VIE introduces a distortion, which benefits US and other non-Japanese chip firms, while reducing the welfare of consumers.

Therefore, the welfare impact of the SCTA comes down to whether the Japanese market was initially protected, and whether the agreement facilitated an anticompetitive cartel in semiconductors.

Clearly, by 1986 traditional border protection in Japan was minimal, so that the case for a VIE had to be made on the basis of private practices that discriminated against imports.
It may be argued that keiretsu links provide considerable scope for trade discrimination, having a well-known efficiency cost. However, this claim of keiretsu barriers has to be examined very carefully.
Firms that do not source from the most efficient suppliers will themselves be put at a competitive disadvantage. Since Japanese electronics firms do compete in world markets, this argument is incorrect or there are other barriers in the production system which generate rents for the electronics firms.

Therefore, there are a few criteria for deciding whether VIEs will enhance world economic welfare:
a) there is strong evidence of barriers to market access, even if a specific, tangible barrier cannot be identified;
b) foreign firms and products are demonstrably competitive;
c) the best option, that is removing the market-access barrier, is not available (e.g. improved antitrust enforcement);
d) the products in question are intermediate, not consumer, goods;
e) VIEs are implemented on an MFN basis.

Following Irwin (1994) several lessons emerge from the experience with the SCTA.

I) VIE import targets are arbitrary on several dimensions.
The particular commodities that come under the scope of a VIE are arbitrary. The broader the industrial aggregate chosen for an import target, the more arbitrary the VIE becomes by including different types of goods.
US competitors are not necessarily competitive in all product segments and not all those segments may be appropriate to the needs of the foreign market.

II) If explicit government restrictions are not apparent, one can never be sure whether hidden or informal barriers do in fact exist.

Low market shares alone cannot be accepted as prima facie evidence of discriminatory practices.
There is no reliable economic basis for determining the foreign market share without the alleged discrimination.

No satisfactory methodology can calculate the target market share; the choice of which is therefore inherently arbitrary and devoid of any serious economic foundation.

III) The market share targets have been proposed as temporary indicators. However, when the market share reached its target of 20% at the end of 1992, the SIA urged that the import target be maintained, if not increased.
Any shortfall is ground for complaint by the USA and any increase is hailed by Japan as progress.

IV) VIEs raise the issue of enforcement. To be credible, the VIE must be backed by the implicit or explicit threat of retaliation in case of noncompliance.

There is an inherent uncertainty surrounding the import target. The problem is whether failure to satisfy the import target is evidence of Japanese recalcitrance or is

the target set at the wrong level, or has the composition of demand in the foreign market changed?

V) VIEs diminish competition.
If no explicit government barriers have been identified, enforcement of the VIE target is unlikely to enhance competition.

The SCTA has clearly altered the nature of competition in the semiconductor industry as indicated by the proliferation of joint ventures between the US and Japanese firms since 1986.
The manifold joint ventures have diminished the high degree of rivalry between US and Japanese firms.

VIEs may not increase competition but merely create rents for the first few foreign firms that are beneficiaries of the action, especially if they are imperfectly competitive and recognize their bargaining power vis-à-vis their Japanese customers and if they already have long-standing direct investments in Japan with selling advantages over other US rivals.

Even if as a result of a VIE additional firms enter the market, this does not necessarily increase competition. If there are fixed market shares, (that is not competition), this share agreement implies cartelization.

The VIE may be a facilitating practice that fosters collusion, just like VERs. The act of the Japanese government forcing Japanese firms to reduce their domestic sales and to share the market with foreign rivals has given rise to a more coordinated and more collusive interplay between foreign and Japanese firms. In the end, competition has not been enhanced, only profits are shared.

VI) VIEs are likely to become managed trade in the worst sense. They require substantial government intervention to become effective, depending on explicit and continual administrative or enforcement actions. Imports must be rationed and allocated among domestic consumers to satisfy the market share target. Results-based trade policy is not about opening markets at all; it is about granting special favors to prominent and politically powerful US industries.

VII) VIEs may degenerate into discriminatory and preferential treatment for certain suppliers, leading to trade diversion, constituting export protectionism for one’s own (in this case US) producers.

The SCTA was officially nondiscriminatory since it referred to foreign capital-affiliated semiconductor firms, not simply to US firms. In 1988 the EU lost a GATT

panel decision challenging the SCTA as a violation of MFN.

Despite formal assurances to the contrary, there is ample reason to believe that VIEs will continue as an explicit discriminatory device in favor of the USA. In negotiating a new automobile and auto parts VIE, the Clinton administration proposed "specific expectations" for greater Japanese imports specifically of American-owned companies.

However, the Japanese government and firms interpret the VIE as encouraging imports principally from the USA. Japan recognizes that the pressure to import more arises almost exclusively from the USA.

Other countries interpret the VIE as a preference to US firms. Therefore, the EU has pressed for an own market share target of 5% in Japan. Its market share in Japan was only 1%, while its share outside Europe and Japan is 5%.

VIII) VIEs make a country believe that it can achieve market opening without reciprocal liberalization, reducing support for the open multilateral system. As the setting of import targets by two countries is perceived by other countries as fixing market shares to their detriment, bilateral trade restrictions tend to spread. This tends to carve up world markets by political fiat and pressure.
VIEs are inherently bilateral and damage third countries. Smaller and weaker countries with less political and economic influence are left behind to fight over the remaining scraps of the market. This threatens the WTO system.

IX) The VIE exacerbates the political capture of US trade policy and reduces the role of the government as an agent for interest groups.
The USA indeed has a producer-oriented complainant-initiated trade policy system, in which domestic exporting interests lobbied for the VIE. During the negotiation of the 1986 SCTA, SIA representatives were often in the next room and received frequent updates from US negotiators about the status of the talks. The SIA had veto power over the agreement.

Moreover, there is the question of what criteria are used in picking and choosing the industries to benefit from US government action. The arbitrary nature of selecting industries for VIEs raises the possibility that political pressure results in the wrong sectors chosen for a VIE. This may reduce welfare if there is an expansion in output from a sector benefiting from a government subsidy.

An increase in US exports does not correspond with an increase in economic welfare. In a price-distorted sector the distortion may be magnified, reducing welfare.

**The danger is that US trade policy may simply mirror the concerns of the most vocal complainants with little consideration of the nation's economic interest.
VIEs will exacerbate this trend and will encourage greater lobbying for export protectionism.**

**An example is the case of Micron Technology which in April 1992 filed an antidumping petition against South Korea. In October, the Commerce Department announced dumping margins as high as 87% against Samsung, Goldstar and Hyundai.
The Korean government offered to sign an agreement committing itself to a VIE, but it was rejected by the Clinton administration, because Micron vetoed the Korean proposal. It felt secure behind high antidumping duties imposed against Korea and was unaffected by the prospective Korean market-opening actions.**

Active use of VIEs in US trade policy would reinforce the grossly exaggerated notion that foreign unfair trade practices are a prominent feature of international trade.

**An estimate of the increase in US exports that would arise if Japan fully liberalizes its trade is about $13.6 billion, roughly equal to a quarter of US bilateral trade deficit with Japan, 2% of US exports and 0.2% of US GDP in 1992.
The completion of the Uruguay Round is reckoned to increase US income by about $20 billion annually, but this figure does not receive the public attention that trade disputes with Japan do.**

**The intense obsession and focus on Japan's hidden practices reinforces the faulty notion that Japan can be blamed for the economic shortcomings of the USA.
US trade policy is again taking on the tenor of a statement made in 1985 by Senator Joseph Biden: "I don't want to compete, I just want to win".**

**Blaming unfair discrimination abroad or unfair practices for one's own economic shortcomings is an easy way to avoiding serious discussion of domestic solutions.
If the USA wants to reduce its current acount deficit, reduction of the fiscal deficit and the promotion of domestic savings are a vastly superior approach to VIEs. Once its own house is in order, the political pressures for the management of international trade will subside.**

5) Another point of criticism on the SCTA concerns the arbitrary nature of the 20% target, so that the negotiated outcome could be inferior to what would

prevail if the underlying barrier to exports could be removed.

For chips the 20 percent market share appears to have been a lower-bound estimate of what the foreign producer market share would have been if the Japanese market were like markets elsewhere in the world. (In 1986, US firms had a 40% share of European market and a 66% share of the world market excluding Japan.)

In the wake of the SCTA total sales of semiconductors by North American firms in Japan grew from $1.2 billion in 1987 to $2.8 billion in 1991, with a 23% growth rate for North American sales in Japan versus 11.2% growth rate of the total Japanese market over this period.

This increase has been attributed to shifts in the composition of demand in Japan and to technological innovations by US firms (such as the development of the 486 chip by Intel). However, the latter hypothesis is difficult to assess and the former does not appear to be supported by the data.

The market segment where North American presence was greatest, namely, bipolar digital logic chips, actually shrank between 1987 and 1991. Rather, US firms increased their shares in the most rapidly growing part of the market, that is in MOS memory chips, MOS logic chips and MOS microcomponents. This may be interpreted as supporting the notion that entry is easiest in expanding sectors, where domestic firms may not be able to meet demand and where imports do not directly displace existing domestic production.

Total US exports to Japan increased from $384 million to $969 million, with a growth rate of 26%.
Therefore, data do indicate that the growth rate of US exports actually exceeded the growth rate of sales by North American firms. However, caution is warranted in making comparisons between data on sales and those on exports; they are from two different sources, product definitions may differ and the sales data include Canadian firms. Hence, the results for sales by US firms do not necessarily hold for exports from the US.
Recall that, under the SCTA, the nationality of a product was determined by the producer's headquarters, not the location of production. Therefore, a TI chip produced in Japan is counted as American and a Hitachi chip produced in the US is counted as Japanese for the purpose of calculating market shares.

The absolute increase in exports was greatest in bipolar devices, while the growth rate was greatest in MOS memory devices. The same enormous increases did not occur in microprocessors, so that technological innovations did

not generate the growth in US semiconductor exports.

Taken together, the data on sales and exports do not support the contention that the increase in foreign market share has been due largely to either shifts in demand toward market segments of high foreign penetration or technological innovation in semiconductors.

The question is how much of this increased foreign activity can be ascribed to the SCTA?

Bergsten and Noland (1993) argue that if the foreigners had merely maintained their market shares in Japan and if bipolar devices (where North American firm share of sales actually declined) are excluded and the North American market shares in 1987 are applied to each segment of the Japanese market in 1991, the predicted *sales* would have been $1.4 billion.

In fact, sales were $2.5 billion. The difference of $1.1 billion could be interpreted as an upper-bound estimate of the impact of the SCTA. This is an upper-bound estimate because it ascribes all market gains to the SCTA and not to other factors such as technological innovations or changes in exchange rates.

A similar calculation has been done with respect to US exports. If the share of US exports in each product category (including bipolar devices, where their share increased) had remained constant between 1987 and 1991, US exports would have been $457 million, while in fact exports were $872 million (excluding other devices with $97 million), yielding $415 million as an upperbound estimate of the SCTA’s effect.

These calculations suggest that the impact of the SCTA was to nearly double US chip exports between 1987 and 1991.

6) The SCTA does not guarantee that the 20% level be maintained and whether it can depends on how far the US chip producers can persuade Japanese electronics producers to design-in US components for their products in the long run.

7) A lesson of the SCTA is that sustained US pressure backed by credible commitments to sanctions is often necessary to secure Japan’s adherence to a formal trade agreement that threatens the interests of powerful Japanese companies.

8) The SCTA’s greatest benefit of the USA in the long run may be substantial foreign direct investment by Japanese firms in the USA, which has sparked a heated policy controversy.

FDI is not just a substitute for trade, it drives trade as well. FDI opens up a wedge that often expands trade as subsystems and production equipment are shipped from the home country to the host country where production takes place. FDI may also stimulate exports from the host country as foreign firms buy into a source of product.

Proponents of FDI point to benefits in the form of jobs, capital, technological know how and local externalities. Moreover, greater competition reduces prices for consumers.

Opponents emphasize three possible disadvantages of FDI.
1) By establishing early mover advantages it may displace or deter or discourage the entry or expansion of US-owned companies.
2) FDI may reduce market competition by buying out domestic competitors directly or by squeezing them out gradually, so that a more concentrated industry may result.
3) FDI may threaten national security by transferring control over key military technologies to foreign firms.

In case due to FDI national security is at stake two principles should be followed to enhance control over foreign suppliers.
1) Performance requirements on foreign investors for national ownership or, local production by foreign suppliers should be used.
2) A diversity of suppliers should be sought to maintain a competitive supply base.

However, the Committee on Foreign Investment in the US (CFIUS) was not seriously concerned about the potential national security threat posed by the Japanese control over the semiconductor industry.

Ultimately, FDI should be evaluated against its counterfactual: what would be the result if the FDI did not take place?

FDI is preferable when the alternative is increasing dependency on imports or in case of failure to develop a new technology because of limited domestic capital or manufacturing capabilities.

It may be concluded that investment by domestic companies may be the first best outcome. If not available, FDI is second best.

The size of the FDI activities of Japanese semiconductor firms in advanced countries rests on their technological leadership in semiconductor technologies, that is MOS memory. Japanese firms felt threatened by the imminent protectionism arising in the USA and undertook FDI there.

Policymakers should be aware that policy efforts to exclude or ward off imports may accelerate rather than decelerate market penetration by the Japanese.

6.6. *Deficiency of cost-based definition of dumping*.

The basis for the dumping decision of the ITC has been the subject of some controversy because the low prices charged by Japanese firms were a normal feature of semiconductor pricing over the product cycle rather than the result of dumping and were consistent with the goal of maximizing profits over the full product cycle of each generation.
It can be argued that the procurement behavior of the vertically integrated Japanese electronics firms prior to the SCTA reflects economically rational behavior where an upstream component (chips) is subject to scale economies. Vertically integrated firms will tend to source inputs internally in products such as chips that are characterized by huge fixed costs and significant learning curves over the product cycle, but this is efficient and not a trade impediment per se, as argued by the US negotiators.

The criterion to determine whether or not imports have been dumped in the USA was a constructed "fair value" concept. The most widely publicized application of this standard was in the case of imports from Japan of DRAM semiconductors in 1985.

Although prices for these chips in the US market actually have been marginally higher than prevailing prices in the Japanese market, (the exact opposite of the traditional concept of dumping as sales abroad at less than home market prices), the US complainant charged that Japanese chips were being sold at prices not covering the full costs of production, the new definition of dumping in the US trade laws.

According to US antidumping law a good is "dumped" if it is sold somewhere else for a higher price, or if it is sold below what the US Department of Commerce (DOC) defines as average cost plus an 8% markup for normal profit. Pricing below this constructed long-run average cost has become the principal grounds for applying the dumping laws to US imports of foreign products.

The economic motivation for antidumping laws that led to this situation is that they prevent anti-competitive strategic behavior called predatory pricing.
If a firm sells below cost for long enough, it may drive its competitors out of the market leaving it free to charge high monopoly prices in the future. This is especially irksome when the predator is foreign since the

monopoly profits do not accrue to domestic residents.

However, predatory pricing is not always a good idea. Think of the losses of the predator as an investment. The firm must expect higher than normal profits after it has driven out the competition - high enough to cover the cost of the predation.

The key to profitable predation is the existence of barriers that prevent other firms from entering or reentering the market when the predator jacks up his prices.

It is sometimes asserted that the learning curve provides just the sort of entry barrier that would make predatory pricing profitable. Hard evidence is difficult to come by, but anecdotal evidence suggests that this be incorrect.

It seems that entry and reentry are *too* easy in the semiconductor market to make predatory pricing worthwhile. Therefore, is seems unlikely that Japanese firms would have pursued such a strategy, at least for profit motives.

The economic problem with cost-based definitions of dumping is their use of the wrong cost concept, long-run average cost instead of short-run marginal cost.
The DOC's "Foreign Market Value (FMV) concept is based strictly on average cost pricing and admits no role for the type of forward pricing that is normal in a learning curve industry like the semiconductor industry.

In an industry subject to learning economies (where unit production cost falls with cumulative production experience) it is possible that producers may rationally choose to "forward price", that is sell at a price below current marginal cost for completely competitive nonstrategic reasons. In that case it may be argued that a criterion based on marginal cost might serve as a useful screen for potentially predatory behavior by foreign exporters.

In the absence of learning effects, pricing below short-run marginal cost is sufficient to conclude that a firm is acting strategically.
However, some cautiousness is required here.
When fixed investments in R&D are very large in relation to a firm's sales, such as in the semiconductor industry which spends almost 15% of sales on R&D, there is a significant gap between average variable cost and long-run average cost, and short-run marginal cost may fall significantly below long-run average cost.

Then, perfectly competitive behavior may often trigger

pricing below long-run average costs. This is because an R&D investment is generally charged against revenue at the moment it is incurred, (this is called "front loading" of R&D), and not spread over its economically useful life.

Moreover, the FMV concept does not consider the fact that since demand in this market is elastic, the free trade price path must fall more slowly than the average cost path. The FMV calculation had made no provision for the fact that normal competitive firms initially may price below average cost, but above variable costs, when faced with an unexpected downturn in demand.

In this respect two questions may be posed:
1) Should pricing below fair value when making learning investments be a violation of the predatory behavior provisions of the US Trade Act?

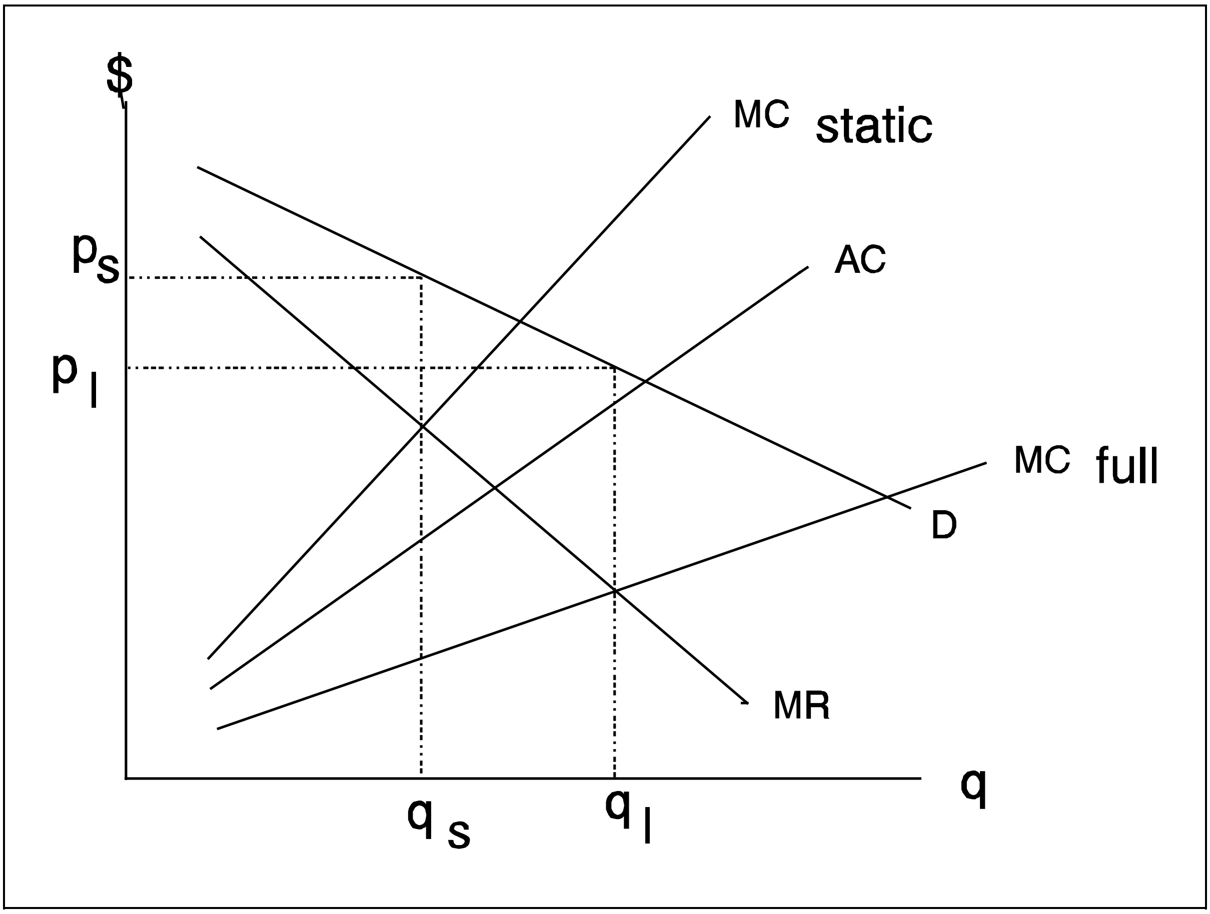
2) Were the Japanese firms acting in a predatory fashion during 1985-1986 or is pricing below fair market value as determined by the Department of Commerce an indication of learning-associated investments?

ad1) The investment associated with learning is like any other investment in cost-reducing technology and yields exactly the same sort of efficiencies so long as the investments are taken to the appropriate margin.

It is easy to miss the point that such investments are efficiency-creating when there is little recognition of the potentially-significant difference between static and full costs with learning and one must understand that firms attempt to use the correct, full marginal cost including the present value of learning effects in their decisions.

ad 2) While the ITC found that many Japanese companies were selling their semiconductors in the US at prices below their production costs, there is little evidence that this was done to undercut the prices of US producers. Instead, it was more the result of intensive competition within Japan and a drop in demand for personal computers in the mid-1980s, which caused the prices for chips to fall rapidly. In order to cut their losses, many Japanese semiconductor firms which had overproduced and had bulging inventories sought to cut their losses by quickly selling off their stockpiles.

Next figure helps to explain that Japanese semiconductor manufacturers might have expanded output by investing in learning and that neither the Department of Commerce nor the ITC have developed the data necessary to investigate this possibility in the US Trade Act of 1974 proceedings.



This figure shows that below fair market pricing by the Japanese was simply an indication of learning-associated investments, whereby the American authorities reached an incorrect conclusion.

In case there is no learning the product will be sold at price P_s where marginal revenue and static marginal costs equal. The price is above static marginal cost and also above average total cost, providing profits. A section 301 violation of the Trade Act would not be found under these conditions.

If there are significant opportunities for learning the relevant marginal cost schedule is MC full and the firm produces the greater quantity sold at price P_l . This output expansion involves a current investment in learning equal to the difference between P_l and average cost times output q_l.

While the firm is investing at the proper margin to reduce its future costs, the fact that price P_l is below the calculated fair value at this greater output (AC + 8%) means that a trade violation under Section 301 would be invoked. In this case the price is confused with predatory pricing while the firm legitimately attempted

to capture economies of learning by doing.

Therefore, in the presence of learning economies, below marginal-cost pricing can be rational. A rational firm will generally equate marginal revenue to a value below its current short-run marginal cost, as it takes into account the cost-reducing effect of current production on future production costs.

Chip prices typically drop very quickly over the first part of the product cycle, drop less quickly as the product approaches maturity, and fall very slowly, if at all, at the end. In this case rational firms engage in "forward pricing", that is choose output levels where marginal revenue lies below their current short-run marginal cost, or marginal revenue equal terminal (not current) marginal cost.

This does not necessarily mean that price falls below current marginal cost since price will in general exceed marginal revenue.

It may be concluded that in case of learning by doing stategically pricing (to influence the behavior of rivals) below marginal cost is normal business practice that should not be condemned as dumping or predation.

A policy measure that prohibits marginal cost pricing by foreign exporters will increase domestic production at the expense of domestic consumers. By so doing foreign producers are denied national treatment in the importing country and are forbidden the right to economic behavior which is permitted to domestic firms.

In HT sectors in the presence of scale and learning economies there is a strong incentive for forward pricing by setting current prices on the basis of future cost. It is very difficult to distinguish between forward pricing and predatory pricing. This has to be established by careful consideration of cost and demand characteristics in a particular industry.

In many countries national antidumping rules do not require the determination of predatory intent or of market power by foreign sellers. Foreign suppliers are precluded from using the same competitive tactics, like forward pricing, as domestic suppliers.

Because of these deficiencies national antidumping laws of some countries need revision. Dumping should be assessed on the basis of actual price differences between markets and not on the basis of constructed cost measures.

Injury alone should not be a sufficient condition for

obtaining relief from excessive imports due to dumping, because competition usually injures some firms to the benefit of others. Only when injury is the result of unfair or predatory practice or has long-term consequences for market structure, some kind or remedy is required.

The time required to process antidumping complaints is also causing business concern. In the USA a full year passes from filing a complaint to the issuance of an antidumping order. This is very long for HT industries with their short product cycles where foreign producers may cease dumping one product and move on to selling its next-generation successor by the time an antidumping case has run its course.

Therefore, fast track dumping procedures are required to avoid that domestic suppliers are exiting production such as in DRAMs with its delayed antidumping remedy.

Finally, antidumping duties have several shortcomings. They do not provide compensation to the domestic producers injured. Foreign firms guilty of dumping are subject to no penalties beyond the duties imposed. Often these firms increase their prices just enough to avoid the duties. The duties collected are paid by importers, not by foreign producers and turned over to the treasury, not to the injured domestic producers.

Antidumping duties are a second-best solution. The first best remedy is to offer some form of countervailing-subsidy (CVS) or government support program. But in the absence of first-best remedies, antidumping provisions are often the only option available.

Although Foreign Market Values (FMV), derived from the fair value constructed cost concept, have been dropped from the 1991 Semiconductor Trade Arrangement (SCTA), Japanese producers are required to continue to collect data in order to facilitate a fast response dumping investigation.

7. *SEMATECH*.

The establishment of SEMATECH in 1987 represented a major policy response to the decline in the US semiconductor industry's performance.

SEMATECH, located in Austin Texas, provides a valuable example of the use of joint development consortia among the American leading companies in partnership with the US government to strengthen competitiveness.

The centralized operating entity structure contrasts with

the "umbrella" or secretariat model used in the European Union, where there are small administrative directorates overseeing independent collaborative projects carried out in-house by small groups of member firms. In Europe programs such as ESPRIT were motivated more by broad economic and political concerns than by industry initiative.

SEMATECH is closer to the pattern of many Japanese collaborative consortia with the objectives of improving competitiveness of firms as a group.
Its goal is to bring US semiconductor manufacturing capability to equal or exceed the world’s best, including the design for manufacture as much as the manufacturing process itself.

SEMATECH is not intended to manufacture any particular product, or to develop specific processes for any product. It is a non-profit organization that is not permitted to sell chips.

The original mission of SEMATECH was to provide a research facility for member firms to collaborate on projects to improve their semiconductor manufacturing process technology. However, within two years of operation, the focus of the consortium changed from the on-line testing and optimization of existing manufacturing equipment to strengthening the semiconductor manufacturing equipment (SME) industry. This shift in the focus of Sematech was a response to the rapidly declining competitive position of US equipment and materials suppliers.

This was due to a failure to commit sufficient capital to the development of next-generation equipment, a problem exacerbated by the small size of most equipment firms and by their notoriously poor relations with semiconductor producers. An investment gap had emerged in the area of next-generation manufacturing equipment.

The main focus of SEMATECH is now on the relationship between the semiconductor and equipment industries. This includes the development of manufacturing materials and equipment, the integration of these into manufacturing systems and the diffusion of best practice techniques. SEMATECH is concerned as much with technology diffusion as with the advancement of the technological frontier.

The largest area is equipment development, accounting for 60% of the budget. Central funding and testing can lower the costs of equipment development and introduction by reducing the duplication of firms’ efforts to develop and qualify new tools.

SEMATECH also decreases the fragmentation of product designs and increases the supply of complementary products and services, such as maintenance, software and user familiarity with their operation, and so facilitates the adoption of new processing equipment by US semiconductor manufacturers.

Today, SEMATECH is a consortium of 11 private US companies together with the US Department of Defense (DOD). SEMATECH resembles an industry association, diffusing information and best-practice techniques, setting standards, and coordinating generic research.

Most members of SEMATECH are large corporations. But non-members - large or small - also benefit from spillovers from SEMATECH efforts. There are no restrictions now on technology developed in the consortium. These spillovers constitute a justification for government support.

US affiliates of foreign firms are not allowed to enter SEMATECH. SEMATECH is not open to non-US firms, though there has been some discussion with the European JESSI program over mutual research interests. However, there are no restrictions on joint ventures between SEMATECH members and foreign partners.

The hypothesized advantages of collaboration in research include the ability of participating firms to lower costs and spread risks, reduced duplication in their R&D investments, and the exploitation of economies of scale in the R&D process.

However, reduced duplication of research projects also creates a potential disadvantage. Diversity in research projects provides an important hedge against the possibility that any single research project will be fruitless. Centralization of such research could lower the productivity of an industry’s research investment.

There are concerns over appropriability and spillovers within the consortium. Even a precommercial R&D consortium typically involves the sharing of sensitive information and know-how among competing firms. The fear of knowledge spillovers may cause firms to resist knowledge-sharing within a consortium. Defining a consortium’s research agenda is difficult because of appropriability concerns and divergent member firms objectives.

Originally, the results of SEMATECH research were to be licensed exclusively to member firms for two years and then made available to US firms at nominal royalty rates. Now the benefit to corporations which contribute to SEMATECH occurs from having access to newer equipment and processes six to nine months before they are generally available, which may be crucial for leading-edge product

introductions.

A main problem was that the development of advanced manufacturing processes is crucial to the competitive advantage of firms, but member firms are reluctant to share such sensitive information with other members. Moreover, there was the danger that some firms could free ride on the contributions of the technology leaders. Therefore, members questioned whether the development of advanced manufacturing processes was an appropriate objective for an industry consortium.

In response to these controversies, SEMATECH altered its research agenda to one that sought to improve the technological capabilities of US SMEs and to strengthen vertical cooperation between US suppliers and US users of semiconductor process equipment.

This may reduce the appropriability problems associated with the original research agenda. The new research agenda has shifted the focus from the development of a complete state-of-the-art production process to knowledge diffusion and technology transfer.

Three firms have withdrawn from the consortium: Micron Technology, LSI Logic and Harris Semiconductor, because of their dissatisfaction with the consortium's decision not to pursue the development of an advanced manufacturing process that all members could apply.

SEMATECH has provided a single common qualification point for complex production equipment, leading to a reduction of development and qualification costs. Instead of trying to meet the requirements of 11 different customers, equipment suppliers can now work to a single set of specifications.

7.1. Evaluation of SEMATECH.

Although SEMATECH remains controversial, many credit it with saving US industry's place in semiconductor manufacturing. The establishment of SEMATECH has coincided with a resurgence in the US chip industry. In 1992, the US won a larger share of the world market than Japan and USA firms took the leading positions in both the chip and equipment markets.

Though much of this may be due to market dynamics beyond SEMATECH's influence, there seems to be widespread recognition that it has helped with some of the industry's problems. However, it is difficult to separate the influence of SEMATECH from other changes taking place in the industry and hence to argue what would have happened without it or what would have happened had federal sponsorhip taken other forms.

SEMATECH has sought to improve an area in which US semiconductor manufacturing firms lagged behind Japanese competitors, namely, the weakness of vertical user-supplier relationships.

SEMATECH objectives have shifted during its existence so that there is the issue of what targets it is evaluated against. Although a full evaluation is some years away, initial evidence suggests that SEMATECH has had at least partial success in meeting its revised goal of bolstering the capability of domestic equipment suppliers. This is visible in a number of different areas.

1) The decline in worldwide market share of US semiconductor equipment suppliers has essentially been halted and has actually increased from 42.8% in 1990 to 47.1% in 1991. Several US firms increased purchases of US equipment as a result of SEMATECH programs.

2) SEMATECH is widely credited with improving communication within the semiconductor industry, shifting the culture of firms toward long-term relationships and interfirm partnerships with equipment suppliers. SEMATECH can take credit for restoring domestic capability in advanced lithography equipment.

3) Moreover, SEMATECH has pursued a broader agenda of R&D funding that includes semiconductor manufacturing technology and procedures, such as programs to develop computer-integrated manufacturing and flexible manufacturing systems, including process control software and automated materials handling capability. Moreover, SEMATECH is in a good position to define industry-wide standards for equipment and software interface.

SEMATECH has gone some way in addressing the immediate challenge of achieving parity with international competitors in submicron process technology and equipment. Nevertheless, the underinvestment by private semiconductor firms in manufacturing equipment and process technology remains a problem.

While the competitive position of domestic equipment manufacturers has improved, they have not yet regained substantial market share and the associated revenues necessary to fund new rounds of large-scale R&D.

Moreover, there is little evidence to suggest that semiconductor firms are willing to redirect substantial amounts of their internal R&D away from product design and into equipment and process development.

Rather, a substantial "free rider" problem has emerged regarding SEMATECH's efforts to improve manufacturing equipment. Much of the benefit of a healthy domestic

equipment base is available to all semiconductor firms, whether or not they are members of SEMATECH.

The key to SEMATECH's success lies in the fact that its goal has been relatively clear: US firms needed to catch up in manufacturing equipment and supplier relations.

One of the most significant effects of SEMATECH is the impact on the purchasing habits of US semiconductor manufacturers, who have increased the amount of equipment they buy from US suppliers, due to the increased reliability of equipment under SEMATECH programs.

Although the improvement in performance of the US semiconductor manufacturers may be attributable to SEMATECH, there is little credible direct evidence that SEMATECH is responsible for such gains.

In one important segment of the US SME industry, lithographic "steppers", SEMATECH has not prevented erosion in US firms' competitiveness.
This highlights the argument that technology alone is rarely sufficient to restore the competitiveness of firms or industries that lack critical complementary personnel, marketing, managerial and financial resources.

Irwin and Klenow (1994) have tried to disentangle the effects of the consortium on US firms' R&D spending, profitability, investment and productivity.
They have tested two hypotheses: the "commitment" hypothesis and the "sharing" hypothesis.

According to the commitment hypothesis SEMATECH obligates member firms to spend *more* on high-spillover R&D. As firms may be tempted to let others fund high-spillover R&D, the 50% government subsidy is crucial. Therefore, this hypothesis provides a rationale for the government subsidies.
The sharing hypothesis is that SEMATECH promotes sharing of R&D within the consortium, thereby *reducing* duplicative R&D, which implies greater efficiency of consortium R&D than of independent R&D. From a private standpoint SEMATECH contributions are all the more efficient because of the 50% government subsidy.

The responses from questioning alI SEMATECH members by Irwin and Klenow appeared to be more consistent with the sharing hypothesis, which predicts a reduction in R&D spending, than with the commitment hypothesis, which predicts higher R&D spending.

With respect to the effects of SEMATECH on profitability, the commitment hypothesis implies that members' profitability relative to non-members will rise so long as SEMATECH R&D results do not spill over 100 percent to

**other US firms in the industry. However, the profitability gains lag the R&D outlays by at least one year.
Under the sharing hypothesis the jump in profitability is equal to the fall in R&D spending due to R&D savings.**

**No evidence has been found that SEMATECH changed the investment patterns in the semiconductor industry.
The results are also uninformative about whether SEMATECH had any appreciable impact on productivity.**

The principal finding has been that SEMATECH induced members to cut their overall R&D spending providing support for the sharing hypothesis over the commitment hypothesis.

Most members reported positive returns on their investments in SEMATECH, due to reductions in their costs. SEMATECH has passed a critical market test of viability as 11 of the original member firms thus far have maintained their contributions, (1 percent of semiconductor sales with a minimum of $1 million and a maximum of $15 million).

Since SEMATECH members have become increasingly involved in joint ventures with large foreign rivals, in May 1993 SEMATECH decided to make an exception to its policy of restricting even indirect participation by foreign firms.

Any dramatic relaxation in this policy, such as opening SEMATECH to membership by foreign firms, could jeopardize future federal funding because it is pointless to provide public funding primarily for the benefit of foreign firms.

Although the US government *supports* funding for technology development activities within the SEMATECH consortium, it *opposes* technology and product development subsidies extended by European governments to the Airbus consortium.

The apparent inconsistencies between the US government's position on SEMATECH as a matter of *technology policy* and its position on subsidies as a matter of *trade policy* reflect broader problems of coordination between trade and technology policies that will figure prominently in industries other than semiconductors.

SEMATECH now focuses on technology development, rather than fundamental research and SEMATECH's experience shows that consortia are likely to be most effective in supporting the improvement and adoption of technology rather than focusing on long-term research.

However, SEMATECH based near-term R&D cannot be a

substitute for the scientific and technological longer-term R&D activities performed by government, universities and industry.

SEMATECH experience supports the importance of industry cofunding and participation. Its research agenda has more to do with "catching up" with global best practice than with leading the next generation. Therefore, SEMATECH has been a model of catch-up situations.

There is now widespread interest in the development of collaborative research consortia in other US industries from electric cars to high-definition television.

The economic case for federal support is *strongest* in research areas characterized by high uncertainty, lengthy time horizons, and substantial spillovers and external effects primarily to the benefit of US firms and taxpayers.

To the extent that SEMATECH's research agenda is dominated by routine equipment qualification (demonstration of performance specifications), standard-setting and support for suppliers' management skills, the case for large federal subsidies will be *weakened*.

The questions of how and when governments should intervene are becoming more, not less, complex. The growing interdependence of trade and technology policy, and the emergence of intellectual property rights and commercial standards are issues of central importance to the competitive success of high-technology firms.

In an era in which technological knowledge flows rapidly around the world, it becomes increasingly difficult to target the support of technology in ways that primarily benefit domestic firms and workers.

Policies that attempt to support only domestically-owned firms may not be the best strategy for improving the economic welfare of domestic citizens.

The key issue may be the ability of a country to capture a large number of high-technology jobs in growing industries, regardless of whether the employer is a domestically-owned or a foreign-owned firm.

Rather than trying to exclude foreign firms from access to government sponsored basic research, it will likely be more advantageous to negotiate reciprocal access to research sponsered by foreign consortia.

Given the strong US congressional support for SEMATECH, it is unlikely that funding for the consortium will actually be cut in the near term.

However, the US government should consider the desirability of a longer-term commitment to SEMATECH and to the domestic semiconductor industry, support that is not received by a multitude of other potentially worthy industries.

Instead of bilateral negotiations, balanced trade and sustained growth will require a multilateral framework covering the multiple issues of market access, property right protection and industrial policy.

8. Strategic alliances.

Over the past decade, semiconductor manufacturing has become dominated by Very Large Scale Integration (VLSI) technologies that combine thousands of electronic functions at microscopic scale in a single chip. The movement to higher levels of circuit integration, to sub-micron fabrication, and to new Application Specific Integrated Circuit (ASIC) and Computer Automated Design (CAD) technologies has fundamentally altered the existing structure of economies of scale and scope in semiconductor manufacturing and triggered important changes in the organizational structure of the industry.

Strategic alliances have long played a limited role in the semiconductor industry. Since the mid-1980s, however, the number of US - Japan alliances was increasing sharply from the low level of activity prior to 1980. An alliance boom in semiconductors emerged in the mid-1980s and again in the late 1980s.
This general trend has continued to the present and the alliances appear to become deeper and more significant in terms of its impact on companies and the competitive landscape.

Mass volume sales constitute the sine qua non of low-cost production and of moving rapidly down steep learning curves. Therefore, it is essential to find ways of getting close to foreign customers. Because the up-front costs and risks of breaking into foreign markets can be prohibitively high, there are strong incentives for companies to find foreign partners through strategic alliances.
The key technological and manufacturing development underlying the formation of interfirm partnerships has been the shift to VLSI production and submicron fabrication. This shift has led to a rapid increase in the costs of R&D, equipment, and facilities, as well as to an increase in the risk of market failure.

Perhaps the most obvious generic force is a trend toward the globalization of markets. Companies cannot afford to confine themselves to domestic markets, no matter how large they may be.

The twin processes of circuit integration and miniaturization have strengthened two important incentives for organizational change:
1) Increased pressure on firms to share the expense and risk of rapid growing investments in R&D facilities, and equipment.
2) The tendency toward greater design and market specializaton.

Jointly, these two incentives explain the formation of partnerships among firms possessing complementary manufacturing expertise and market specialization.
In response to these developments semiconductor firms throughout the world have formed partnerships with producers possessing complementary marketing and technological expertise in order to minimize the production costs of providing new technological solutions to diverse market segments.

Thus the motivation for forming partnerships has increased in recent years, driven by the rising cost of process technology and leading-edge production facilities, the emergence of new markets for low-volume, design-intensive devices, and the globalization of demand for semiconductor products.

However, partnering with outside manufacturers presents the risks of how the partner firms can avoid free-rider problems and exercise proprietary control over the knowledge generated by the partnership. As technologies and ideas are transferred from one partner to another collaborators rapidly become competitors and the alliance collapses. The key issues for the partners are trust, reciprocity, and forbearance. Partnerships have to be structured so that the opportunities for and gains from malfearance are outweighed by the benefits of continuing the alliance.

Many partnerships involve a trade-off between short-term gain, i.e. access to additional production capacity or investment credit, and mid-to long-term disadvantage, i.e., the accelerated transfer of technology.

Partnership agreements between US design houses and foreign wafer fabrication foundries represent a substantial proportion of the total number of strategic alliances established during the 1980s. 80% of the foundry work for US design houses is performed by foreign firms, primarily Japanese and South Korean manufacturers.

The pairing of major producers in the USA and Japan constitutes a major shift in the terms of competition and cooperation in the semiconductor industry. The focus of these partnerships is not so much on the transfer of existing technologies as on the sharing of the cost of

developing next-generation products and production processes.

Most high-tech companies build strategic alliances in order to:
1) compensate for in-house weaknesses or technological gaps;
2) fill out product lines and portfolios;
3) position the company to enter lucrative new markets;
4) better serve an established or targeted customer base;
5) reduce the costs, risks, and time required to develop new product and process technologies.

To achieve these goals, US and Japanese companies are willing to swap technology (e.g., cross-licensing), second source, undertake joint development projects and organize joint ventures. The fixed costs of doing research and of building new plant facilities have soared to almost prohibitive heights.

The ongoing tendency of contraction in product life cycles means that the window of opportunity for rent retrieval has become exceedingly short.
Perhaps the key competitive requirement is achieving economies of scale. A high production threshold must be crossed to justify the costs of R&D and new plant investments at a rate of around 20 to 30% per year. Therefore, the incentives to enter into manufacturing alliances with Japanese firms are strong.

The present partnerships are characterized by a more balanced flow of knowledge and technology as compared to the largely one-way flow of technology that characterized the earlier alliances between US start-up firms and larger Japanese manufacturers. In many cases, the expertise of US firms in product technology is matched with Japanese prowess in process technology and high-volume production.

The emergence of successful global alliances has the potential to shift competition away from the current, predominantly nationalistic focus to a struggle among competing global partnerships. The emerging partnerships between US and Japanese firms will likely form the basis for a series of global semiconductor "camps", each centered on the process-technology capabilities of two or three global firms linked to a multitude of smaller, allied producers. Therefore, the primary axis of competition will not be between the USA and Japan, but between competing camps of global producers.

From the US perspective, small start-up firms increasingly turn to large Japanese companies to supplement or replace traditional sources of financing for growth, such as venture capital.

Linking with Japanese partners can provide American companies access to advanced manufacturing capability and to the rapidly growing Japanese market.

For the Japanese integrated "silicon majors" linkages with small US firms provide access to complementary technical capabilities that can be leveraged to gain a stronger position in new, design-intensive semiconductor markets as well as downstream systems.

However, the spread of alliances raises concerns as well. The prevailing flow of semiconductor technology through alliances is from the US to Japan. The USA is trading product design technology for Japanese process and manufacturing technology.
A largely one-sided outflow of technology from the US to Japan, if continued over the 1990s, could have the cumulative effect of eroding the foundations of America's capacity to innovate in the industry, with serious consequences for the US computer and telecommunications companies that use semiconductors. Therefore, as US design technology leadership is the cornerstone of US competitive advantage, this may be a risky game.

Individual US firms may have earned a steady stream of patent revenue, but most US companies failed to appreciate the impetus for rapid catch-up that the transfer of technology gave to Japanese firms, which contributed to an erosion of America's industrial preeminence.

US companies had reasons for selling their hard-earned technology.
Many were preoccupied with the huge and expanding US domestic market, which brought in profits that would dwarf anything earned from foreign markets. Why bother incurring the costs, risks, and uncertainties of trying to break into what was, in the 1960s, a small and distant Japanese market?

The far-sighted US companies which understood the long-term importance of breaking into the Japanese market ran into the roadblock of formal and informal barriers, which led them to abandon or delay early plans to establish a presence in Japan.
They concluded that earning royalties from the sale of their technology patents was better than having nothing.

American companies have learned some hard lessons from past experience. Today, the value of state-of-the-art technology is recognized more clearly than it was two decades ago. They realize that the possession of key technologies can be converted into major gains in the commercial marketplace.

Therefore, many US companies have tightened up their licensing practices, often choosing either not to license at all or to use their patents to obtain know-how of comparable value in return.

Crisscrossing linkages of strategic alliances now tie together virtually all major semiconductor companies in ever denser and more complicated networks.
It is hard to find a single significant semiconductor company anywhere in the world today that has managed to remain isolated from the powerful pull of alliance linkage.

What explains the marriage of US and Japanese firms?
The most obvious explanation for the preponderance of US -Japan alliances in semiconductors is that the US and Japanese semiconductor industries are the biggest and best developed in the world.

Small venture start-up firms in the US, in need of funds, manufacturing foundries, and marketing outlets, look to large, deep-pocketed, vertically integrated, and diversified Japanese corporations to meet these needs.

Capital is available in the US to start new semiconductor firms if their contribution is focused on a *specific* issue in the strata of semiconductor technologies. But capital is not available to build fully integrated firms, and therefore alliances have become a way of life.

Many of the large Japanese giants look to small US start-ups to provide new product designs to fill niche markets or to compensate for certain deficiencies in their own innovative capabilities.

In the best of circumstances, opposite firms attract and combine in ways that overcome the respective limitations of different systems of industrial organization (levels of vertical integration and diversification within firms, corporate finance, and capital markets).

Large US corporations have been less active in developing strategic alliances with smaller US firms.
Certain features of Japanese industrial organization, especially intercorporate shareholding, make it easier for them to operate on the basis of a longer time horizon than US companies, which are confronted with the tyranny of short-term profit maximization.
Corporate shareholders in Japan, such as banks and insurance companies, do not buy and sell their stocks in response to short-term fluctuations in share prices. They seek a steady appreciation of stock value through long-term company growth.

The vast majority of US-Japan alliances are between

small- or medium-sized US companies, (many of them young start-ups) and large, vertically integrated, diversified Japanese corporations, the *kaisha*.
These alliances transfer the bulk of American know-how to Japan.

The primary explanation for US companies to "give away" technology lies in the asymmetry in the size and staying power of small US firms and of large, diversified Japanese kaisha.

To get what the small US firms need, i.e., large infusions of capital, manufacturing capabilities, marketing, distribution and servicing networks in Japan, and continual development of next generation products, they often have to give up their only valuable assets - marketing rights for new niche products or leading-edge know-how.

The bargaining power of small US companies is often limited by a strong sense of urgency occasioned by short-term time goals and horizons.

However, even when large US corporations are involved, fundamental deficiencies in America’s industrial base - weaknesses in its manufacturing infrastructure, the short-run imperatives of US capital markets, the overreliance on the computer industry and the absence of a substantial consumer electronics industry - have resulted in transfers of state-of-the-art-technology to Japanese competitors.

Japanese corporations generally find it easier to deal with smaller US firms. Having the flexibility to pick and choose partners based on specialized products and technologies - what is called "boutique technology shopping"- is an advantage compared to being locked into deals with large US corporations.

Interesting is that there is a negative correlation between downturns in business cycles and peak periods of alliance formation.
When business conditons turn bearish, US companies appear more disposed to enter strategic alliances to meet their financing needs and to survive the sharp downturns in demand without having to revamp existing structures. The alternative is to cut back on R&D projects, net capital investments and core technical personnel.

Indeed when business conditions in the semiconductor industry slackened in 1986 and 1987, the number of American-Japanese alliances hit a peak.
When there was a revival of demand in 1988, the number of alliances plummeted.

However, the situation is more complex. Factors other than fluctuations in business demand can also have significant effects.
In 1988 the number of US-Japan alliances fell abruptly from 124 in 1987 to 46. This was due to the Toshiba Machine Company incident in 1987 which involved that company's sale of militarily sensitive technology to the Soviet Union. In order to avoid exposing Japanese companies to possible foreign criticism, MITI discouraged Japanese firms from entering strategic alliances.

In 1989 there was a surge in strategic alliances while business demand was strong. This was due to technological developments leading to new product clusters due to the coming on stream of ASICs, a major new family of products.

Another major driving force is the struggle to define and establish broadly based standards in operating and applications software and the choice of chips, shaped by the rush to establish dominance in software and chip standards.

In 1990 joint development projects represented the most common form of strategic alliance, accounting for nearly one quarter of the total. This type of alliance appears to be increasing steadily over time and is likely to continue to rise.

8.1. Diversification.

To date, Japan is one of the few advanced industrial countries in the world in which established companies in smokestack sectors (steel), old-line manufacfuring (machinery, automobiles) and skilled assembly (precision equipment) are making the transition into the high-tech world of semiconductors and electronics.

Large Japanese steel and equipment companies ("lateral entrants") use linkages with US companies to acquire the critical mass of technology necessary to diversify into semiconductors and other information industry markets.

Perhaps the most obvious reason for this diversification is the Japanese practice of lifetime employment. When the core business loses comparative advantage, the kaisha begin branching out into promising new fields of business activity.
Diversification enables them to retain their work force, utilize sunk investments, and survive as corporate entities.

The need to diversify has been one of the driving forces behind a noteworthy trend in US-Japan strategic alliances, namely, the proliferation of tie-ups between

large Japanese corporations outside electronics and both small and large American electronics companies.

8.2. National security concerns.

A basic problem is: What is the connection between the commercial health of an industry such as semiconductors and national security?

In the past national security has been defined in terms of supply dependence and disruption. The policy solution was to develop a safety net consisting of supply diversification (procuring from domestic and foreign sources, or from more than one foreign source) and accumulating a stockpile of supplies that could be drawn upon during emergencies.

Today it is no longer possible to cling to old concepts of security based solely on supply disruption. It now involves such complex issues as the commercial competitiveness of domestic producers in key high-tech industries, the scope of the state's role, and coping with the consequences of proliferating ties of economic interdependence.

In theory, the slippery notion of economic security can be best understood in terms of enhancing the twin objectives of economic efficiency and adaptability. What damages economic efficiency and adaptability is considered to be threatening for economic security.

A fundamental question is:
To what extent is the nation's capacity to innovate and manufacture diminished in technologies critical to military security?

In case a strategic alliance involves the transfer of technology and places the capacity to innovate and to manufacture essential weaponry at risk, then the proposed alliance would constitute a national security question, requiring possible public policy action.

8.3 *Assessing Costs and Benefits*.

In this paragraph we summarize the costs and benefits of strategic alliances as highlighted by the National Research Council of the USA.

Costs.

The costs of US-Japan alliances can be divided into those incurred by the company that forms the alliance and those incurred by industry, including the upstream and downstream industries.

For individual companies, perhaps the biggest potential cost is creating a formidable competitor through technology transfer.
For the US industry as a whole, the loss of semiconductor manufacturing capability and infrastructure may be the most serious potential cost.

1. *Transferring Enabling Technology.*
Possession of the capability to design software codes that are embodied in advanced microprocessors, in which area Japanese firms are still behind the US, would allow Japanese companies to challenge US industry in its most important stronghold and would create new competitors for a wide range of US semiconductor companies.

However, industry trends towards open systems may reduce the importance of proprietary microprocessing unit (MPU) architectures. Then the lack of capability to design superior MPUs would be less of a hurdle for Japanese companies seeking to compete in systems markets.

2. *Transferring Incremental Technology*.
The costs incurred from transferring incremental technology by developing improvements on a technology are less severe than those incurred by transferring enabling technology.

The case of Power Integrations is a good example of how it is possible for US companies to control their technology and avoid this risk. Power Integrations structured an alliance with Matsushita for internal use of the power management technology, but could keep Matsushita from selling the improvements outside, as long as the original patents remained in force.

3. *Low Return on Resources Expended*.
A low return on expenditures incurred by US companies trying to break into the Japanese market is a short- and long-term cost. In that case an alliance may be used to enter the market and avoid enabling a long-term competitor or avoid incurring the technology transfer-related costs outlined above.

4. *Unsuccessful Licensing Alliances*.
These occur when a Japanese company uses the technology in a way that makes the American company believe the agreement is being violated.
Then the licensing firm regrets granting a license and typically sues. Generally, however, US-US suits over microprocessors appear to be more common than US-Japanese suits. Being in a position to license and then bring suit is preferable to not being able to enforce intellectual property protection at all.

5. *Semiconductor Specific Opportunity Costs.*

When a fabless start-up (fabless refers to companies which do not possess their own fabrication facilities) decides to consign manufacturing to Japanese companies rather than build internal manufacturing capability, it passes up experience in making devices that could bring greater technical independence and could facilitate entry into other product lines.

6. *Foregone Synergies*.
If a company would have built a semiconductor manufacturing facility, it would have the incentive and the capability to develop components besides microprocessors that add value to its systems, which would constitute a competitive advantage in the future.

Because of the American exit from much consumer electronics manufacturing during the 1970s, the US economy and upstream semiconductor industries have clearly incurred long-term costs.

7. *Technical Dependence.*
Reliance on one supplier or small group of suppliers for a critical component incurs the risk of supply cutoff or price gouging.

In the short term, American systems makers are more vulnerable in areas such as LCDs and DRAMs where US manufacturers are weak.

In the long term, concentration of the most advanced manufacturing capability in Japan might give Japanese foundries more bargaining power vis à vis US companies.

8. *Lost political independence*.
If a US company gets involved in a US - Japan alliance it may take a position on policy matters that it would not otherwise take because of a desire to maintain good relations with the Japanese partner.

In this sense, there is a risk that technical dependence would serve to constrain the political positions taken by US companies.

***Benefits*.**

The benefits that accrue to US companies can be largely characterized as access to resources and capabilities that allow American companies to bring products to market more quickly and effectively.

1. *Capital for Survival.*
Some alliances may ensure the survival of small, financially weak US partners. However, even the deep pockets of a Japanese partner do not always prevent bankruptcy.

In case a US start-up does not survive without Japanese backing, whose products do not find a significant market, benefits to the US industry and the economy are likely to be minimal.

2. *Leverage of Resources for Development and Growth.*
The American partner in a US - Japan alliance may leverage the Japanese capabilities to build a leading position in a rapidly growing market.

Linkages between fabless US companies and Japanese foundries yield these benefits when they are successful.

3. *Leverage of Investment Resources*.
Linking with Japanese partners sometimes helps larger US companies leverage investment in fabrication facilities.

For the US company, the benefits of access to a world-class fabrication facility at a cost lower than it would have paid on its own are considerable. This increases the viability of the US firm.

4. *Leverage of Technical Resources.*
American partners also benefit when Japanese companies bring technical resources to the alliance.

5. *Access to the Japanese Market*.
Often it is necessary to trade technology for market access, but a presence in the Japanese market is increasingly essential for long-term survival and growth in the semiconductor industry and the upstream and downstream industries.

6. *Freedom to Focus Resources on High-Return Activities.*
Rather than invest in semiconductor manufacturing, the American partner may be able to focus on building marketing resources and on designing the next-generation chip.

7. *Organizational Learning*.
The experience that the American partner gains can be utilized in the service of long-term strategic objectives. E.g., American telecommunications equipment business is affected by government regulations and knowledge of Japanese government operations and key officials will be useful to the company.

Generalising:
The *costs* of US - Japan semiconductor alliances are largely long-term, potential and difficult to quantify. The most serious costs fall on actors and interests external to the company forming the alliance.

The *benefits* are often more immediate, concrete, easy to quantify and directly appropriable by the US company that forms the alliance.

Over time, the "terms of trade" in semiconductor alliances appear to be improving for US participants. It is now possible to gain valuable resources, such as investment capital, access to the Japanese market, and manufacturing services and know-how.

Strategic alliances constitute an important mechanism for semiconductor technology transfer between the US and Japan. They are manifestations of underlying conditions, not the root cause of what ails the US semiconductor industry.

8.4. *Conclusions*.

The world semiconductor industry will see more alliances concluded between American and European firms, between Asian and American companies, and between European and Japanese corporations.
In addition to the usual bilateral alliances, the number of trilateral and multilateral tie-ups is bound to increase.

Linkage between the US and Japan will probably continue to constitute the bulk of international marriages, which will be extended by alliances with new players in Singapore, Taiwan and Korea.

To maintain world-class competitor, the semiconductor industry needs to maintain the full complement of capabilities, including leading-edge R&D, fabrication, equipment making, manufacturing, some testing and assembly, marketing, and servicing.

The semiconductor industry cannot afford to rely exclusively on the computer industry to drive its growth; it must also ride the wave of growth in consumer electronics, telecommunications, aerospace, and other end-user industries.

Strategic alliances with Japanese companies can contribute to the maintenance of manufacturing and fabrication facilities and to the expansion of market opportunities abroad.
One of the long-term objectives should be not simply the crossing of a market share threshold in the Japanese market but, more fundamentally, the establishment of a permanent foothold in Japan’s industrial structure, a breaking into the Japanese labyrinth of long-term, inter-firm relationships.

Strategic alliances constitute perhaps the best means of establishing a permanent foothold in the Japanese semiconductor market. The prime objective should be to

upgrade America's and Europe's manufacturing and equipment making capabilities.
A high priority is to obtain a reverse flow of technology in forming strategic alliances in the area of manufacturing know-how.
Firms contemplating alliances with Japanese companies should enter with the idea of learning as much as possible and of effectively applying what they learn to the development of new sources of competitive strength.

In the past, too many US firms entered with only short-term quick-fix objectives, whereas the Japanese approached the alliance in a spirit of moving down an organizational learning curve and creating long-term competitive strengths.

The role of strategic alliances has grown enormously over the past and will continue to increase functioning as the most important mechanism for technology transfer in the semiconductor industry.

***9. The position of Europe*.**

9.1. *European weakness.*

The semiconductor sector is the most evident area or European weakness. European producers in 1991 held only 10% of world semiconductor production, compared to 38% for the US and 46% for Japan.

The European producers hold less than 40% of their own market. More than 30% of European use is supplied by foreign companies manufacturing in Europe. The rest is provided by imports. The trade deficit in active components was $4 billion in 1990.

Europe does not have an entrenched position in any segment of the sector. In DRAMs only Siemens remains in the game. Moreover, the equipment that underlies production is dominated by Japan and the US.

The positions shifted in favor of Japan in the 1980s and have shifted somewhat back toward the US in the last several years.

One area of European semiconductor strength is in application-specific and customized chips that are adapted to particular market needs and usually made with processes that are not state of the art.

But the American and Japanese have established extensive production facilities in Europe in anticipation of political restrictions that would close the market to them.

European policy has made things worse because support has gone to those activities that encourage European firms to compete directly with American and Japanese firms in the main industry segment and not to those that would develop European market strength.

Overall, the European producers do not appear cost-competitive, are generally slower and less effective at establishing new product niches and spend less on R&D than their Japanese competitors.
At the moment, the points of leverage and advantage in new product lines are dominated by the Americans and the Japanese.

The Americans create distinct product definitions, which are often produced for them by the Japanese.
The Japanese often then produce next-generation design improvements, which the Americans often then distribute under their own labels.

Part of the European problem certainly lies within European companies, that is in their limited ability to bring new products to the market, but part also lies in the character of the European market that the companies are addressing.

There is seemingly little room for European companies unless they are able to find new and innovative product strategies.

9.2. *Unsuccessful European strategy.*

A European strategy, similar to the Japanese in the 1980s was clearly unsuccessful.

The Japanese restricted FDI and used import substitution to create and promote indigenous suppliers.
The European strategy was one of import substitution through substituting the local production of American companies for imports from them. In essence Europe's policy consisted of trading, i.e. discouraging, imports for foreign direct investment (FDI).

The objective of the Japanese strategy was the creation of a Japanese industry, whereas the European objective was the establishment of a European production base, regardless of ownership.

The Japanese strategy closed the Japanese market to investment by American companies, reserving domestic demand for Japanese companies and forcing US firms to transfer technology to Japanese competitors if they wanted to profit from growth in that market.

The European strategy allowed American companies to earn

a rate of return by investing in Europe without transferring technology to European competitors. Through FDI American companies preempted the developing European market for advanced products that European companies could not yet supply.

Another reason for the weakness of European producers was the fragmentation of the large European market into much smaller national markets, which eliminated the potential for European product specialization. National policies discouraged cooperation between European companies while encouraging them to cooperate with American firms. As a result, US companies captured the benefits of scale that were denied to European firms.

Europe’s difficulties in semiconductors were aggravated by the failure of a promotional policy in the computer industry. The basic European computer strategy was to protect national markets with high tariff walls and to select "national champion" firms that were given favored treatment with direct subsidies and preferential procurement. This strategy was a failure.

The reasons for failure include:
*** Being sheltered from competition often means lessened pressure to stay technologically abreast in a rapidly changing market.**
*** Being pushed by national policy to go head-to-head against IBM in existing markets and applications (rather than identifying and entering new markets) has proved unsuccessful in the computer industry.**
*** Alliances to gain access to new technology with US producers often left European partners stranded with an installed base of orphaned technology.**

The weakness of the European computer industry implied that there was a relatively small demand there for the high-performance state-of-the-art chips that were driving technology development in the USA.

European chip production focused on discrete semiconductors and ICs oriented toward the telecommunications market. European chip-manufacturers placed the emphasis on servicing the needs of local equipment manufacturers rather than competing with foreign producers in the more rapidly developing global markets tied to the computer industry.

The attempts to protect the European semiconductor and computer industries from imports has created a vicious circle.

High tariffs and high costs for imported semiconductors meant higher prices and diminished sales for European computer systems makers.
Diminished computer sales meant a smaller demand for locally produced semiconductors and this meant greater political pressure for protection, and so on.

The solution chosen in Europe was to protect the chip market and to permit free investment within Europe by foreign producers in order to maintain access to leading-edge semiconductor technology developed abroad.

The Europeans continued to target the computer industry directly with little support for the semiconductor industry, while the Japanese promoted the semiconductor industry directly as a means of building strength in the computer industry.

Only in the late 1980s Europe finally began to develop programs to support the semiconductor producers.

9.3. *European reaction to the SCTA.*

Europe reacted negatively to the SCTA because of procedureal, economic and psychological reasons.
The secret bilateral negotiation without consultation with the EC caused procedural damage.
Europe was not consulted because the EC and USA were at the time embroiled over agricultural trade issues and that may have made cooperation on other issues more difficult.

The implementation of export price "monitoring" mechanisms by MITI designed to raise prices in third-country markets caused economic damage.

The implicit message that Europe ceased to be an important player in the international semiconductor industry and could safely be ignored caused psycholo-gical damage to Europe.

With a global market share of 10-12% European producers were considered to be marginal players, complicating for the Americans the already difficult bilateral talks with Japan.

Before the SCTA Europe had access to semiconductors without an artificial price floor.
Unhappy about having the competitiveness of their electronics firms harmed by a price floor that the US Department of Commerce set for Japanese chip sales to Europe, the European Commission filed a formal complaint with GATT.

The GATT Panel concluded that the agreement itself was

permissible under GATT, but the way in which it was enforced was not.
In particular the MITI monitoring of production and export prices constituted a coherent system restricting exports in a manner inconsistent with Article 11 (prohibiting quantitative restrictions both on imports and exports) so that MITI agreed to halt the monitoring of prices to third countries in March 1989.

9.4. *Forms of protection in Europe.*

In February 1989, the European Commission approved a regulation that drastically altered the rules of origin for chips made in the EU. Although a small change, it had very large consequences for the origin assigned to chips produced and consumed in Europe.

Before 1989, the origin of a chip was assigned to the country in which the last substantial process or operation that is economically justified was performed. In practice location of assembly and test was the de facto standard for origin.
Under the new rule, origin is determined by the place of fabrication, or diffusion as it has been called, (this is the process by which electronic circuit elements are etched on the wafer).

The major loser was Japan. About 40 percent of Japanese companies' sales in Europe qualified for national origin based on the old rules, while under the new diffusion standard only 12 percent of sales qualifies for national origin.

American producers gained by the change because their share in European IC sales qualifying for national origin roughly doubled to 50 percent.
Interestingly, US chip producers, not the Japanese, reacted most negatively to the change.
Part of the answer is that the gains were very unevenly distributed. The big losers were Intel which had no European manufacturing and AMD which did test and assembly in Europe but had not invested in costly fabrication lines. In fact some European subsidiaries of US companies lobbied *for* the change in regulation.
Another reason is that the determination of origin internationally virtually took place on the basis of the test and assembly standard, so that the change in Europe seemed to be an open assault on the prevailing mainstream consensus.

The example given by the Americans of the losses suffered was the case of a Japanese printer company, being found guilty of dumping in the EU, that had opted not to use US chips on its printed circuit boards because of the new rules of origin. Japanese producers were faced with the

requirement to use non-Japanese components, not European components. According to the "antiscrewdriver" regulation (designed to prevent circumvention of a dumping penalty through the minimal performance of local assembly of imported parts) a 40 percent minimum level of non-dumped content was required to avoid dumping penalties.
The problem is how to decide the nationality of assembled printed circuit boards for electronic products on which semiconductors have been mounted and in which many parts from many different countries have been assembled.

Two other sets of recent changes promise to create higher walls around the European semiconductor market after 1992.
The first is a recent change in the rules for the tariff suspension program.
The second is the price undertaking that settled the DRAM dumping case, which will be the model for a price undertaking to settle the EPROM dumping case.

No urgent sense of crisis seemed to mark European trade policy in the early 1980s. Formal barriers to semiconductor imports were relaxed a bit. In the 1980s tariff suspensions play a significant role in IC imports. European chip producers began asking for tariff suspensions. For a given period, they permit non-payment of all or some of the duties appicable to imported goods. Goods imported under the suspension arrangement enjoy freedom of movement throughout the Union. It allows enterprises to obtain supplies at a lower cost for a certain period, so that it becomes possible to stimulate economic activity, to improve the competitive capacity and to enable a reduction of consumer prices and to create employment. The use of tariff suspensions became so widespread as to effectively open the European market, reducing the average collected duty to 5 percent of import value and which has been a significant (though not overwhelming) factor in lowering prices in the European market. Some 20 percent of IC imports benefited from duty suspensions.

Despite the increased openness of the European market, resistance to dismantling tariff barriers lingered on. In 1985, as Japan and the USA dropped all tariffs on semiconductors, Europe decided to lower the tariff on semiconductors by only 3 percent to 14 percent, which is still the ruling tariff. These apparent contradictions probably reflected political compromises rather than a purposeful strategy. A certain amount of de facto liberalization was taking place as European equipment producers, struggling to stay competitive with mounting Asian imports, successfully lobbied for tariff suspensions on components where domestic production was nonexistent or technologically backward.

The Commission Communication of September 1989 specifies that the aims of tariff suspensions are to afford EU producers better access to raw materials, semi-finished goods and components that are not available in the Communities.

Tariff suspensions have been relatively frequent in microelectronics, accounting for some 550 cases per year and duties forgone in the order of ECU 600 million. Suspensions are granted mostly for one year, or in some cases for six months. As a general rule they are not to be prolonged systematically. Requests for the suspension of customs duties must be submitted by firms proving that they have unsuccesfully attempted to obtain the goods from the main potential Union suppliers. Requests are not considered when the amount of uncollected customs duty is estimated to be less than ECU 20000 per year for the whole of the Union and will be forbidden where the goods are covered by an exclusivity agreement.

The DRAM dumping investigation instituted in early 1987 was suspended as a consequence of a price undertaking (a confidential commitment) agreed to with Japanese producers in August 1989. The intention of the price floor was to provide a "safety net" for European producers, to encourage them to increase their investments in an environment free of fear that prices will fall below production costs as a consequence of cutthroat Japanese competition. A target of 20 percent of the European market for European-based firms has been mentioned as the desired outcome of the safety net. A single general reference price for all imports from firms signing the undertaking would be calculated and communicated to the Japanese producers on a quarterly basis. Due to pressure from European chip consumers the undertaking set prices at relatively low levels.

The European price floors differ from the American Fair Market Value (FMV) system. The European reference pricing scheme includes a profit margin of 9.5 percent added on full cost, compared with a 8 percent minimum profit margin used in US-constructed cost calculations.
In this respect a distinction can be made between "hard" dumping (selling at prices below even the most efficient producer's full average cost of production) and "soft" dumping (selling at prices below one's own cost, but not necessarily below the cost of more efficient producers). The American system is more stringent in that it attempts to eliminate soft dumping, while the European system is more liberal in that it bans only hard dumping.

However, a defender of the American system might reply that it is more liberal because it permits efficient producers to expand at the expense of less-efficient producers, while the European scheme hinders even the

most efficient exporting firm by setting a price above its cost.

This entire discussion is moot. More important is that an era is beginning in which different regions of the world are setting floor prices for key semiconductors using inconsistent and incompatible pricing formulas.

9.5. *Management of dependence.*

For now Europeans have not found distinctive solutions that will allow them to capture powerful competitive positions that can be translated into standards and proprietary technologies that can be the base of competitive advantage.

If a firm does not have a technology, it can develop technology in house (hierarchies) for proprietary technologies; buy on the open market to assure access to commodity products; and team up with others via joint ventures and networks for projects too expensive for technologies not under a firm's control.

There are no general rules that guide decisions for companies and government when to buy or develop and on what terms. But the objective must be access on a timely basis on terms at least equal to one's competitors.

If the world economy conforms to symmetrically interdependent globalization in which technology flows rapidly across national and regional borders, there might no need for European electronics policies.

However, there is no guarantee that relevant technologies will be available in a timely fashion within Europe. Ideally it would be best to have evolving technology close to home to profit from any spillovers. Therefore, local technological capabilities will need to be nurtured within Europe.

However, this is not realistic. Europe's dilemma is that American and Japanese firms, not indigenous European producers are the primary source of advanced electronics technology.

In the short term Europe cannot hope to re-create under European control the various elements of a sophisticated electronics supply base. Therefore, assuring leading-edge technology becomes a matter of securing access to other regions' supply.

Europe must ensure that European producers have market access to the supply bases of the US and Japan. Diversity of supply is essential to guard against exploitative dependency; several suppliers in at least

two regions ought to be the policy goal.

Europe must settle for maintaining alternative regional sources, maintaining a healthy US - Japan competition by playing suppliers in the different regions off one another.

The question for Europe is how it should manage this dependence.
Should Europe accept imports to maintain lower prices, focusing on users and emphasizing applications know-how, while downplaying concerns about foreign supplies of technology or should Europe restrain imports to encourage local producers, even if that involves penalties for the users employing the products, emphasizing the need for intimate access to rapidly evolving cutting-edge technology?

In the past European policies for the diffusion and use of advanced technology never received the same attention and weight as did producer-oriented support. The policy debate emphasized the production of particular products, not the broad economic gains from widespread adoption of new technologies benefiting users.

The appropriate policy balance between emphasizing user application and promoting directly the development of particular products is very difficult.

The two views outlined are complements. A strong application position can create a foundation for strength in the production of underlying components. There must be a balance between the two.

Strength in semiconductors often reflects the final products and market position of the customers.
Final market position in fact creates semiconductor strength. Final market strengths should be the basis for formulating a strategy to induce innovation in supplier industries.

Highly competitive electronic systems industries require a strong semiconductor industry and a strong semiconductor industry needs strong process equipment and material industries.

A critical issue concerns the terms on which technologies are available. In this respect the concept of "supply base" may be helpful.
The supply base describes the technologies - the parts, components, subsystems, materials and equipment technologies - necessary for product development and production in a range of activities and it describes their interconnections.

The supply base shapes the possibilities confronting users by enabling or deterring access to appropriate technologies in a timely fashion at a reasonable price. The architecture of supply is a tool for helping to determine when dependency is acceptable or dangerous.

When suppliers have the ability to exercise market power or to act in concert to control technology flows, or when markets and technologies are not accessible because of protection, then the architecture of supply can significantly constrain competitive adjustment to the disadvantage of domestic industry.

Such an architecture is emerging today because a small number of foreign suppliers, principally Japanese, are more and more driving the development costs, quality and manufacture of technological input critical to all production.

Europe and the USA share common interests. American suppliers now hold a larger share of the European market than either the European or the Japanese producers.

Both want to avoid the strategic threats posed by the market power of their Japanese competitors and they are working together on a variety of cooperative ventures to address these threats.
E.g., at company level the joint venture between IBM and Siemens may be mentioned and at industry level there are regular talks to develop common positions on trade policy issues, such as on dumping.

Strategic alliances in R&D with US and Japanese firms may also be an effective approach alternative to, or complementary with, the independent EU-based development project.

The EU realizes that nowhere is the common interest in an open trading system more threatened than in semiconductors, where the world seems to be sliding rapidly toward a collection of balkanized regional markets.

9.6. *Technology policy in Europe*.

A growing flow of public subsidies into joint R&D activities in semiconductors has become increasingly central to the European strategy for competing in semiconductors.

The 1983 Megaproject to develop advanced semiconductor technology played a catalytic role in the creation of the joint European Submicron Silicon Initiative (JESSI) launched in 1989. It was later pulled into the framework of the pan-European Eureka R&D initiative established in

1985 which is clearly quite a large semiconductor R&D program.
The main purpose of JESSI was to overcome the technological backwardness with respect to the USA and Japan. It is too early to evaluate its effective impact on technological and market competition in the EU because it only finishes by the end of 1996. However, at this moment it may already be concluded the JESSI is on the right track and the first results have found their way to the market place such as the wafer stepper of ASM Lithography. It seems that JESSI contributes to the strenghtening of the competitive position of the European micro-electronics.

EU technology programs are generally characterized as "pre-competitive", while Eureka technology projects have more immediate relevance to the commercial market place. Another initiative announced in 1984 was Esprit, directed at the collaboration among industrial firms and the academic community. An explicit part of the Esprit program was the encouragement of alliances and collaborations among European companies. EU subsidiaries of American companies with European research facilities have been eligible to participate. But the idea of reciprocity in access to research programs in European talks with the USA has become a major issue in the semiconductor industry.

Increasingly the focus within the European semiconductor industry is the regionalization of R&D subsidies and the active encouragement of pan-European collaboration which implies a shift away from competition among rival national champions. Meanwhile, the EU is embarked on a path toward technological integration, which means a declining use of national R&D programs which favor national companies.

Recently, the European Commission called for a special consultative forum on semiconductor trade within the OECD to establish a plurilateral agreement to achieve deeper integration not only on trade issues, but also on policy issues such as R&D support, procurement and FDI.

10. Recent developments and the future.

To a significant degree competitive success in semiconductors depends upon a dynamic process of continuous innovation, involving advances in technology, markets and production processes.

The principal barrier to achieving this goal was the organizational and geographical separation of innovation and production within the US semiconductor manufacturing systems.

Since the mid-1980s, US semiconductor firms have taken steps to overcome this fragmented manufacturing form, seeking to reintegrate production into the technology-development process.
US manufacturing performance has improved and market share has stabilized.

The changes implemented by US semiconductor firms, in conjunction with equipment suppliers and with the support of SEMATECH and government programs have constituted nothing less than a remaking of the US semiconductor industry.

For the first time since 1985, US firms captured the largest share of the world-wide semiconductor market. In 1992 US-based firms were responsible for 43.8% of worldwide semiconductor shipments while Japanese firms held a 43.1% market share.

This derives as much from weaknesses in the Japanese economy as from refound strength in US semiconductor manufacturing.

1) The recession in the automobile and consumer electronics industries is a key factor in the loss of market share by Japanese semiconductor firms, which continue to buy most of their semiconductors from domestic suppliers. When the recession ends, it is likely that Japanese firms will regain much of the market share they lost since 1992.

2) Of greater long-term concern to Japan is the loss of market share to South Korean firms which have captured 20% of the global DRAM market, at the expense of Japanese firms, forcing the price of DRAMs to new lows.

3) An indication of the increasing competitiveness of US semiconductor producers is the way they have responded to the most recent period of recession. During the past two years Japanese firms cut back on capital investment, while many US producers added to existing fabrication capacity.

This will help ensure large-volume production of the next-generation microprocessors and other design-intensive products introduced in 1993 by US firms.

The costs of developing the factories for future generations of memory chips are so high that companies have begun banding together into different groups, each to attack in its own way the enormous problems posed by fabricating these extremely dense chips economically.

The common theme in industries from aviation, railroad and automobiles to semiconductors, is that their initial

phase was dominated by efforts to improve performance and to lower cost.
A second phase in those industries was characterized by product refinement and diversity, what is now starting to happen in chipmaking. Companies are shifting their use of technology from lowering manufacturing costs to enhancing product lines. All these industries managed to thrive in spite of higher manufacturing costs.

It may not be long before the semiconductor industry plateaus. The pace of transistor integration will decline, and manufacturing costs will begin to soar. In a more mature industry, growth will almost certainly come from refined products in more diversified lines.

Information storage will keep moving forward. Even in the semiconductor industry, maturity can be a splendid asset by giving computer architectures and software time to begin assimilating the great leaps in chip performance.

Semiconductors have been the most productivity-enhancing, life-changing technological revolution since the harnessing of steampower in the 18th century or, in the 19th, of electricity itself.

However, there are signs of two big changes.
1). Within the semiconductor industry itself.
The first half of the 1990s was especially lucrative; sales in 1995 topped $155 billion. Since Christmas 1995, however, demand has fallen below expectations.

There are grounds for expecting a big impact on the shape of the industry. Chips have become just any other commodity. From the point of view of national economies, it matters little where they are made, provided that they are available to be cheaply bought.
What matters more is how they are subsequently used.

2). For the first 20 years or so of micro-electronics, the applications for the new technology seemed obvious. The potential applications seemed as boundless as the human imagination.
But the trouble is that the imagination does have bounds. The computational power has outstripped useful applications for it.
E.g., people are reluctant to buy Microsoft's new operating system, Windows 95, which requires more memory than most home computers currently possess. And consumers seem to have decided, for now at least, to forgo the marginal improvement the software provides.

Moreover, the consumer-electronics industry must now struggle to dream up new "killer applications" as lucrative as personal stereos and video recorders.
The computer is now in the early throes of a new phase of

its revolution, as it beomes more an instrument of communication, less of computation.

A machine that transforms communication impinges far more radically on people’s lives than one that transforms computations. Why mass media, when information can be consumed in individualised packets? It is people’s willingness to embrace it that matters most.
In any case the semiconductor business is about to go through a period of wrenching change.

Last year, 1995, the number of memory chips sold rose 40% and the memory-chip business probably made profits of nearly $30 billion on revenues of $55 billion. Some fabrication plants have been making nearly $1 billion in net profits each year.
More power for less money (power doubled every 18 months and prices halved) was the combination that made semiconductors *the* business.

In the early 1990s, with personal computer demand skyrocketing and memory chips in short supply, the price of basic chips climbed to three times their cost of production and stayed there, defying every established pattern.

Then, December 1995, it all started to go wrong.
First, prices started to tumble. The market price of the most common memory chip, which had been as high as $13 in November 1995, began dropping by more then $1 a month as PC makers dumped excess stocks after disappointing sales during the Christmas season. By March 1996 the price was down to around $9.

In April 1996, things got worse. The Semiconductor Industry Association reported that its "book-to-bill" ratio had dropped to 0.78, its lowest point since 1985. That meant that for every $100-worth of chips the industry was making, shipping and billing, it was only taking orders (bookings) for $78-worth. Since January 1996 orders were below sales.

It was the first time since 1989 that the indicator had gone below 1.0. In February 1996 the ratio was 0.90. This sort of slump sent businessmen to the window ledge to see what was going on there.

Manufacturers started to postpone planned expansion. In the past six months, the Philadelphia semiconductor index, a measure of share prices of American chip makers, has dropped 45%.

For users of chips the fall in chip prices must be welcome.
However, if memory-chip prices continue to fall, the cash

cows used to bankroll expansion into everything from PCs and cars to aerospace will run dry and the cross-subsidisation from semiconductors will have to stop, which could force firms to pull back from some markets. Therefore, to say that no one need worry about falling semiconductor prices, is to underestimate how much a shake-out in the chip industry would matter.

Worldwide semiconductor sales passed $150 billion in 1995, three times what they were a decade ago. By 1997, if growth rates of 1995 were to continue, America's chip manufacturers would be bigger than its steel industry; by 2000, they would be as big as aerospace. By 2040 the world's semiconductor market would be bigger than the world's GDP. Upheavals in such an industry matter.

Despite current weakness in DRAMs, the world semiconductor's market is expected to grow at an average rate of 20% or more for the remainder of the decade, driven primarily by the increasing semiconductor content in electronic end equipment and the emergence of new markets in Asia.

There are initial signs that the market for DRAM memory chips could remain slow for the next two years. Over capacity is the main concern, as more fabs are coming in line with increased supply. Memory prices and its expectations, as forecasted by Texas Instruments, are shown in next table.

Size	1995	1996	1997
4 MB DRAM	$10	$7	$6.5
Per MB:	$2.5	$1.75	$1.62
16 MB	$41	$27	$19
Per MB:	$2.56	$1.68	$1.18

**Next reasons for the price fall may be mentioned.
All industries have downturns. But the chip market is highly unstable, partly because there are few industries that involve such massive fixed costs and partly because demand for chips can change rapidly, while a new fabrication plant can take a year or more to build.**

Such long lead times mean that the supply of chips tends to be sticky: that is, it does not adjust smoothly to price changes or to changes in demand. Last year's investment in chips will produce a big extra supply just as prices are slumping. This will push prices even lower.

The volatilty of the chip market is compounded by manufacturers' high fixed costs. New fabrication plants ("fabs") can cost well over $1 billion.
State-of-the-art tech fabs become obsolete in three to five years; staying ahead in such a business requires a large chip maker to spend vast sums. Last year semiconductor firms spent $30 billion on new fabrication capacity.

To recoup its investment, a semiconductor firm will want to run the plant as near to full capacity as possible. It will not cut production even when demand drops, producing a glut and even lower prices. Conversely, when demand rises, there may be no spare capacity in existing plants, leading to a shortage and soaring prices.

The chip business shares such characteristic market instability with agriculture. Farming is also a business in which supplies adjust stickily to demand because of long lead times.

With the USA mostly out of the memory market since the the late 1980s, and Japan restricting output to avoid worsening the trade row, the result was another overshoot, this time demand outstripping supply so that prices soared. This created the artifically inflated chip prices of the early 1990s.

South Korean firms such as Samsung and the LG (the Lucky Goldstar) Group looked at high memory-chip prices and saw a chance to make a killing. Last year, South Korea overtook Japan as the largest producer of memory chips.

Chip makers are now in closer contact with their customers than they once were. A chip maker can use "just-in-time" manufacturing techniques to keep supplies tied more closely to demand. Electronics firms have cut their average chip inventory from 11 weeks in 1985 to just 3, which should, in theory, restrain massive over-supply.

The industry is geographically dispersed. Today, new entrants are flooding in from Asia. And chips are now being used in more industries than before, making suppliers - apparently - less sensitive to any one business.

However, these changes have not been enough to flatten out the chip cycle. America and Japan still have nearly 80% of the world market between them. The spread of chips into new markets is not what it seems.

Chip manufacturers still make most of their money from just one industry: computers. Computers account for some

60% of semiconductor revenues; mobile telephones account for perhaps another 10%. Nothing else comes close.

Therefore, chips remain vulnerable to the fortunes of the computer business. Both the recent slump in memory-chip prices and the plunge in the book-to-bill ratio have their roots in changes affecting the PC industry. Those changes stem primarily from the rise of Microsoft, a software company.

Last year, Microsoft released Windows 95, which needed twice as much memory capacity. As PC users groaned under the hype surrounding the new program, chip makers were slavering at the thought of the extra demand it required. But nothing happened, or not much. Companies have been slow to buy Windows 95, partly because of associated hardware costs, partly because it is not clear to them how to use the extra software power, and partly because Microsoft has another more powerful, operating system, called Windows NT, in the wings. The result is that many firms have decided to wait and see whether to upgrade and do not buy in the meantime.

Another problem is the heart-stopping price of a new fabrication plant. Chip makers are running up against the physical limits of the technology itself.
Meanwhile the law of diminishing returns seems to be setting in. Between 1984 and 1990, the cost of a fabrication plant doubled but chip makers were able to triple the performance of a chip. They are unlikely to do as well next time. The next generation of fabs will see costs double again by 1998, but this is likely to produce only a 50% improvement in performance.

According to The Economist for firms there are three alternatives.
1) *Team up*.
Rising costs will soon make chip manufacturing unaffordable for single firms. Increasingly, chip makers are sharing the costs of a new fab with customers, competitors and even countries.

2) *Subcontract manufacturing*.
Fabless firms design the chips and then contract the manufacturing out to a "foundry" (a factory without its own design operations).

The advantage for the fabless firms is that they can get into the chip business without having to spend billions on manufacturing. Then, foundries face the problem of the investment cycle, but they can mix and match customers to help spread the risk. Fabless chip firms make up just 1% of the market today, but are expected to have 5% by 2000.

3) *Specialise.*

Separating design from production let companies exploit technology niches while leaving the cost of manufacturing to a contractor.

Firms that survive to produce chips in 5 or 10 years' time are likely to have adopted one or all of these strategies.

The immediate concern is simply to survive the next year or two as new entrants flood into the market. Profits that lured them into the business are no longer there.

10.1. *Possible scenarios.*

I. *Gradual US recovery*.
In this optimistic scenario, the US industry gradually regains a market share, rising above 40% share to 45-50% global share.

A number of conditions are attached to this possibility:
1) **Declining dollar.**
2) **Lower interest rates.**
3) **Increased manufacturing investment and US industry productivity.**
4) **Increased venture capital and long-term corporate investments.**
5) **Better access to Japanese and Asian markets.**
6) **Massive global marketing efforts by US companies.**
7) **Design-intensive technologies increase in value.**
8) **Success of emerging global standards.**

If these conditions improve, US companies will be under less pressure to enter alliances.

II. *Market share equilibrium*.
The US market share would hover between 35 and 40%. This requires more US effort to counterbalance a greater mobilization of resources in Japan and Asia. Conditions 1, 2, and 4 have to show more stability. The use of Asian fabs might expand US market share.

In this "business-as-usual" scenario, the number of US-Japan alliances would continue at current rates and would fluctuate with business and product cycles.

III. *Gradual US decline*.
The US semiconductor industry would lose a small but significant portion of world market share to 20-25% by 2000.

This would result from next factors:
1) **Stronger dollar.**
2) **Rising interest rates.**
3) **Inadequate manufacturing investment by US companies.**
4) **Reduced venture capital and corporate investments.**

5) Opportunity costs in Japanese and Asian markets.
6) Declining global marketing efforts by US companies.
7) Variability in value of design-intensive technologies.
8) Japanese successfully adapt to emerging global standards.
9) Asian fab alliances falter.

IV. *Japanese dominance.*
The US semiconductor industry would lose 2 to 3% each year to Japan, leading to a US share of only 10-15% in 2000.
This sharper decline would result from the same forces at work as in the third scenario but in worse form.

Then US companies have no choice but to enter into alliances with Japanese companies in order to secure manufacturing, design, market access and global marketing. Alliances emerge from weakness, not from strategic calculations and result in accelerating technology outflows.

V. *Pacific dominance.*
Japanese and Asian companies would account for 70-80% of the world market share. American and European producers would be relegated to minority status, with only 15 and 5% market share, respectively.

The conditions for this "doomsday" scenario are:
1) Grossly overvalued dollar.
2) Very high (15-20%) interest rates.
3) Meager manufacturing investments and sharp US productivity setbacks.
4) Market falloff of venture capital and corporate investments.
5) Diminished access to Japanese and Asian markets.
6) Woeful global marketing efforts by US companies.
7) Design-intensive technologies lost through alliances.
8) Japan and Asia leverage global standards.
9) Use of Japanese and Asian fabs accelerates technology leakage and loss of US comparative advantage in product development and standard setting.

The US would be relegated to serving as merely an R&D laboratory for Asia and Japan, with little or no infrastructure for mass manufacturing. The US would become a satellite participant. There would be a massive loss of jobs, a traumatic shake out of the semiconductor industry’s fragmented but dynamic structure.

It may be concluded that the US semiconductor industry today stands closest to the second scenario, an equilibrium model. Or the US industry seems perhaps to be headed to the gradual decline of scenario 3.
The most likely scenario for the US semiconductor industry in the 1990s is that its market share will

stabilize at or close to the current level.

To maintain the status quo, US companies will have to pay greater attention to their competitive fundamentals, including the retention of a viable manufacturing infrastructure.
A continuation of the status quo would be less likely to aggravate potentially volatile trade tensions.

To maintain market share two critical steps must be taken.
1) Given the underlying structural problem of underinvestment in manufacturing technology and equipment, new rounds of investment in the US are required. Continued US government support may be required.

2) The issue of trade relations will grow in importance in the 1990s. US-based firms must increase their share of semiconductor shipments to Japan and other foreign markets to retain their current global market share.

Of great concern is the possibility that US industry will undermine its ability to achieve breakthrough innovations.
In this regard there are two trends emerging in the US.
1) There are some signs that the US is cutting back its commitment to basic research. The percentage of GNP devoted to R&D is in 1991 lower than in Japan and Germany. Several of the major industrial R&D laboratories have reoriented their efforts from basic to applied research.
2) There is a severe shortage of investment capital which drives start-up firms into licensing agreements with offshore foundries of foreign competitors. These impediments can be overcome by increasing the number of production facilities by partnerships and joint ventures by US-based firms.

A final prediction is that Japan will continue to fight neck-and-neck with the USA for number one position, but their cumulative relative weight will be progressively reduced. The market share for Japan and North America is expected to remain fairly constant through the rest of the decade.
The major change will be in the relative positions of the Asia/Pacific region and Europe.
By the start of next decade Asia/Pacific will have overtaken Europe to become the third largest semiconductor producer.
Europe although in fourth place, will have a bigger market share than today, which is expected to grow to 15 percent during this decade.

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