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Japanese Competition in Semiconductors, 1980-1995**

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Abstract

The transistor was an American invention, and American firms led the world in semiconductor production and innovation for the first three decades of that industry's existence. In the 1980s, however, Japanese producers began to challenge American dominance. Shripping cries arose from the literature of public policy, warning that the American semiconductor industry would soon share the fate of the lamented American consumer electronics business. Few dissented from the implications: the only hope for salvation would be to adopt Japanese-style public policies and imitate the kinds of capabilities Japanese firms possessed. But the predicted extinction never occurred. Instead, American firms surged back during the 1990s, and it now seems the Japanese who are embattled. This striking American turnaround has gone largely unremarked upon in the public policy literature. And even scholarship in strategic management, which thrives on stories of success instead of stories of failure, has been comparatively silent. Drawing on a more thorough economic history of the worldwide semiconductor industry (Langlois and Steinmueller 1999), this essay attempts to collect some of the lessons for strategy research of the American resurgence. We argue that, although some of the American response did consist in changing or augmenting capabilities, most of the renewed American success is in fact the result not of imitating superior Japanese capabilities but rather of taking good advantage of a set of capabilities developed in the heyday of American dominance. Serendipity played at least as important a role as did strategy.

Journal of Economic Literature Classification: L1, L5, L6, N6

Introduction.

The transistor was an American invention, and American firms led the world in semiconductor production and innovation for the first three decades of that industry's existence. In the 1980s, however, Japanese producers began to challenge American dominance. Shrill cries arose from the literature of public policy, warning that the American semiconductor industry would soon share the fate of the lamented American consumer electronics business. Few dissented from the implications: the only hope for salvation would be to adopt Japanese-style public policies and imitate the kinds of capabilities Japanese firms possessed.¹

But the predicted extinction never occurred. (See Figure 1.) Instead, American firms surged back during the 1990s, and it now seems the Japanese who are embattled. This remarkable American turnaround has gone largely unremarked upon in the public policy literature. And even scholarship in strategic management, which thrives on stories of success instead of stories of failure, has been comparatively silent.²

¹ A contemporary exception is Langlois *et al.* (1988).

² The exceptions include Macher, Mowery, and Hodges (1998b) and Afuah (1998).

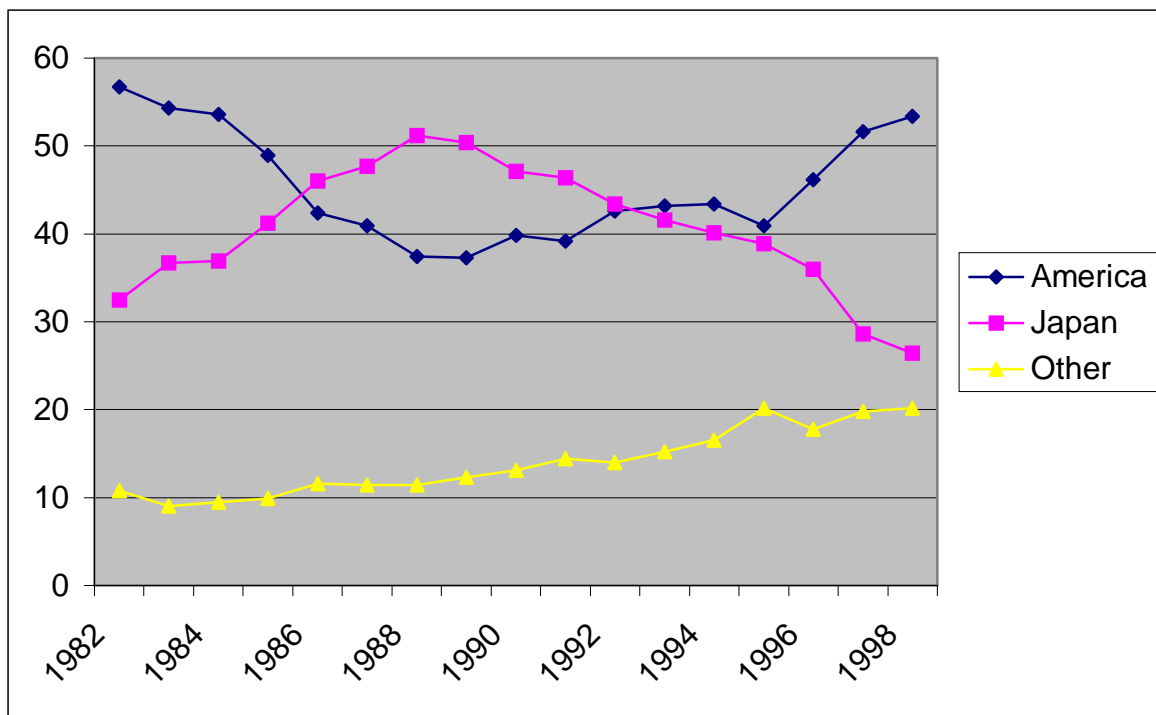


Figure 1
 Worldwide semiconductor market shares (in percent), 1982-1998
 Source: [Semiconductor Industry Association](#)

Drawing on a more thorough economic history of the worldwide semiconductor industry ([Langlois and Steinmueller 1999](#)), this essay attempts to collect some of the lessons for strategy research of the American resurgence. We argue that, although some of the American response did consist in changing or augmenting capabilities, most of the renewed American success is in fact the result not of imitating superior Japanese capabilities but rather of taking good advantage of a set of capabilities developed in the heyday of American dominance. Serendipity played at least as important a role as did strategy.

The origins of American capabilities.

For a variety of reasons, both political and strategic, AT&T chose to offer easy intellectual-property access to what is perhaps the most important and fertile commercial invention of the century. Firms of all shapes, sizes, and national origins were able to license the transistor for a nominal fee. Bell Labs even provided some early seminars and technical assistance in producing the device. Perhaps most important, Bell Labs personnel soon found themselves in demand from companies wishing to develop transistor technology, and their departure initiated the pattern of defection and spin-off that continues today in the U.S.

For example, William Shockley left Bell Labs in the early 1950s for the San Francisco peninsula, where he founded Shockley Semiconductor Laboratories. Although his enterprise was never a commercial success, eight of Shockley's team defected in 1957 to found the semiconductor division of Fairchild Camera and Instrument Corporation, an organization of seminal importance in the industry. Largely through the efforts of Jean Hoerni, one of the eight defectors, Fairchild developed the planar process, a technology that allowed large-scale batch production of transistors. Almost immediately, Hoerni's colleague and fellow defector Robert Noyce would extend the planar process to the fabrication of multi-transistor devices — integrated circuits (ICs). By 1968, Noyce and others had left Fairchild to found the next generation of semiconductor firms.³

A significant feature of the transition from discrete transistors to the IC was the disappearance of the vertically integrated American electronics companies that had led in

the production of vacuum-tubes and that had been able to stay in the race during the discrete semiconductor era. The market shares of those firms declined in the face of new entrants and the growth of relatively specialized manufacturers like TI, Fairchild, and Motorola. By 1965, the vertically integrated systems firms had fallen from the top five slots in American semiconductor sales, and by 1975 all but RCA had fallen off the top-ten list (Mackintosh 1978, p. 54).

Why did the vertically-integrated electronic system firms do so poorly in this era? Wilson, Ashton, and Egan (1980) point out that the new leaders were either specialized startups or multidivisional firms (like TI, Fairchild, and Motorola) in which the semiconductor division dominated overall corporate strategy and in which semiconductor operations absorbed a significant portion of the attention of central management. By contrast, the semiconductor divisions of the integrated system firms were a small part of corporate sales and of corporate strategy, thereby attracting a smaller portion of managerial attention and receiving less autonomy.

This is consistent with the literature of management strategy urging corporations to cultivate their “core competences” and to recognize that deviation from these competences is risky (Teece 1986, Prahalad and Hamel 1990). Indeed, recent evidence suggest that specialized competence is important not so much in the core technology itself as in the complementary activities necessary to transform the technology into highly demanded products (Christensen and Rosenbloom 1995). Granstrand, Patel, and Pavitt (1997) argue in general that firms should not try to limit their core competences but

³ As Saxenian (1994) and others have argued, the localization of many of these firms on the San Francisco Peninsula created the kind of industrial district discussed by Alfred Marshall (1961),

rather should strive to widen those competences while retaining focus in complementary and downstream activities. Gambardella and Torrasi (1998) show that electronics firms in the 1980s did better when they narrowed their product focus while expanding their technological competences. Such product specialization is arguably of even greater value when market and technological opportunities are expanding rapidly along a well-defined trajectory (Patel and Pavitt 1997, p. 153). American merchants in the integrated-circuit era arguably followed this advice: they expanded their technological competence in semiconductor design and fabrication while limiting their product diversification (relative to the large system houses) in a way that was shaped by the pattern of end-use demand. As we will see presently, however, the product diversity of American merchants did grow over time, to an extent that was to make them vulnerable to a challenge from even more narrowly focused Japanese firms wielding wide technological capabilities.

The price advantage of the integrated circuit compared with transistors assured a relatively rapid diffusion of the new technology. It did not, however, immediately create major shifts in the electronic-system industries. During the first half of the 1960s, the methods for IC manufacturing were still under development and the technical characteristics of the ICs were limited, particularly for use in analog circuits.⁴ But the technical capabilities of ICs were ideal for digital circuits, the major customers for which were the military and the computer industry. Early military and space procurement

generating a self-reinforcing system of external economies.

⁴ Analog circuits involve the continuous variation of current or voltage, in contrast to the on-or-off character of digital circuits.

hastened American firms down the slopes of their learning curves.⁵ And the government insistence on second sourcing sped the diffusion of IC technology. As IC prices fell, however, civilian uses, especially for the computer, quickly came to dominate government procurement. (Table 1.)

Markets	1962	1965	1969	1974	1978
Government	100%	55%	36%	20%	10%
Computer	0	35	44	36	38
Industrial	0	9	16	30	38
Consumer	0	1	4	15	15
Total U.S. domestic shipments (millions)	\$4	\$79	\$413	\$1,204	\$2,080

Table 1
End Use Shares of Total U.S. Sales of Integrated Circuits and Total Market Value
1962-1978

Source: Borrus, Millstein, and Zysman (1983, p. 159)

The 1960s was a period of rapid growth for the American computer industry. The leading firm, IBM, had built up its position during the 1950s by relying heavily on outside suppliers. By 1960, however, IBM had created its own components division, which geared up to make semiconductors for the phenomenally successful IBM 360 Series, announced in 1964. By the 1970s, IBM's dominance in computers had made it the world's largest producer of ICs. Thus the vertical division of labor in the United

⁵ Along with Westinghouse and RCA, Texas Instruments participated in the Minuteman II Program, the first major military use of ICs (Kleiman 1966, p. 195; Levin 1982, p. 62). And, while shunning military markets, Fairchild was the major IC vendor to NASA for the Apollo Project (Levin 1982, p. 62).

States became markedly different from, and more diverse than, that in Europe and Japan.⁶ Many small, highly specialized merchant firms dealing with relatively autonomous systems companies stood along side a handful of large, vertically integrated captive producers.⁷

Merchant semiconductor firms faced basically two options. One class of product strategies involved making high-volume standard products, notably memories. Despite IBM's moves to covert from ferrite-core to semiconductor memory, this market continued to be relatively small until 1972. In that year, Intel's 1003 DRAM became the best-selling IC in the world, accounting for more than 90 per cent of the company's \$23.4 million in revenue (Cogan and Burgelman 1989). The other class of product strategies involved attempting to use the rapidly growing complexity of ICs to create differentiated products. For a time, American firms were able to do well with both sets of strategies.

The Japanese challenge.

During the 1970s, the integrated circuit reinforced American dominance of the international market for semiconductors. The U.S. held a two-to-one overall advantage over Japan in market share in semiconductors and a better than three-to-one advantage in integrated circuits (Braun and Macdonald 1982, p. 153). A decade later, as Figure 1 suggests, Japan had overtaken the U.S. in semiconductor market share.

⁶ As Gavin Wright (1997, p. 29) has argued, the “coexistence and complementarity of large and small technology-based firms has been a persistent feature of the US in major twentieth century industries.”

⁷ The other major American captive producer was AT&T. These two American captives also behaved differently from their integrated counterparts overseas in that they generally refrained from selling on the merchant market at all — because of legal constraint in the case of AT&T and of company policy in the case of IBM.

The loss of American dominance is striking. How and why did this happen? The answer is to be found in the dynamics of competition between American and Japanese companies in the new generations of IC products introduced beginning in the late 1970s. This competition involved issues of productive efficiency, investment rates and timing, and design strategy. The success of Japanese companies was aided by the nature of end-use markets in Japan, the timing of market developments, and the patterns of investment by American and Japanese companies.

The vitality of the American IC industry during its period of dominance was its intense technological competitiveness, supported by its industrial structure. That structure was one in which relatively small, often vertically specialized firms played a major role. Among the benefits of this structure were flexibility, focus, and the ability to take advantage of the “external economies” of participation in technological and geographic networks like Silicon Valley (Saxenian 1994; [Langlois and Robertson 1995](#)). Almost from its origins, the industry had been oriented toward growth rather than toward profit margins. Indeed, the profitability of the industry collectively ran below the average for American manufacturing.⁸ The the industry maintained prosperity through the growth of product markets, a process that required continual investment in physical capacity and in research and development. This meant that American IC companies could not generate large cash reserves from retained earnings; moreover, as these companies were not typically divisions of larger organizations, they could not benefit from intraorganizational transfers of capital. The result was that, during periodic industry downturns, the industry reduced investment spending and laid off workers; in the upturns,

the industry delayed in committing to new plant, which led to capacity shortages.⁹ In Japanese firms, IC production occurred within a vertically integrated structure that allowed Japanese firms to mobilize internal capital resources to make investments in the IC industry in a way that U.S. companies could not.

In addition, the very wealth of product possibilities offered by the rich technological trajectory of the IC and the planar process meant that American firms rationally directed their energies as much — or more — to product innovation as to process innovation. By focusing on the task of reducing the process specification for the next stage in the industry's technological trajectory while selecting a mass-produced and potentially standard product, a potential challenger could make significant gains.

The structure and capabilities of Japanese industry thus led naturally to a two-pronged strategy for challenging American dominance: investment in capacity and investment in manufacturing quality. This left the problem of identifying which products were vulnerable to a challenge. Hindsight makes it obvious that the emerging dynamic random-access memory (DRAM) of the early to mid-1970s was the most attractive market to challenge. At that time, Japanese producers could certainly have concluded that the DRAM market would be suited to the Japanese approach to manufacturing. The

⁸ See Braun and Macdonald (1982, p. 148) for net earnings after tax as a percent of sales for 1967-77.

⁹ American firms did, of course, have recourse to the arms'-length capital markets. And most economists would see this chronic "undercapitalization" of the industry as a sign that capital markets had "failed." In fact, of course, arms'-length capital markets and the internal capital markets of multidivisional firms are both institutions with pluses and minuses, and neither is sensibly judged against an abstract ideal standard. As we will see, the decentralization and independence of American firms served the industry well in many circumstances, both early and late in our story. But, because of what one might generally view as transaction-cost problems, arms'-length financing may be less adept in smoothing cyclical fluctuations than is internal financing. We include in this venture-capital financing, which is, in any case, typically used for start-up capital rather than for ongoing capitalization of mature businesses.

potential for the DRAM to become a standardized, mass-produced product had already been demonstrated by Intel's 1003, the 1K DRAM that established the market.

American firms continued to dominate in the early — 1K and 4K — DRAM markets. But an industry recession delayed the American “ramp-up” to the 16K DRAM, which appeared in 1976. Aided by unforeseen production problems among the three leaders, Japanese firms were able to gain a significant share of the 16K market. By mid-1979, 16 companies were producing DRAMs, and Japanese producers accounted for 42 per cent of the market (Wilson, Ashton and Egan 1980, pp. 93-94). (See Table 2.) The opportunity opened for Japanese producers in the 16K DRAM market had proven sufficient for them to advance to a position of leadership in the 64K DRAM. Their success relied upon manufacturing advantage and price-cutting. The Japanese fixed early upon a conservative design for their 64K DRAMs, which allowed them simply to scale up existing process technology. By contrast, the American firms insisted on radical new designs and new process technology, which increased development times and startup problems (Borras 1988, p. 144). As a result, Intel, Mostek, and National encountered production difficulties, giving Japanese firms a head start down the experience curve.

Device	Maximum Market Share (%)	
	United States	Japan
1K	95	5
4K	83	17
16K	59	41
64K	29	71
256K	8	92
1M	4	96
4M	2	98

Table 2
Maximum market share in DRAMs by American and Japanese companies, by device.
Source: Dataquest, cited in Methé (1991, p. 69)

Japanese dominance accelerated in the 256K (1982) and one-megabit (1985) generations. The scale up of 64K DRAM production had caused a very rapid reduction in price, which, combined with the general recession in the U.S. industry in 1985, caused all but two American merchant IC companies to withdraw from DRAM production¹⁰ (Howell *et al.* 1992, p. 29). In 1990, American market share had fallen to only two per cent of the new generation 4-megabit DRAMs.¹¹ (See Table 2.)

¹⁰ The exceptions were Texas Instruments, which produced in Japan, and Micron Technology, which produced in Idaho.

¹¹ These figures do not take into account the sizable captive production at IBM and AT&T.

As had been the case in the rise of the American semiconductor industry, the pattern of end-use demand was crucial in shaping the bundle of capabilities that Japanese industry possessed — as well as in narrowing and limiting the choices the Japanese firms had open to them. In this case, that end-use demand came largely from consumer electronics and, to a somewhat lesser extent, from telecommunications. Consumer demand helped place the Japanese on a product trajectory — namely CMOS ICs — that turned out eventually to have much wider applicability. And NTT’s demand for high-quality memory chips for telecommunication switching systems helped nudge the industry into a strategy of specialization in high-volume production of DRAMs.

Japan was without a significant military demand that could provide a market to support specialized high-performance devices. Japanese computer manufacturers had attained a moderate success, with 1973 production of ¥472 billion (\$2.15 billion). Nonetheless, the consumer electronics market of that year was far larger at ¥1,685 billion (\$7.66 billion). Consumer electronics accounted for one half of all electronic equipment production in Japan in 1973, a share that was to remain almost constant throughout the 1970s despite a 50 per cent growth in the overall size of production.

The particular consumer product of greatest relevance in the early years was the desktop (and eventually hand-held) calculator. Although this product may seem mundane, it created a very large demand for ICs: in the early 1970s, nearly 50 per cent of the Japanese IC market went for desk-top calculators (Watanabe 1984, p. 1564). Calculators thus provided Japanese firms with a “product driver” that could be used to fund large-scale production of ICs (Borror 1988, p. 124). More significantly, perhaps, the calculator market started Japanese firms down the technological trajectory of CMOS

production.¹² American firms favored the alternative NMOS technology for the early generations of DRAMs, largely because of its (initially) lower cost and because of conservatism about the technological risks of CMOS. Japanese firms chose to develop expertise in CMOS because its lower power consumption — useful in portable devices — had offsetting benefits in calculators and other consumer applications. But a technological change in the lithography process canceled out the cost advantage of NMOS, and CMOS turned out to have a steeper learning curve. By 1983-84, the cost of CMOS had fallen below that of NMOS, and CMOS quickly became the clear technological choice for almost all applications. The Americans thus found much of their previous experience with NMOS had become obsolete, and that they lagged behind the Japanese in CMOS.

The American resurgence.

The American resurgence reflects a combination of several factors of varying importance.

These include:

- A renewed emphasis on manufacturing and some success in improving productivity;
- Organizational innovation and specialization, allowing the American industry to take advantage both of its own structural advantages and of global manufacturing capabilities; and, relatedly and most significantly,
- A favorable shift in the importance of those products in which American firms have specialized.

¹² The remainder of this paragraph follows Ernst and O'Connor (1992, p. 66).

As we saw, Japanese firms had been nudged by the character of the demand they faced onto the technological trajectory of CMOS — a technology that was to prove superior in cost and performance dimensions in most applications. In 1988, CMOS represented about 40 per cent of the value of IC production; by 1994, it was responsible for 80 per cent of production value (ICE 1995). Because American firms had concentrated on NMOS technology, they lagged in converting to CMOS, which meant that the American companies were engaged in a process of “catch up” with their Japanese competitors in process technology. This seemed an insurmountable problem, as most American companies feared that DRAM production was the only means of improving or “driving” the state of the art in CMOS technology. In the end, however, this fear proved groundless. American companies were able to make CMOS circuits with sufficient quality, performance, and transistor counts to meet the competition using experience with logic chips and specialized memory devices such as SRAMs.¹³

What evidence is there that American firms improved their manufacturing productivity significantly? One piece of indirect evidence is that American firms were able to hold their market shares in a number of product segments, including application-specific integrated circuits (ASICs), where American and Japanese companies compete nearly head-to-head.¹⁴ There is also more direct evidence.¹⁵ One of the factors driving

¹³ In part, the claim that the production of DRAMs was necessary as a process driver confused the properties of DRAMs with the fact of volume production. As microprocessors and other non-memory chips began to be produced in greater volume (because of the growth of the personal computer industry), those devices were able to serve as process drivers (Robertson 1997). Indeed, microprocessor chips are in many ways more complicated than RAMs. They typically require more layers, which helped give American firms, and their American equipment suppliers, advantage in (among other things) the complex technology of interconnecting levels (Langlois 2000).

¹⁴ Even here, American firms tend to specialize in the standard-cell approach to ASICs, which is more design-intensive and less manufacturing intensive than the linear and gate arrays favored by the

the success of Japanese firms in memory products in the early 1980s was the higher quality of the chips they produced. For Japanese chips, defect rates — the fraction of chips that prove to be defective — were probably half to one tenth the rates for American products. By the second half of that decade, however, American firms had dramatically increased expenditures for quality control, imitating Japanese practices such as Total Quality Management (TQM), greater attention to preventive maintenance, and automated process control and monitoring. By the early 1990s, American manufacturers had probably begun to match the defect levels of their Japanese counterparts. Intel reportedly reduced its defect rate by a factor of ten (Helm 1995). There is also evidence that American firms have improved manufacturing yield rates and direct labor productivity since the early 1990s.¹⁶ This represents a closing of the gap, but it doesn't mean that American fabs have reached the levels of Japanese or even Taiwanese fabs, in part because American fabs operate at smaller scales on average and cannot take as much advantage of the economies of large production runs.

Nonetheless, the Americans's improved manufacturing capabilities were more than adequate in view of favorable structural changes and demand shifts. The abandonment of the DRAM market by most American firms — including Intel — was a dark cloud with a bright silver lining. When Intel led the world industry in almost all

Japanese. Between 1989 and 1994, however, this specialization diminished somewhat as American firms lost two percentage points of share in standard cells but gained a point in linear and gate arrays (ICE 1990, 1995).

¹⁵ The remainder of this paragraph follows Macher, Mowery, and Hodges (1998a).

¹⁶ According to one study, the yields of American firms increased from 60 per cent in 1986 to 84 per cent in 1991. The yields of Japanese firms increased over the same period from 75 per cent to 93 per cent, implying that American firms narrowed the gap in yield rates from 15 per cent to nine per cent. (US GAO 1992).

categories, it and many of its American counterparts faced a full plate of product alternatives. With the elimination of mass memory as a viable market, these firms were impelled to specialize and narrow their focus to a smaller subset of choices. As we saw earlier, a relatively narrow product focus coupled with a deepening technological competence can be an extremely successful strategy, as it arguably was in the early days of the industry. It is also, indeed, the strategy that Japanese firms leveraged to success in DRAMs.

The areas in which American firms concentrated can generally be described as higher-margin, design-intensive chips. For such chips, production costs would not be the sole margin of competition; innovation and responsiveness would count for more. And innovation and responsiveness were arguably the strong suit of the “fragmented” American industry. As Nelson and Winter (1977) and others have argued, a decentralized structure permits the tying out of a wider diversity of approaches, leading to rapid trial-and-error learning. And the independence of many firms from larger organizations permits speedier realignment and recombination with suppliers and customers. Building on existing competences in design (especially of logic and specialty circuits) and close ties with the burgeoning American personal computer industry, American firms were able to prosper despite the Japanese edge in manufacturing technology.

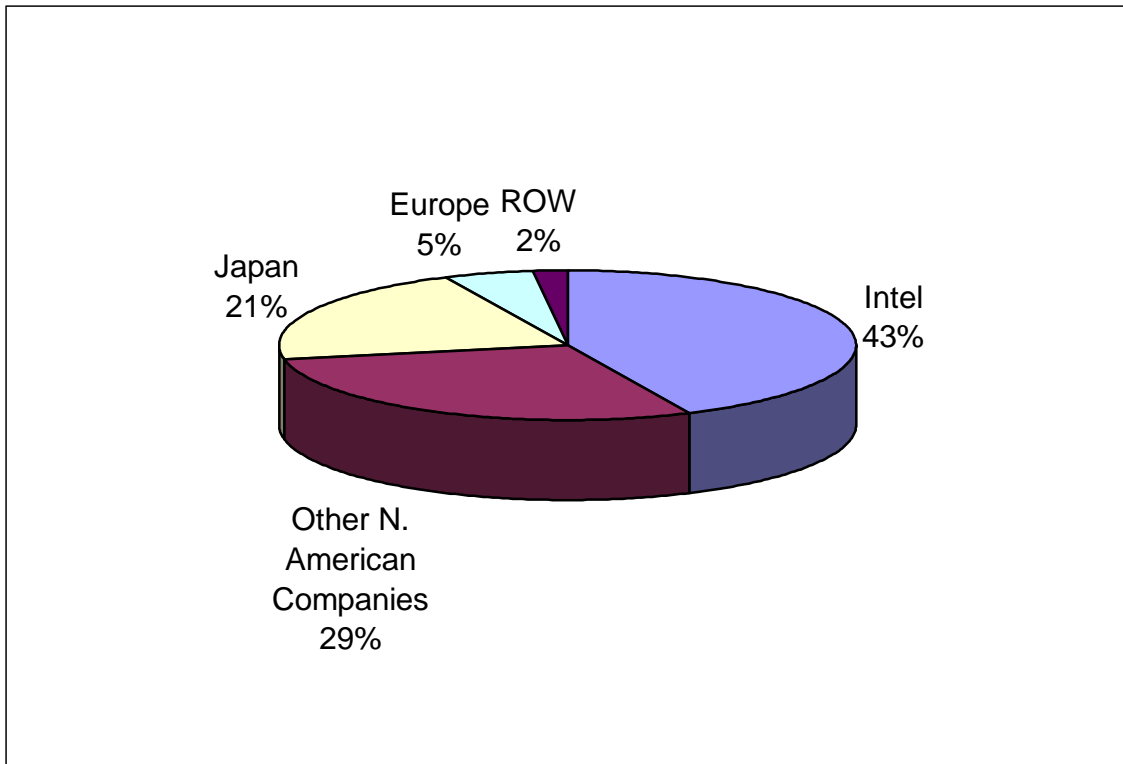


Figure 2
 1996 MOS MPU, MCU, and peripherals Production (percent).
Source: ICE (1998).

Product design has once again become a major determinant of competitive outcomes. This is true not only in the area of custom logic chips and ASICs but — perhaps most importantly — in microprocessor unit (MPU) and related segments, also called the microcomponent (MCU) segment.¹⁷ Between 1988 and 1994, a period in which merchant IC revenues grew by 121 per cent, MPU revenues grew much faster than did memory revenues (ICE 1998). This evolution of the product mix in the industry has strongly favored American producers. In the microcomponent portion of the chip market,

¹⁷ This segment includes not only microprocessors, but also microcontrollers (less sophisticated microprocessors that are used in embedded applications) and related “support” chips, such as memory controllers, that are necessary to assembling a microprocessor system.

American companies accounted for 72 per cent of world production in 1996, compared with a 21 per cent share for Japanese companies. (See Figure 2.)

The importance of the microprocessor segment has meant that a single company, Intel, is responsible for much of the gain of American merchant IC producers. In 1996, Intel accounted for 43 per cent of world output in the microcomponent market, led by its strong position in microprocessors. (See Figure 2.) Intel's strategy for recovery, begun in the 1980s, has proven remarkably successful (Afuah 1998). In the late 1980s, the firm

<i>Company</i>	<i>Revenues</i>
Intel	22,675
NEC	8,271
Motorola	6,918
Toshiba	6,055
Texas Instruments	6,000
Samsung	4,752
Hitachi	4,649
Philips	4,502
STMicroelectronics	4,300
Siemens	3,866
Fujitsu	3,866

Table 3.

Estimated 1998 semiconductor revenues (\$ million).

Source: Dataquest, cited in *Electronics Times*, January 11, 1999, p. 3.

consolidated its intellectual-property position in microprocessors by terminating cross-licensing agreements with other companies and, more importantly, began extending its first-mover advantage over rivals by accelerating the rate of new product introduction. These developments pushed Intel into the position of the largest IC producer in the world,

with 1998 revenues of \$22.7 billion — more than the next three largest firms combined. (See Table 3.) Although Intel dominates the microprocessor market, it is not entirely without competitors; and it is significant that its principal competitors are also American companies.

The success of American firms in microprocessors and related chips has been reinforced by trends in end-use demand. In 1989, computer applications took 40 per cent of merchant IC sales, followed by consumer and automotive applications at 28 per cent.¹⁸ By 1996, the respective shares were 50 per cent for computer and 23 per cent for consumer and automotive applications. The world-wide changes have led to increasing specialization. Between 1989 and 1994, North American use of ICs for computer applications soared from 15 to 24 per cent of the total value of world merchant sales, while the Japanese IC market for consumer applications fell from 13 per cent to 10 per cent of world merchant sales. Thus, in contrast to rough parity (15 versus 13 per cent) in 1989, an enormous gap has opened between IC demand for consumer and computer applications in the Japanese and American markets. Keep in mind that these figures are in terms of revenue not physical units, and much of the reversal of American fortunes has to do with the high value per component of microprocessors and other design-intensive chips, as against the low value per unit of the mass-produced DRAMs on which Japanese firms long rested their strategies.

Another aspect of specialization that benefited the American industry was the increasing “decoupling” of design from production. Such decoupling is in many respects

¹⁸ These and succeeding figures in this paragraph are from ICE (1990), ICE (1995), and ICE (1998).

a natural manifestation of the division of labor in growing markets (Young 1928); in this case, it was abetted by the development of computerized design tools (Hobday 1991) and the standardization of manufacturing technology (Macher, Mowery, and Hodges 1998a). On the one hand, this allowed American firms to specialize in design-intensive chips, taking advantage of an American comparative advantage that arguably arises out of the decentralized and “fragmented” structure of that country’s industry.¹⁹ On the other hand, it also allowed many American firms to take advantage of growing production capabilities overseas.

“Globalization” has long been a trend in the semiconductor industry (Langlois *et al.* 1988), and American firms had long used “offshore” production as a strategy for cost-reduction, beginning with outsourcing of assembly and packaging stages. But the decoupling of design from production has enabled American firms to benefit from globalization without investing large amounts of their own money overseas. These “fabless” semiconductor firms are able to contract out production to “silicon foundries” around the world, especially in the Far East.

¹⁹ Perhaps surprisingly, the mid-1980s — that dark period for American fortunes — was actually the most fertile period in history for the startup of new semiconductor firms, by a large margin. Most of these new firms were involved in design-intensive custom devices and ASICs (Angel 1994, p. 38).

As globalization (broadly understood) has bolstered the fortunes of American firms, it has eroded those of the Japanese. Japanese firms were not the only ones who could understand the economics of capacity investment or productivity in manufacturing,

<i>Company</i>	<i>Country</i>	<i>1995</i>	<i>1996</i>
Samsung	Korea	6,462	4,805
NEC	Japan	4,740	3,175
Hitachi	Japan	4,439	2,805
Hyundai	Korea	3,500	2,300
Toshiba	Japan	3,725	2,235
LG Electronics	Korea	3,005	2,005
Texas Instruments	U.S.	3,200	1,600
Micron	U.S.	2,485	1,575
Mitsubishi	Japan	2,215	1,400
Fujitsu	Japan	2,065	1,350
Others		4,999	1,880

Table 4
Worldwide merchant-market sales of DRAMs (\$ million)
Source: ICE (1998)

and they were soon joined by Korean semiconductor producers and by larger American companies who matched Japanese productivity by the simple expedient of establishing Japanese plants. The result is a dilution of the control of capacity investment by Japanese producers. By the mid-1990s, a Korean firm had displaced Japanese firms as the leading producer of DRAMs in the world, and two other Korean firms had joined the top ten. (See Table 4.)

Conclusions.

For a number of reasons, including the early pattern of military, space, and computer demand in the United States, American semiconductor firms developed a distinctive set of capabilities and a distinctive industrial structure. Because of the richness of the technological paradigm opened up by the integrated circuit, and the planar process that underlay it, American firms in the 1970s and 1980s began to broaden not only their technological capabilities but also the menu of product alternatives the integrated circuit had made possible. By concentrating narrowly on specific products, Japanese firms were able to challenge American dominance in the 1980s, taking advantage of their own distinctive capabilities in high-quality manufacturing and of the benefits that their own industrial structure conferred on them for capital-intensive mass production.

In part, the more recent American resurgence was the result of imitating these Japanese capabilities, notably by improving semiconductor manufacturing. In the large, however, that resurgence reflects a renewed focus on what had long been distinctive American capabilities in design-intensive chips, especially logic chips. It also reflects a favorable shift in end-use demand that gave advantage to those American capabilities and to the American industrial structure that had grown up in the period of America's early dominance.

What lessons does this episode provide for research on corporate strategy? The American response to Japanese competition reflects not so much the ability of firms to "reengineer" themselves or their capabilities in the face of change. Rather, it suggests that, as Penrose (1959) taught, the pattern of capabilities or resources available to a firm evolves slowly out of earlier patterns, largely in response to the opportunities the world

presents. Strategy is not a matter of creating capabilities out of whole cloth but rather of picking and choosing among existing capabilities from a menu that circumstance dictates. And even that choice is often constrained and shaped by conditions outside the control of managers.

References.

- Afuah, Allan (1999). "Strategies to Turn Adversity into Profits," *Sloan Management Review* **40**(2): (Winter).
- Angel, David P. 1994. *Restructuring for Innovation: the Remaking of the U.S. Semiconductor Industry*. New York: Guilford Press.
- Borras, Michael G. 1988. *Competing for Control: America's Stake in Microelectronics*. Cambridge: Ballinger.
- Borras, Michael G., James E. Millstein, and John Zysman. 1983. "Trade and Development in the Semiconductor Industry: Japanese Challenge and American Response," in John Zysman and Laura Tyson, eds., *American Industry in International Competition: Government Policies and Corporate Strategies*. Ithaca: Cornell University Press.
- Braun, Ernest, and Stuart Macdonald. 1982. *Revolution in Miniature*. Cambridge: Cambridge University Press. (Second edition.)
- Christensen, Clayton M., and Richard S. Rosenbloom. 1995. "Explaining the Attacker's Advantage: Technological Paradigms, Organizational Dynamics, and the Value Network," *Research Policy* **24**(2): 233-257.
- Cogan, George W., and Robert A. Burgelman. 1989. "Intel Corporation (A): the DRAM Decision," Stanford Business School Case II-10, reprinted in Robert A. Burgelman, Modesto A. Maidique, and Steven C. Wheelwright, *Strategic Management of Technology and Innovation*. Chicago: Irwin, second edition, 1996.
- Ernst, Dieter, and David O'Connor. 1992. *Competing in the Electronics Industry: the Experience of Newly Industrialising Economies*. Paris: OECD.
- Gambardella, Alfonso, and Salvatore Torrisi. 1998. "Does Technological Convergence Imply Convergence in Markets? Evidence from the Electronics Industry," *Research Policy* **27**(5): 447-465.
- Granstrand, Ove, Pari Patel, and Keith Pavitt. 1997. "Multi-Technology Corporations: Why They Have 'Distributed' Rather Than 'Distinctive Core' Competencies," *California Management Review* **39**(4): 8-25 (Summer).
- Helm, Leslie. 1995. "In the Chips," *The Los Angeles Times*, March 5, p. D1.
- Hobday, Michael. 1991. "Semiconductor Technology and the Newly Industrializing Countries: The Diffusion of ASICs (Application Specific Integrated Circuits)," *World Development* **19**(4): 375-397 (April).

- Howell, Thomas R., Brent Bartlett, and Warren Davis. 1992. *Creating Advantage: Semiconductors and Government Industrial Policy in the 1990s*, Cupertino, California and Washington, D.C.: Semiconductor Industry Association and Dewey Ballantine.
- Integrated Circuit Engineering Corporation (ICE). Various years. *Status of the Integrated Circuit Industry*. Scottsdale, Arizona: ICE.
- Kleiman, Herbert S. 1966. *The Integrated Circuit: A Case Study of Product Innovation in the Electronics Industry*. DBA Dissertation, George Washington University.
- Langlois, Richard N. 2000. "Capabilities and Vertical Disintegration in Process Technology: The Case of Semiconductor Fabrication Equipment." in Nicolai J. Foss and Paul L. Robertson, eds., *Resources, Technology, and Strategy*. London: Routledge.
- Langlois, Richard N., Thomas A. Pugel, Carmela S. Haklisch, Richard R. Nelson, and William G. Egelhoff. 1988. *Microelectronics: An Industry in Transition*. London: Unwin Hyman.
- Langlois, Richard N., and Paul L. Robertson. 1995. [*Firms, Markets, and Economic Change: A Dynamic Theory of Business Institutions*](#). London: Routledge.
- Langlois, Richard N., and W. Edward Steinmueller. 1999. "The Evolution of Competitive Advantage in the Worldwide Semiconductor Industry, 1947-1996," in David C. Mowery and Richard R. Nelson, eds., [*The Sources of Industrial Leadership*](#). New York: Cambridge University Press.
- Levin, Richard C. 1982. "The Semiconductor Industry," in Richard R. Nelson, ed., *Government and Technical Progress: A Cross-Industry Analysis*. New York: Pergamon Press.
- Macher, Jeffrey, David C. Mowery, and David Hodges. 1998a. "Performance and Innovation in the U.S. Semiconductor Industry, 1980-1996," in Ralph Landau and David C. Mowery, eds., *Explaining America's Industrial Resurgence*. Washington: National Academy Press.
- Macher, Jeffrey, David C. Mowery, and David Hodges. 1998b. "Reversal of Fortune? The Recovery of the U.S. Semiconductor Industry," *California Management Review* **41**(1): 107-136 (Fall).
- Mackintosh, I. M. 1978. "Large-Scale Integration: Intercontinental Aspects," *IEEE Spectrum* **15**(6): 51-56 (June).
- Méthé, David T. 1991. *Technological Competition in Global Industries: Marketing and Planning Strategies for American Industry*. Westport: Quorum Books.

- Nelson, Richard R., and Sidney G. Winter. 1977. "In Search of More Useful Theory of Innovation," *Research Policy* **5**: 36-76 (Winter).
- Patel, Pari, and Keith Pavitt. 1997. "The Technological Competencies of the World's Largest Firms: Complex and Path-Dependent, but not much Variety," *Research Policy* **26**: 141-156.
- Penrose, Edith T. 1959. *The Theory of the Growth of the Firm*. Oxford: Basil Blackwell.
- Prahalad, C. K., and Gary Hamel. 1990. "The Core Competence of the Corporation," *Harvard Business Review*, May-June , pp. 79-91.
- Robertson, Jack. 1997. "Logic Is Taking Over as a Technology Driver," *Semiconductor Business News*, March.
- Saxenian, AnnaLee. 1994. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge: Harvard University Press.
- Teece, David J. 1986. "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing, and Public Policy," *Research Policy* **15**: 285-305.
- U.S. General Accounting Office. 1992. *Federal Research: Sematech's Technological Progress and Proposed R&D Program*. Washington: U.S. GAO.
- Watanabe, Makoto. 1984. "Semiconductor Industry in Japan — Past and Present," *IEEE Transactions on Electron Devices* **ED31**(11): 1562-1570 (November).
- Wilson, Robert W., Peter K. Ashton, and Thomas P. Egan. 1980. *Innovation, Competition, and Government Policy in the Semiconductor Industry*. Lexington, Mass.: D. C. Heath.
- Young, Allyn A. 1928. "Increasing Returns and Economic Progress," *Economic Journal* **38**: 523-542.