Discussion Paper # 90 - DOF - 7

STRATEGIC ASPECTS OF SEMICONDUCTOR TRADE POLICY

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January 1990

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January 1990

* This paper was written and submitted in December 1989 as a research report by Dr. Flamm who conducted his research at Research Institute of International Trade and Industry as a Visiting Researcher.

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In recent years, continuing trade friction in the international semiconductor industry has been the barometer of increasing stresses on the trading system for high technology goods among industrialized countries. This paper argues that structural changes in the semiconductor industry have made **strategic** issues-- that is, predicting how the actions of others may be affected by one's own choices, and vice-versa-- central to an understanding of these conflicts. The nature of the strategic issues created by the current structure of semiconductor trade and investment is examined. Possible responses to these problems, and the way in which such tensions might be reduced over the long term are analyzed.

Structural Change in the Semiconductor Industry.

Until the late 1970s, international semiconductor trade was dominated by a relatively large and fluid group of relatively young and entrepreneurial American companies, so-called **merchant** chip producers.[1] These firms specialized in the production of leading edge ICs, which were then sold at arms-length to an entirely different set of firms, that is, electronic equipment

[1] The standard source for this history is John Tilton, **International Diffusion of Technology**, (Washington: Brookings Institution), 1971.

producers.

The development of this distinctive semiconductor industry structure in the United States was linked to a number of factors: on the demand side, much was owed to the willingness of the military, the largest consumer of leading edge components in the 1950s and 1960s, to buy expensive products from brand-new firms who offered the ultimate in performance in lieu of an established track record; and the rise of a highly competitive commercial computer industry[a] which was willing and able to buy the most advanced component technology from whomever offered it for sale. Other factors at work included the high degree of mobility within American industry, which made it easy for engineers to leave established firms and start new firms if an existing company was slow to commercialize new developments, the ready availability of venture capital to fund such new spin-off companies, huge federal investments in R&D in the underlying technology base from which companies drew to develop their commercial products, and a first class educational and scientific university infrastructure which fed research and manpower to the electronics industry (again built with large of federal support, and disposed to cooperate with industry as a consequence of the conditions tied to that federal funding).

The semiconductor industry developed quite differently in Europe and Japan. Established electrical equipment manufacturers

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[a] Whose main customer, in turn, for the most technologically advanced products in the 1950s and early 1960s was the U.S. military. See Kenneth Flamm, **Targeting the Computer**, (Washington: The Brookings Institution), 1987, chapter 4; **Creating the Computer** (Washington: The Brookings Institution), 1988, pp. 13-19.

were the primary force driving investment in semiconductor electronics, as they sought to produce cheaper components for use in their electrical product lines. For the most part, semiconductors were developed and produced within existing electrical equipment companies and semiconductor production took place within **vertically integrated** electronics producers.

At first driven largely by demand for use in consumer and industrial products, cost rather than the highest possible performance was the primary force driving semiconductor technology in Japan, which lacked a significant military demand. However, Japan embarked on a program to catch up in computer technology in the 1960s, and development of high performance components was a prerequisite for success in this area. Since the 1960s, both MITI and NTT have invested substantial resources in promoting semiconductor research and development. The focus of these programs was almost always on technology to be used in producing high performance components for use in computer systems. By the end of the 1970s, it became clear that-- combined with large private investments by companies-- these support programs had paid off, and that Japanese companies had arrived at the technological frontier in semiconductors.

From 1980 to 1984, Japanese-based producers made significant inroads into global chip markets, at the expense of both European and American firms' market shares. Trade friction in semiconductors gradually began to increase during this period. After the deep semiconductor industry recession of 1985, a particularly large decline in the U.S. industry's share of world markets was registered, as American firms dropped out of some segments of the semiconductor market. It is probably fair to say that a very sharp increase in trade friction also occurred. This period of friction culminated in the signing of the U.S.-Japan Semiconductor Trade Arrangement in September of 1986. However, instead of ending, trade problems in semiconductors entered a new-- and potentially more difficult-- stage.

Increasing Concentration. The rise of Japanese semiconductor producers coincided with some important changes within the global industry. Some of these changes were ultimately driven by technology.

The semiconductor business in general was becoming much more capital intensive. Packing the maximum amount of circuitry onto a state-of-the-art chip required increasingly expensive manufacturing equipment and facilities. Table 1 shows that the capital costs of a fabrication line for leading edge chips had risen from about 15 percent of the total fabrication cost in the mid-1970s to about half of cost by the mid-1980s, and was projected to pass 60 percent of total cost by the early 1990s. Since much of this equipment was highly specialized-- had little or no scrap value outside of the semiconductor business-- and, due to the continuing rapid pace of technological change, had a relatively short economic life span. Investments in semiconductor manufacturing facilities, therefore, were often difficult to liquidate for more than a fraction of their acquisition cost. Such investments took on the character of a sunk cost. The increasing share of such sunk costs in total manufacturing cost made entry and exit from the industry more expensive and difficult.[3] Even having made the decision to undertake this investment, it typically took a year or more to carry out such a project, adding a further element of risk in a notoriously cyclical market.[4]

Table 1
IC Fabrication Line Costs*

	Mid-1970s	Mid-1980s	Early 1990s
Total Wafer Fabrication Facility Cost (Million $)	30	100	300
Depreciation Share of Wafer Fabrication Cost (%)	15	49	61

*Assumes 4000 wafer starts/week. Source: ICE, cited in R.M. Reynolds and D.R. Strom, "CEM:Process Latitude In a Bottle," **Semiconductor International**, October 1989, p. 123.

In the view of many, the increasing capital intensity of a high volume, state-of-the-art wafer fabrication facility is one causal factor behind increasing concentration within the IC industry, particularly in key mass market products in which competitive success is tightly linked to manufacturing cost.

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[3] The figures in Table 1 refer to a state-of-the-art facility for manufacturing a high volume, mass-produced commodity product. Facilities investments relative to other costs would be substantially lower for a smaller facility, used in producing lower volume, more specialized products. Manufacturing cost would also be a smaller share of product price for such more specialized, non-commodity products.

[4] The world record for bringing up a new plant appears to be held by NMB Semiconductor, which claims that it took only nine months to go from initial groundbreaking on a new fabrication facility to initial production of 256K DRAMs in 1985. See Larry Waller, "DRAM Users and Makers: Shotgun Marriages Kick In," **Electronics,** November 1988, p. 30.

Certainly a trend toward increased industrial concentration is clearly evident in mass market products like commodity memory chips, particularly dynamic random access memories (DRAMS), the single largest value product segment in the semiconductor industry. The top 11 suppliers of DRAMs went from accounting for under two-thirds of open market sales in 1981, to essentially all sales by 1988.[5]

Increasing Importance of Vertical Integration. Another change within the industry was also ultimately driven by technological forces. As the level of integration (the number of circuit elements packed onto the surface on an IC) increased, it became possible to put more and more of the circuitry for an electronic system onto a single IC. Today, in fact, virtually the entire circuitry of an entire complex system, like a computer, can be packed onto one or two chips.

This has led to an important change in the relationship between systems producers and chip manufacturers. In the past, when only relatively small numbers of circuit elements could fit within a single IC, chip manufacturers developed "standard" parts which performed general, "generic" functions that could be designed into more complex-- and proprietary-- systems. Today, however, when an entire system can be integrated onto a single chip, it is no longer economic to take standard "building block" chips and wire them together into a more complex system, since the cost of wiring together the standard components and testing

[5] This statement is based on figures from Dataquest and Nomura Research.

the system so built is prohibitively expensive.[6]

This has meant that a systems designer building a complex electronic system has increasingly had to furnish proprietary design information to the component manufacturer producing the ICs used in the system. This need to transfer proprietary information from designer to component maker has made vertical integration an increasingly attractive option for systems houses. It has also made it difficult for systems designers to use vertically integrated chip producers, who might also be in competition with them in downstream systems markets, to supply them with needed ICs.

In the electronics marketplace, three sorts of changes pushed by the trend toward increasing integration between chip and systems producers have been evident. First, electronic systems companies with existing in-house chipmaking capacity have generally strengthened and increased these activities. Second, so-called "merchant" chip producers have increasingly been integrating downstream into systems production. Companies like Intel and Texas Instruments have increased their involvement in computer systems production, and National Semiconductor recently acquired computer board manufacturer Quadram.[7] Third, chip makers

[6] It is uneconomic because lower density parts are more expensive per circuit element than higher density parts, and because physically making and testing connections between circuit elements mounted on a circuit board is much more expensive than making such connections within the internal microcircuitry of a single IC.

[7] American "merchant" producer Motorola has long been involved in systems production; indeed, semiconductor sales account for only about one-third of its revenues.

and systems houses have been increasingly involved in so-called strategic alliances, relationships in which proprietary design information is combined with chip-manufacturing in exclusive product-based relationships. This may be regarded as a form of "virtual" vertical integration, in which a systems house combines its design know-how with a chip-producer's manufacturing expertise, and in which neither is threatened by potential competition from the other in the specific upstream or downstream markets involved.[8]

Both of these factors-- increasing capital intensity, and the requirement for greater proprietary information transfer between chip producer and systems designer-- may have played some role in the rapid rise of the Japanese chip industry in the early 1980s. Japanese chip production has been dominated by large, vertically-integrated systems houses, and both size and integration may have been increasingly advantageous in the changing environment for the semiconductor industry.

The Growing Importance of Strategic Concerns

While trade friction in semiconductors can be traced back to the 1970s, until recently it represented only a conflict between the semiconductor industries of the countries involved, and did

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[8] The "virtual" terminology is borrowed from the computer industry, where virtual memory is memory space available to a program which may not actually be physically available to the computer system, but whose existence is mimicked by the system so that it operates "as if" such memory was actually available to the program. "Virtual" vertical integration therefore means a mode of operation where the firms behave as if vertically integrated, even though they are not actually linked by common ownership.

not represent a major problem for other industries outside this sector (aside from the potential cost-raising effects that protectionist trade remedies might bring about). This was the case because the semiconductor marketplace was highly competitive.

Throughout the 1970s, for example, European systems companies grew increasingly reliant on chips produced by American semiconductor companies. This posed no threat to their systems business, however, because these merchant chip companies were not in direct competition with their systems products, downstream. Indeed, the intense technological competition among American merchant semiconductor manufacturers meant a continuous stream of new, leading edge products was forthcoming, with prices dropping rapidly as the result of aggressive imitation and competition from the many other merchant chip producers fighting for the same markets. While they may not have been happy about the poor showing of European-based producers (often components divisions within the same companies), this posed no threat to their downstream systems business. Indeed, cheaper components may even have decreased costs and prices, and increased the overall size of systems markets.

In the early 1980s, competition entered a new phase as Japanese companies reached the technological frontier in semiconductors, and entered international markets in force. Initially, this led to even more intense competition in the semiconductor market, and put further downward pressure on chip prices, to the apparent benefit of systems producers. During this period, however, as the chip divisions of some vertically-integrated Japanese companies became the industry's technological leaders in some areas, the first inklings of a new concern appears to have become evident among some European and American systems producers. Because Japanese chip producers were part of larger systems houses, some foreign competitors began to suspect that systems divisions of belonging to the same Japanese companies were getting access to leading edge products before their foreign competitors. While this may have been perfectly natural, insofar as systems divisions and chip-making divisions collaborated in the design of new products, and were therefore able to design them into new systems earlier because of their privileged access to the development process, it put foreign systems houses at a competitive disadvantage in getting timely access to the new part. The resurgence of European support for semiconductors in the mid-1980s, in frameworks like the so-called "Megaproject," and the Esprit program, in some measure reflected these mounting concerns. Similar worries had also begun to take root in the United States.

After 1985, and the exit of many American merchant chip producers from the commodity DRAM market, trade frictions in semiconductors entered a new phase. For the first time, the important commodity memory market (a cost-sensitive input important to a large number of downstream systems products) was dominated by a handful of integrated Japanese companies. At first, such worries seemed a highly academic concern. The Japanese companies producing these products competed ruthlessly against one another, and prices for DRAMs continued to plummet throughout 1985.

In the fall of 1986, the U.S. and Japan signed the Semiconductor Trade Arrangement (STA), which fixed price floors for DRAMs and erasable programmable read-only memories (EPROMs), which accounted for a large share of the commodity memory market, and introduced a price monitoring mechanism for Japanese exports of many other ICs. At first, the STA seemed ineffective, as systems producers shopped for chips outside the U.S. in order to avoid the minimum price floors, the so-called Fair Market Values (FMVs). Bowing to U.S. pressure to end sales at less than FMV prices in so-called third country markets, however, MITI issued "guidance" to Japanese firms in 1987 to cut production of DRAMs to drive prices above the FMVs. MITI also used the export control system to eliminate free access by foreign firms to the Japanese chip "gray market" and to fix a higher price level for memory chip exports.[9]

Memory chip prices subsequently rose far above the FMVs, and stayed well above them throughout 1988 and 1989. This created immediate and severe impacts on chip users outside Japan (users inside Japan appear to have suffered somewhat less, and a significant price differential between the Japanese and other markets apparently opened up in 1988). For the first time, strategic concerns of user industries became part of the trade friction environment, and remain a significant issue today. These strategic concerns have two dimensions: coordination within an

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[9] This is essentially the conclusion of a GATT panel report on a European complaint against MITI controls on export prices for chips shipped to markets other than the U.S.

oligopolistic supplier industry being used to increase collections of monopoly rents from users, and vertically integrated chip producers using their monopoly power to increase their market share in downstream systems products.

Rent Collection by Coordinated Suppliers. The first strategic concern troubling chip users was that a small group of suppliers might use their market power to coordinate production or pricing in order to maximize profits collected on sales to outside customers, rather than compete as aggressively against one another as had been the case in the past. That this was more than a theoretical argument was proven when MITI's 1987 production guidelines successfully reduced DRAM production on a scale large enough to significantly boost DRAM prices. To be sure, this measure was a response to external foreign pressure. But it succeeded in greatly improving the profitability of Japanese DRAM producers, and showed that coordinated action by Japanese producers was feasible and profitable.

Though the subsequent rise in DRAM prices to levels far above FMV levels was undoubtedly in part due to other factors, including a recovery in semiconductor demand, restraint in expanding supply and production capacity by Japanese producers also was notable through mid-1988. By 1989, the concept of "bubble money"-- super-normal profits due to abnormal scarcities of product-- was widely used in Japanese industry circles to describe the profits being made on DRAMs, and estimates of "bubble money" being collected in DRAMs by early 1989 hovered around 3 to 4 billion U.S. dollars per year. This was quite a significant sum in an industry whose global sales in 1988 were only a little over 30 billion dollars. Some evidence of the extreme profitability of DRAM sales was apparent in Toshiba's balance sheets. Toshiba, the largest producer of 1 megabit DRAMs, received only 20 percent of company sales revenues from semiconductor components, yet was estimated to have received half of its FY 1988 operating profit on semiconductors!

More troubling were indications that Japanese companies were determined to put a permanent end to the "excessive competition" that had a triggered rapid price declines in periods of slack semiconductor demand in the past. Beginning in the second quarter of 1988, despite price levels that by all accounts remained vastly higher than average (or marginal) costs of production, producers began to reduce production in order to stabilize prices, rather than cut price in order to continue to sell more chips, as would occur in a competitive industry operating with price well above (an essentially constant) marginal cost. By late 1989, continued production cutbacks by leading Japanese producers appeared to have slowed down price declines in a seriously depressed chip market, and rampant price cutting had not broken out despite price remaining well above the average cost of production for leading Japanese producers.

To be fair, an outbreak of vigorous competition on price might well have pushed prices down to the politically determined floor levels, and provoked another round of recriminations from American chip manufacturers. So profitable restraint on production, and the imposition of the discipline needed to avoid excessive price competition by Japanese companies, could easily be defended as unavoidable consequences of continuing trade friction.

Furthermore, the Trade Agreement put the Japanese government in an unenviable position. If MITI kept chip prices up, the American users complained. If chip prices fell sharply, the American chip producers complained even more loudly, and could be counted on for a sharp political counterattack. It is perhaps understandable, then, that the choice to maintain relatively high chip prices appeared to be the more attractive one.

In any event, with or without MITI's assistance, Japanese DRAM manufacturers seem determined to avoid the unbridled price competition of the past. One way in which this determination has been manifested is in the widespread industry speculation that memory pricing in the future will follow the "bai-rule," rather than the "pi-rule". The "pi-rule" refers to the fact that in the historical past, DRAM prices for each generation of chip had tended to decline asymptotically toward the $3 level as mass production of that generation peaked. Since a new generation of chip was introduced on average about every three years, and each new generation of chip quadrupled the number of bits on a chip, this amounted to a seventy-five percent reduction in the cost of a bit of memory every three years, or an annual rate of decline of about 36 percent per year.[10] The "bai-rule," (bai is the kanji character meaning "doubling") on the other hand suggests that in

[10] Remarkably, this is roughly the estimate of annual decline in memory bit cost produced by analyses of actual historical data.

the future, every new generation chip will approximately double in price as mass production peaks. Following the previous logic, this means a fifty percent decline in bit cost every three years, for an annual rate of decline of about 20 percent, or about fifty percent less than under the pi-rule.

If this scenario comes to pass, it has serious implications indeed for the downstream computer industry. Technological progress reflected in the declining cost of semiconductor memory has been a major contributor to the extraordinary decline in the cost of computing capacity. Computer demand, on the other hand, is quite sensitive to computer price. Some rough but conservative calculations suggest that the growth in the computer market due solely to declining semiconductor cost might change from perhaps 5.5 percent per year, under the pi-rule, to only 3.1 percent per year, under the bai-rule.[11]

Diminished industry growth is not the worst possible scenario for downstream users, however. What should trouble them more is the possibility that differential access to chips could leave them disadvantaged relative to their vertically integrated

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[11] These estimates are produced by noting that the elasticity of computer demand with respect to semiconductor price is approximately equal to the product of the elasticity of computer demand with respect to computer price, times the cost share of semiconductors in computer cost. We have also assumed in this approximation that there are constant returns to scale in computer manufacturing, and that computer price is approximately proportional to computer manufacturing cost. The price elasticity of computer demand is about -1.5, and we have used a conservative figure of .1 as the share of semiconductor cost in computer systems value. Under these assumptions, the pi-rule results in an annual increase in computer demand, all else being equal, of about 5.5 percent per annum, while the bai-rule yields an annual increase of 3.1 percent in computer demand.

competitors.

Downstream Competition by Vertically Integrated Suppliers. Given that upstream chip suppliers are in a position to exercise monopoly power in order to collect rents from chip users, charging chip users a premium price does not maximize rent collection. It is well known that in the case of an intermediate input, like ICs, rent collection by a producer with monopoly power is maximized by integrating forward into the downstream industry (like computers) and collecting the rent in the downstream industry.[12]

In short, if chip suppliers have the technological capability, they can maximize their return by integrating forward into systems industries, like the computer industry, and competing against unintegrated foreign competitors. Indeed, the U.S. market share of Japanese computer companies has risen substantially since 1986, at least in part due to differentials in memory chip cost. Two companies-- NEC and Toshiba-- offered personal computer systems in the U.S. market configured with substantial memory as standard, which were very competitively priced compared to what domestic manufacturers were charging for configurations with comparable memory. Not surprisingly, both NEC and Toshiba PC market shares in the U.S. have risen substantially, at least in part due to the fact that their products were so competitively priced.

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[12] See John M. Vernon and Daniel A. Graham, "Profitability of Monopolization by Vertical Integration," **Journal of Political Economy**, vol. 79, July-August, 1971, pp. 924-5. This is because the user would normally substitute other inputs for the monopolized input as price is raised.

Implications for Policy

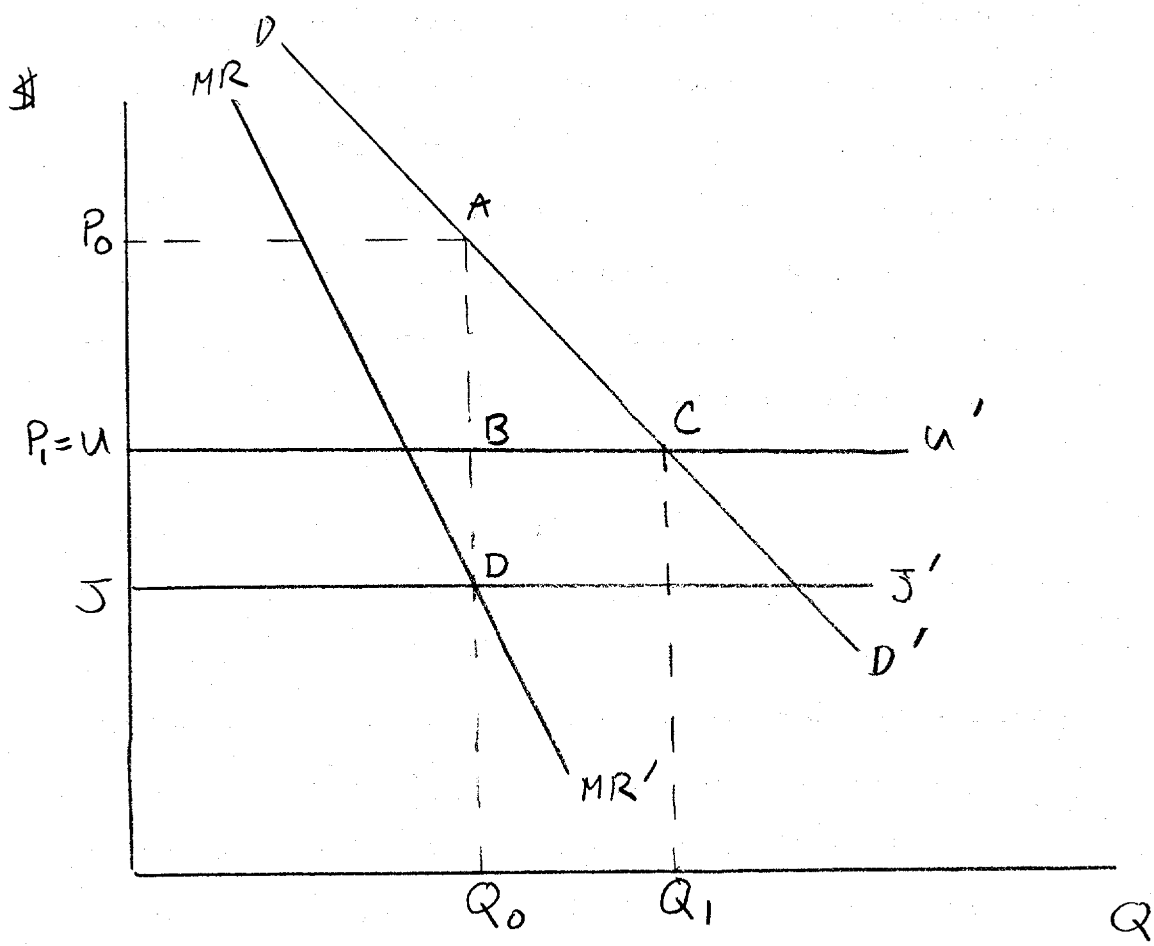
The main point of the above analysis is that trade friction in semiconductors has entered a new stage. Prior to the mid-1980s, sufficient competition within the industry prevented fears of strategic behavior by vertically integrated chip suppliers from being a major worry for systems companies lacking a large, vertically-integrated chip-making capability. Trade friction in semiconductors was largely a series of disputes among chip makers based in different regions.

Since 1985, however, increasing industrial concentration in the production of key products, and the need to transfer increasing flows of proprietary information between chip producers and users, has been coupled with the growing domination of merchant semiconductor markets by vertically integrated Japanese chip suppliers. This has created strategic concerns for other systems companies which, in my view, will play a new and increasingly prominent role in semiconductor trade issues.

Whether or not monopoly power in chip supply is currently being exercised, and whether such hypothetical exercise of monopoly power is undertaken by private firms on their own, or under the guidance of government in order to avoid trade friction which might result from falling prices in an excessively competitive free market, the potential exercise of such monopoly power creates an economic argument for coordinated defensive action by user industries.

The essentials of this argument are spelled out in Figure 1. For simplicity, I have assumed constant returns to scale in chip

Figure 1



production, and have assumed that technological investments and past learning have created a cost advantage for Japanese chip producers, so that their constant cost of production is J dollars (and their marginal and average cost schedule represented by line JJ'). Foreign companies have higher unit costs of U dollars (and their cost schedule given by line UU'). Foreign demand is given by demand curve DD', and marginal revenue by line MR-MR'. If Japanese producers were then able to act as a profit-maximizing cartel, without fear of foreign entry, they would produce output Q0, charge price P0, and collect monopoly profit P0ADJ. If entry and exit in the industry were costless, however, foreign producers could effectively contest the market, and a cap at U placed on price by the threat of entry into a contestable market. I have argued that sunk costs-- in the form of specialized and short-lived capital investments-- are substantial in this industry, however. No individual foreign firm, then is going to be willing to invest in a high cost production facility, then, because in the event of a price war, the cartel can lower its price below U and still fully cover costs, while the high cost foreign producer will be forced to produce at a loss or to shut down and lose an amount equal to its sunk costs.

If the alternative is to face a cartel charging price P0, however, it is clearly advantageous from the viewpoint of the foreign country to subsidize high cost domestic production of output Q1 at cost level UU'. Monopoly profits equal to P0ABP1 which would otherwise have been paid to the cartel are saved, and in addition, consumer surplus equal to triangle ABC is gained. Subsidy of high cost domestic production is superior to passive acceptance of uncontested, cartelized imports.

Thus, viewing trade friction in semiconductors from the perspective of a user industry which believes it faces a foreign cartel supplying it with needed chips (whether or not this is true), leads one to a very different prescription than has thus far been adopted in American semiconductor trade policy. Floor prices which raise costs above those faced by overseas competitors, and might even facilitate coordination among foreign suppliers, are not welcomed. Direct subsidization of entry by domestic producers, while maintaining imports of chips at competitive international price levels, is welcomed. This would seem to be a solution acceptable to both domestic producers and users.

Unfortunately, the introduction of subsidies raises whole new types of difficulties, given the general trend toward reducing the role of direct subsidies for traded goods. Whether or not this may be practical, this line of thinking sets a new direction for further trade friction in semiconductors: a new stage in which user concerns greatly complicate the orderly resolution of trade frictions.

On the other hand, if the objective of subsidy is to facilitate entry into the industry, a creatively formulated subsidy-- one focused on R&D-- might be set up in a way that stimulates entry into the industry, yet does not grant an advantage to national firms at the expense of foreign competitors. Some such policy would be a welcome addition to the trade regime for high technology industries, where future discussion of the rules for R&D subsidies seems inevitable.

Some Final Thoughts on Subsidies in High Technology Industries

Subsidies to high technology industries have been advocated for two quite different reasons. One argument follows even in an economy cut off from international trade, and might be labelled the **domestic social** grounds for policy intervention.

With the growth of technology investment during and after World War II, and the emergence of modern high technology industry, came an economic literature which argued that government support for research was desirable, if it corrected for certain market failures which caused private return to investment in technology to fall short of the full benefit to society. The principal cause for market failure was thought to be the difficulty of an investor in R&D in appropriating, or capturing, the outcome of that R&D for his exclusive and private use. Both case study and statistical research has confirmed the widespread empirical relevance of this argument, and the notion that it is in the more basic research-- rather than the opposite extreme, pure development-- where this gap between private and social return is greatest, and where the case for government support is therefore easiest.

Indeed, international flows of goods and technology greatly complicate matters. Foreign producers may capture some of the return on R&D that otherwise might have been reflected in greater profits for domestic producers or lower prices for domestic consumers, thus reducing the social return. On the other hand, if foreign markets are open to domestic high technology producers, additional technology-based rents collected overseas will increase national income, and increase the social return. In principle, it is entirely possible for an investment in R&D to be socially worthwhile even if **none** of the production of the product embodying the technology is undertaken by national producers, if the benefit to consumers resulting from a better or lower-priced product exceeds the cost of the R&D (though ensuring that any rent on the superior technology is collected by domestic producers is obviously a more desirable outcome).

The possibility of collecting a rent on the use of superior technology from foreign consumers (or avoiding payment of such a rent) raises a second grounds for government intervention. If national policy can create a situation in which a technology-based rent can be secured for national producers, national income and the standard of living is increased. This may be called the **strategic trade** rationale for intervention in high technology industries. It is strategic in that it is based on the assumption that a country's policies can have a significant impact on the terms of international trade or investment, and requires that the responses of other countries to one's own policy be considered.

The strategic trade argument for intervention does **not** rely on the existence of technology rents. A rent based on monopoly power protected by economies of scale, or large sunk costs of any sort, or learning economies is also fair game as a source of rents, and grounds for inspiring government intervention that might secure it (or prevent it from being collected).

The fact that national security was an important motive for large-scale investment in technology further complicates discussion of policy regimes, since rationales for policies can be constructed with either economic or non-economic motives. When one is under attack, the other can be used as reinforcement.

The upshot is that for all of the above reasons, it seems inevitable that governments will be highly involved in national investment in technology, and technology-intensive industries. The multiplicity of motives means that such involvement cannot be regulated-- in an operational way-- by any rules that rely on restricting policies aimed at some forbidden motive, and tolerate other "acceptable" motives.

The challenge, then, is to propose some way of neutralizing subsidies to R&D as tool of rent-collecting strategic trade policy, yet preserve the ability of governments to engage in socially beneficial public investment in R&D. The concept of reciprocity in R&D-- permitting firms from other countries to join one's subsidized research programs in exchange for one's own firms being permitted to join in another country's R&D projects-- would seem an important step in that direction. Further exploration of how such bilateral or multilateral reciprocity in industrial R&D subsidies might be negotiated would seem an important subject for those interested in preserving an open international trading system.