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Targeting the Computer

Government Support and International Competition

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expensive, high-end products entering the commercial marketplace. (But today's leading-edge product is tomorrow's mundane workhorse in this industry!)

Policies designed to regulate market structure through legal antitrust oversight were largely abandoned in the early 1980s, although the environment in which proprietary rights to new technologies are established may yet reflect the historical legacy of decades of vigorous antitrust actions (as well as the patent licensing policies of government agencies). In the late 1980s the new challenge confronting American industry may be to slow down the diffusion of U.S. technology investments to ever more capable foreign imitators without killing off the freewheeling, loose style of technology diffusion that contributed so greatly to the rapid internal development of the American computer industry.

CHAPTER FIVE

Government and Computers in Japan and Europe

IN THE United States early computer technology had a distinctly military focus and was heavily funded by the government. Japan and Europe pursued rather different technology policies: reducing a substantial lead by U.S. firms in commercial markets was their primary objective. Built into Japanese technology policies devised for their computer industry was a unique blend of cooperation and competition among a diverse group of firms. In Europe, however, all bets usually were placed on a single "national champion," the beneficiary of a steady diet of financial subsidies and preferential procurement policies. As the following history of technology policy in Japan and Europe will show, the competitive approach was more effective.

Technology Policy in Japan

Japan's success in fostering technology-intensive industry has led many to scrutinize the Japanese "model" for clues to help stimulate the U.S. economy. The political air is thick with talk of "targeting," and U.S. managers rush to emulate Japanese management techniques. Yet the historical record seems to show that the Japanese model is more a frame of mind—a willingness to experiment and adapt to changing economic realities, a societal ability to mobilize behind a common social goal—than a rote formula applied year after year to guide economic decisions. The steps taken by the Japanese to foster their computer industry provide a good illustration of this flexibility.

There are four major players on the Japanese computer scene, three of them government organizations: the Ministry of Trade and Industry (MITI) and its technical arm, the Electrotechnical Laboratory (ETL); Nippon Telephone and Telegraph (NTT) and its immense laboratories; and the least significant actor from a purely financial viewpoint, the Ministry of Education, which controls activities within the prestigious national universities. In recent years Ministry of Education funding of research and development in Japan's universities and colleges has grown considerably. The fourth player is industry—the corporate research laboratories of Japan's largest industrial firms. The interaction among these groups is an unusual mix of rivalry and cooperation, and the web of relationships constantly changes.

From the early 1950s to 1961 computer development in Japan was mainly carried out within the ETL, NTT, and the University of Tokyo, the flagship of the national university system. Corporate research laboratories scarcely existed, and the first indigenous commercial computers shipped after 1957 were based on designs transferred to industry from these labs. Although the electronics promotion law of 1957 (extended in 1971 and again in 1978) established legal mechanisms for direct assistance to industry, subsidies for research and development on computers were minimal—less than $1 million—until 1961.

Worldwide Explosion in Demand: The Early 1960s

Within the institutions devised to support the development of a computer technology base in Japan, there have been at least three major periods of reorganization. The early 1960s marked the first. Japanese industry began to look at computers with considerably greater interest after IBM was allowed to establish a computer manufacturing base in Japan in 1960. From then on world-class technology was required to stay competitive. Late in 1960 MITI announced a five-year program for national production of electronic computers.[1] Stiff trade barriers were erected in 1961, and the price for foreign admission was access to important technology. After 1962 would-be computer manufacturers forged joint ventures with U.S. computer makers (under the guidance of MITI). The only Japanese company not to depend on imports of foreign

1. Tosaku Kimura, "Birth and Development of Computers," *National Sciences and Museums*, vol. 46, no. 3 (1979), Special Issue on Computers (in Japanese).

technology was Fujitsu, the first to establish a corporate computer research lab of any significance.

As a "sweetener," perhaps, for pioneering the path of technological independence, Fujitsu was given the leadership of the very first MITI-funded computer development program, the FONTAC project. Oki Electric and the Nippon Electric Corporation (NEC) joined in the effort, developing peripherals for the main Fujitsu-designed computer. The MITI financial contribution was small—only $1.16 million—from 1962 to 1966, but the project was of great importance to Fujitsu. The FACOM 230-50, the most powerful machine of Fujitsu's computer line, was based on the FONTAC prototype, as was the architecture for Fujitsu's largest family of computers. Perhaps more important, the Electronic Computer Technology Research Association appears to have been the first cooperative research venture to have been established among competing Japanese computer firms.[2]

As the impetus for computer development shifted to more explicitly commercial objectives, MITI's Electrotechnical Laboratory was forced to carve out a new role for itself. The economics of the growing marketplace meant that a standard architecture, and software designed for that standard, were needed. Rather than designing and building its own unique architecture for experimental computers, ETL was instead directed to develop high-performance components that could be used in the existing architecture of Japanese manufacturers.[3] In 1965 the last large computer based on a unique ETL design, the Mark VI, was completed. This high-performance machine, intended to be the Japanese equivalent of the American Stretch and LARC projects and the British Atlas supercomputer, never made the transition from research project to commercial product. Times had changed.

Nurturing Industrial Research: The Mid-1960s

The mid-1960s marked a second major transition. IBM had announced its new System 360 line in 1964, and the Japanese, like other competitors, were in serious danger of being overrun. The System 360 used hybrid

2. The $1.16 million figure was reported in Japan Electronic Computer Corporation (JECC), *EDP in Japan* (Tokyo: JECC, 1975), p. 9.

3. Osamu Ishii, "Research and Development on Information Processing Technology at Electrotechnical Laboratory—A Historical Review," *Bulletin of the Electrotechnical Laboratory*, vol. 45, nos. 7, 8 (1981) (in Japanese).

integrated circuits, less advanced than the monolithic integrated circuits that were then the state of the art. Integrated circuits were already widely available in the United States, although mainly in products built for the military market. Japan lagged in this component technology; NEC did not build the first experimental Japanese integrated circuit until 1962.[4]

Integrated circuit development on a broader front began among Japanese firms in 1964, and digital computer applications led the way (as they did in the United States, where integrated circuits used in military and space guidance computers blazed the trail). MITI awarded the six Japanese companies then producing computers $80,000 to develop specialized integrated circuits for computers. By late 1965 the three largest producers (NEC, Hitachi, Fujitsu) had announced models containing some integrated circuits.[5] Progress was slow, however. NEC did not deliver its machine until 1966, Fujitsu and Hitachi until 1968.[6]

In response to System 360 and a perceived lag in Japanese technology, MITI organized the super high performance electronic computer (SHPEC) program, one of three large-scale national research projects that pooled the resources of government labs and private corporations. This pioneering project began in 1966, ran until 1971, and cost the government about $40 million.[7] Basic research pursued at ETL was later translated into deliverable products developed at cooperating corporations' R&D labs. The first semiconductor memories built in Japan were developed for this

4. John E. Tilton, *International Diffusion of Technology: The Case of Semiconductors* (Brookings, 1971), p. 26.

5. Although the grants were nominally supposed to cover half of the companies' research costs, rarely was more than one-third of actual costs covered. One firm's completed research was to be made available to all other companies involved. See Yasuo Tarui, "Japan Seeks Its Own Route to Improved IC Techniques," *Electronics*, December 13, 1965, pp. 90–93.

6. JECC, *Konputa Noto, 1983* [Computer notes] (Tokyo: JECC, 1983), pp. 539–41. The first commercial Japanese computer containing integrated circuits seems to have been NEC's 2200 Model 500. During the 1960s NEC was the technological leader in the commercial Japanese semiconductor industry. See Tilton, *International Diffusion of Technology*, chap. 6.

7. Estimates of the cost vary widely (perhaps because of fluctuations in exchange rates and different assumptions about the time period): $33.3 million (JECC, *EDP in Japan*, p. 9); $44 million ("Government-Funded Industrial R&D in Japan," JEI Report 42 [Washington, D.C.: Japan Economic Institute, November 6, 1981], p. 3); and $35 million (George E. Lindamood, "The Rise of the Japanese Computer Industry," *ONR Far East Scientific Bulletin*, vol. 7 [October–December 1982], p. 64). The other two projects that initiated the National Research and Development Program were energy-related: magneto-hydrodynamic power generation and desulfurization of industrial fuels. See also Akio Tojo, "National R&D Program on Information Processing Technology in Japan," private memo, n.d.

project, as were high-performance semiconductor logic circuits. Hitachi's large-scale 8700 and 8800 computer models were directly based on the machine developed for this project, and component technology from the program was incorporated by other manufacturers into their computer designs.

NTT, which had played a key role in developing computers using the *parametron* (a unique circuit element invented in Japan), also strengthened its commitment to computer research at about this time. The parametron had proven to be a blind alley, and NTT turned back to semiconductors. By 1963 it had developed its CM-100 transistor computer, which trailed the development of transistor computers by private Japanese industry. (Japanese firms generally had the advantage of direct technical ties to American computer companies.) In 1968, as MITI's SHPEC project was just getting under way, NTT also began a large and well-funded industrial computer development project. The DIPS (Dendenkosha—a Japanese acronym for NTT—information processing system) computer, designed for timesharing and data base management, was complementary to the MITI project. The hardware and software for both systems were quite similar, and the first DIPS computer borrowed high-performance logic technology developed for the MITI machine.[8] The memory integrated circuit developed for the SHPEC program was also used in Nippon Telephone and Telegraph's DIPS machine.[9] The NTT contractors participating in DIPS—NEC, Fujitsu, and Hitachi—were three of the five participants in the big MITI computer project.

Business computer sales' explosive growth in the 1960s, coupled with IBM's System 360 bombshell of 1964, seemed to produce a notable willingness in Europe as well as Japan to experiment with new and unproven formulas. The Electronics Industry Act of 1957 had picked electronics as the core of the future industrial development of Japan. A decade later the act's bold declarations had begun to be translated into significant amounts of cash for research. MITI subsidies for research

8. See National Academy of Sciences, National Academy of Engineering, National Research Council, Computer Science and Engineering Board, "The Computer Industry in Japan and Its Meaning for the United States" (Washington, D.C., 1973), pp. 91–92; Lindamood, "Rise of the Japanese Computer Industry," p. 69; and Morihiro Kurushima, "Diffusion of Results, Patent Management," *Tokyo Kogyo Gijutsu*, vol. 20 (August 1979), translated in *Background Readings on Science, Technology, and Energy R&D in Japan and China*, Committee Print, House Committee on Science and Technology, 97 Cong. 1 sess. (Government Printing Office, 1981), pp. 34–36.

9. Ishii, "Research and Development on Information Processing Technology."

and development authorized under this bill were four times greater in 1967 (as the SHPEC program started) than in 1960.[10]

By the end of this second transition Japan had three basic types of institutional mechanisms to directly funnel public resources into computer R&D efforts within industrial firms. There were two distinct sets of programs run by MITI (conditional loans and consigned payments), as well as significant funds provided by NTT (see table 5-1).

The FONTAC development group was among the first private industrial research associations. It was begun in 1962, the year after passage of the law qualifying cooperative research associations for special government subsidies. Industrial research support in the form of conditional loans from MITI is repayable only if the association makes a profit. In practice, they rarely were repaid. Although barred by law from joint research with private corporations, ETL researchers have often been loaned out in recent years on temporary assignment to direct cooperative research.[11]

The other major form of support, the national R&D projects, was managed directly by ETL, rather than being nominally the responsibility of a research association. Funding for the first projects, such as SHPEC, was dispensed to individual firms as contract research.

A quasi-public agency associated with MITI, the Information Technology Promotion Agency (IPA), administers funding and loan guarantees for software development. The agency's capital draws on funding from both private industry and MITI, while MITI subsidies support its current operating expenses.[12] Since 1976 much of this funding has gone to consigned development of software production technology by a private research association; other funding has gone to the consigned development of specific application programs by other private contractors.

NTT, through its relationships with the NTT "family" of suppliers, supported a considerable amount of research conducted in cooperation with, or under contract to, its technical laboratories. The DIPS project marked NTT's first move into large-scale support for industrial computer development. The development of DIPS has required large sums of research money. The third DIPS computer, the DIPS II, is said to have cost NTT more than $10 million for research and development alone in the early 1970s.[13]

The 1950s style of research support—prototypes designed and constructed within government labs later transferred to private industry—was phased out after the early 1960s. In its place arose a set of institutions stressing joint government-industry cooperation during all phases of research and early development.

Growth of Joint Research: The 1970s

A third major period of change occurred in the early 1970s. The Japanese computer industry faced dual crises. First, upheaval in the U.S. industry precipitated by the introduction of IBM's System 370 rippled out to the foreign associates of IBM's American competitors. As General Electric, RCA, and later Xerox abandoned their faltering mainframe computer product lines, serious problems were transmitted to these firms' Japanese partners. Second, government commitments to open up the Japanese computer market to international trade by 1975 compounded the imminent difficulties faced by Japanese computer producers.

The MITI prescription was radical surgery (the grafting of six independent computer producers into just three groups) followed by intensive care (massive doses of cash for research and product development). Fujitsu and Hitachi combined just long enough (and with the invaluable

10. Eugene J. Kaplan, *Japan: The Government-Business Relationship, A Guide for the American Businessman* (U.S. Department of Commerce, 1972), p. 92.

11. See Jimmy W. Wheeler, Merit E. Janow, and Thomas Pepper, *Japanese Industrial Development Policies in the 1980s: Implications for U.S. Trade and Investment* (Hudson Institute, 1982), p. 147. Lindamood, "Rise of the Japanese Computer Industry," p. 66, notes that none of the hojokin for the very large scale integrated circuit (VLSI) program had been repaid. Forty-four percent of all MITI hojokin from this period had been paid back by 1982. None of that appears to have been related to the computer projects. See United States International Trade Commission, *Foreign Industrial Targeting and Its Effects on U.S. Industries, Phase I: Japan*, USITC Publication 1437 (Washington, D.C.: USITC, 1983), p. 105. See also Charles L. Cohen, "Japan Pushes IC Research," *Electronics*, September 8, 1983, pp. 94–96. In 1984 MITI formulated proposals that would permit joint ETL research with private corporations, with joint ownership of resulting patents and half of any resulting profits to be received by the government. See Mike Berger, "Japanese Firms Boost Spending for Short-, Long-Term Projects," *Electronics Week*, September 24, 1984, pp. 32–36.

12. See Japan Information Processing Development Center, *Computer White Paper*, 1980 edition (Tokyo: JIPDEC, 1981), pp. 44–45; and JECC, *Konputa Noto, 1983*, pp. 104–06.

13. See Carl Louis Coran, "The Role and Significance of MITI in the Economic Development of the Japanese Computer Industry" (M.S. thesis, George Washington University, School of Government and Business Administration, 1976), p. 79.

Table 5-1. *Major MITI Research Programs and Cooperative Research Associations since 1962*

MITI program	*Years*	*Research association*	*Type of aid*[a]
Large national R&D projects			
Super high performance electronic computer (SHPEC)	1966–71	None; tasks assigned to individual firms and joint venture Nippon Software Company (Hitachi, Fujitsu, NEC)	Itakuhi
Pattern information processing system (PIPS)	1971–80	Engineering Research Association (est. 1977)	Itakuhi
Optical measurement and control system (OMCS)	1979–85	Optoelectronics Applied System Research Association (est. 1981)	Itakuhi
Fifth Generation project	1981–91	Institute for New Generation Computer Technology (ICOT)	Itakuhi
New function elements (next generation industry)	1981–90	Research and Development Association for Future Electron Devices	Itakuhi
High-speed computer for science and technology	1981–89	Scientific Computer Research Association	Itakuhi
Interoperable database system	1985–	n.a.	Itakuhi
Industrial research support			
FONTAC project	1962–66	Electronic Computer Technology Research Association	Hojokin
Development of new computer types ("3.5" Generation program)	1972–76	Ultra High Performance Computer Development Group (Fujitsu, Hitachi, Nippon Peripherals Ltd.)	Hojokin
		New Generation Computer Series Development Group (NEC, Toshiba, Japan Business Automation, Japan Data Machine)	Hojokin
		Ultra High Performance Electronic Computer Research Association (Mitsubishi, Oki)	Hojokin
Computer peripheral equipment development	1972–76	Granted to 31 companies	Hojokin
IC development	1973–74	Granted to 8 companies	Hojokin
Very large scale integrated circuit (VLSI) program	1976–79	Super LSI Technology Research Association	Hojokin
Next (fourth) Generation computer basic technology	1979–83	Computer Basic Technology Research Association	Hojokin
Small research projects			
Medical information system, health care network system	1973–	Medical Information System Development Center	n.a.
Visual information system (Hi-Ovis)	1972–79	Visual Information System Development Association	n.a.
Information Technology Promotion Agency (IPA) projects			
Information processing industry promotion	1973–75	Technical research groups on Software Modules for Business Processing (15 companies); Software Modules for Business Management (5 companies); Software Modules in Design Computation (5 companies); Software Modules for Operations Research (8 companies); Software for Automatic Control (4 companies)	IPA support
IPA software development program	1976–	Joint System Development Corporation	Grant to IPA
IPA "Sigma" project	1985–	n.a.	Grant to IPA

Sources: Japan Information Processing Development Center [JIPDEC], *Computer White Paper, 1982* (Tokyo: JIPDEC, 1983), pp. 3–4, *1980*, pp. 6, 34–35, *1976*, pp. 30, 33–34, *1974*, pp. 19–22, 24, *1972*, p. 35; JECC [Japan Electronic Computer Corporation], *Konputa Noto, 1983* [Computer notes] (Tokyo: JECC, 1983), pp. 73, 80–93, 106, 447–49, 460–61; H. J. Welke, *Data Processing in Japan*, Information Research and Resource Reports, vol. 1 (Amsterdam: North Holland, 1982), pp. 22–26, 32, 66; Jimmy W. Wheeler, Merit E. Janow, and Thomas Pepper, *Japanese Development Policies in the 1980's: Implications for U.S. Trade and Investment, Final Report* (Croton-on-Hudson, N.Y.: Hudson Institute, 1982), pp. 147–49, 153; George E. Lindamood, "Current Computer-Related Research and Development Expenditures of the Japanese Government," *Scientific Bulletin*, vol. 8 (July to September 1983), pp. 13–15; George E. Lindamood, "Update on Japan's Fifth Generation System Project," ibid., pp. 16–25; Agency of Industrial Science and Technology and Ministry of International Trade and Industry, *National Research and Development Program (Large-Scale Project), 1985* (Tokyo: Japan Industrial Technology Association, 1985), p. 15; Information Technology Promotion Agency, *An Outline of the SIGMA Project: Toward High Software Productivity and Quality* (Japan: IPA, 1985), p. 1-9; Robert L. Eckelman and Lester A. Davis, "Japanese Industrial Policies and the Development of High-Technology Industries: Computers and Aircraft," staff report, project DTR-16-82 (U.S. Department of Commerce, International Trade Administration, February 1983), p. 16; author's interview with Dr. K. Hakozaki from NEC, April 1984; and Tōsaku Kimura, "Birth and Development of Computers," *Natural Science and Museums*, vol. 46, no. 3 (1979), p. 104.

a. *Hojokin:* conditional loans, interest free; repayment linked to profits on technology. Hojokin usually accounts for 40 to 50 percent of research cost; patents usually belong to the research association, but are sometimes assigned to the government. *Itakuhi:* consigned payments; research done on contract basis for MITI; patents usually belong to the government. *IPA support:* 75 percent of expenses provided by IPA; MITI provides operating cost subsidy and loan guarantees from long-term credit banks to IPA. *Grants to IPA:* all funding provided by MITI; resulting technologies belong to IPA.

help of Amdahl, Fujitsu's new American associate) to unravel the secrets of the IBM computer architecture. They then went their separate competitive ways. Of the other two groups' four participants (NEC, Toshiba, Mitsubishi, Oki), only NEC would survive as a manufacturer of major league, mainframe computers. Coincidentally, the three survivors were all participants—as independent manufacturers—in the design and construction of the DIPS series of timesharing mainframe computers.

Japan's technology policy during this third period of transformation was extremely flexible. It promoted survival of the largest and technologically fittest, not slavish adherence to the MITI game plan. Japan's adjustment to the upheavals in the national and international markets was, therefore, successful. The most useful elements of the experiment were chosen as the basis for the next generation of policy.

During the 1970s the Japanese government vastly increased the overall scale of MITI funding for research as well as emphasized support for cooperative industrial efforts. ETL continued to lead large national research projects in computer technology. But the direct R&D funding delivered to ease liberalization, funneled through private research associations, involved much larger sums.

The best way to track these developments is by examining available statistics on computer research and development in Japan. Fortunately, since the early 1970s reasonably consistent measures exist. Research performers report expenditures on *information research and development,* defined as "research on hardware and software."[14] Note that this information technology R&D excludes considerable sums spent on electronic components and communications technology not specifically earmarked for computer systems (see appendix table D-1). Table 5-2 presents a breakdown by product field and by social objective for fiscal 1983.

The absolute growth rate in Japanese computer research was quite striking: 60 percent in 1973 alone. In 1971 about 98 percent of computer R&D was performed in private corporations (funded by both private and public sources).[15] Just three years later only 40 percent of computer

14. See, for example, Statistics Bureau, Prime Minister's Office, *Report on the Survey of Research and Development, 1982* (Tokyo: Japan Statistical Association, 1983), p. 184. Work on semiconductor devices not specifically intended for use in computer systems appears not to be included in these figures.

15. R&D performed in universities and colleges is excluded in 1971, but it would not have altered this picture much. In 1974, when figures first became available, academia accounted for about 5 percent of the Japanese computer effort.

Table 5-2. *Percent Distribution of Industrial R&D by Product Field and Social Objective, Japan 1983*

Industry	Selected product fields: General machinery	Household appli-ances	Communi-cations and electric components	Other electric equip-ment	Electricity and gas	Social objective, informa-tion technology
Electric machinery	6	15	34	29	0	19
Communications equipment and electronic components	7	26	62	7	0	11
Transportation, communications, and public utilities	1	0	61	1	31	8

Source: Statistics Bureau, Management and Coordination Agency, *Report on the Survey of Research and Development, 1984* (Tokyo: Japan Statistical Association, 1985), pp. 126–29.

R&D was taking place inside Japanese companies. As the internal corporate effort declined in importance, R&D in cooperative research associations jumped from less than 1 percent of the total in 1971 to over half in 1974. From 1971 to 1976 Japan's expenditure on computer R&D tripled, with roughly half of the increase being absorbed into external research institutions.

Cooperative research associations blossomed during this period. It appears that they were formally organized as a type of public corporation in 1972 and 1973 and then in 1974 were reorganized as private associations. The reasons are not well documented, but this legal change also occurred in other parts of Japanese industry.[16]

The 1972–76 period marked the era of the "3.5 Generation" program, an effort to catch up to IBM's newly introduced System 370 machines.[17] MITI heavily funded the three computer groups that made up its vision of a restructured Japanese industry. Government funding, matched to private investment, was supposed to have financed roughly half of this

16. In 1973 the Japan Industrial Robot Association switched from *jigyo dentai,* a type of public corporation organized for the promotion of economic and social policies, to *shadan hojin,* a private nonprofit research association. See Leonard Lynn, "Japanese Robotics: Challenge and—Limited—Exemplar," *Annals of the American Academy of Political and Social Science,* vol. 470 (November 1983), p. 19. This was a period of fiscal austerity in Japan. My colleague Ed Lincoln has suggested that this may have been a response to Ministry of Finance pressures to cut down on spending (by forcing the overhead and administrative costs to be absorbed by the private sector instead of the central government). A new Electronics and Machinery Law was passed in 1971, and changes in legal organization may have been helpful in order to qualify for financial subsidies made available from 1972 on.

17. See Kenneth Flamm, *Creating the Computer: Government, Industry, and High Technology* (Brookings, forthcoming), chap. 6.

effort—perhaps 15 to 25 billion yen per year. (Since overhead is not generally funded as part of these programs, somewhat under half of the cooperative expenditure may actually have been covered.) Appendix table D-2 shows major MITI subsidies to computer research programs over the same period, and total subsidies lie in exactly this expected range. Thus the rapid growth of computer R&D, particularly the overnight shift to research performed in research institutions, closely corresponds to the effects of MITI's restructuring of subsidies.

Joint research involved substantial commitments from both government and industry. It was much more than a marginal supplement to industry's own efforts. Computer research performed within corporations actually registered notable declines during some of this five-year period, as research associations stepped up their work. Firms were effectively transferring significant resources out of private, internal efforts and into the joint research associations.

The shift to joint research associations was regarded as an extremely successful experiment. In 1977, more than halfway through the ten-year PIPS project, the contractors were reorganized into a private research association. From then on virtually all MITI funding of computer research in the private sector—including the national R&D projects, which had previously contracted with individual firms—has been dispensed in some form to private cooperative research associations. The Information Technology Promotion Agency channeled much of its resources to another private research association, the Joint Software Development Corporation.

Research in the Public Sector

Within MITI, quite apart from the subsidies administered to outside research laboratories, the Electrotechnical Laboratory has its own scientists doing basic computer research. Although the ETL has received some of the funding from the national research projects, it has additional research resources in its own budget.[18] Most of the computer research

18. In the PIPS program, for example, better than a third of the project's budget was expended within the ETL. See Electrotechnical Laboratory, *Pattern Information Processing System: National Research and Development Program* (Tokyo: ETL, 1978), p. 5. In 1983, in addition to the large-scale national R&D projects, ETL undertook "special research projects" in cryogenic electronics, electronic materials and devices, optoelectronics, intelligent robots, natural language processing, image information

performed within the central government presumably reflects the internal research activity of the ETL. As table 5-3 shows, this has typically ranged from 1.5 to 3.5 percent of all computer R&D in Japan.

For statistical purposes NTT is classified as a corporation, and its research expenditures are buried within the totals for all corporations. The R&D budget of NTT is tabulated separately in appendix table D-1, however. The nearest American analogue to NTT is the Bell Telephone Laboratories, which spent about half of its research resources on computer activities in the 1970s. If one assumes that about one-half of the R&D budget of NTT has gone to computer-related activities, then perhaps one-fifth of Japanese computer R&D has been funded by NTT in recent years.

Unlike Bell labs, NTT has spent a significant portion of its R&D money on research undertaken with, or transferred to, the private firms making up the NTT family. (The Bell labs worked exclusively with AT&T's own internal production arm, Western Electric.) Funds for such joint research seem to be spent within NTT's research laboratories or written into procurement contracts.[19] In recent years NTT appears to

processing, computer hardware and software, and information processing in biological systems. See Electrotechnical Laboratory, *Guide to ETL 1983–1984* (Tsukuba: ETL, 1984).

19. Until 1984 NTT was a "special corporation" (like the Japanese National Railways and the Japan Tobacco and Salt Public Corporation). Because these corporations are sometimes put into a separate category in statistics, their R&D expenditure can often be separated from that of other firms. See Statistics Bureau, Management and Coordination Agency, *Report on the Survey of Research and Development, 1984* (Tokyo: Japan Statistical Association, 1985), pp. 9–10. NTT is classified in the "transport, communications, and public utilities" category. In fiscal 1983 all significant firms in that category (with capital of more than 100 million yen) expended 180.3 billion yen for research and development, of which 63 percent (112.9 billion) was spent by the special corporations. See ibid., table 1, pp. 84–85. The seven special corporations that perform research and development and belong to this industry include NTT, the long-distance communications enterprise KDD, the broadcasting firm NHK, the Electric Power Development Company, Japan Airlines, and the Japanese National Railways. But NTT's total R&D expenditure alone for fiscal 1983 claimed 83 percent of the total for the seven. See Nippon Telegraph & Telephone Public Corporation, *1983–84 Annual Report*, p. 31. And R&D in "telecommunications" only by NTT, KDD, and NHK accounted for 91 percent of the total for the special seven. Ministry of Posts and Telecommunications, cited in K. Suzuki and T. Honda, "NTT: Past and Present," February 1987.

The 112.9 billion yen in R&D expenditures for the seven was made up of 114.1 billion in self-financed R&D and 0.7 billion in funds received from outside, less 1.9 billion yen paid for work performed outside. Thus almost no funds could have been paid directly by NTT to outside firms. A similar analysis holds for published data sampled from the early 1970s. NTT's support for outside R&D has either been covered

Table 5-3. *Information Technology R&D in Japan, 1970–84*

Item	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
								All expenditures							
Millions of U.S. dollars	83	118	168	301	314	348	398	438	626	725	726	978	1,014	1,230	1,645
Percent performed in															
Industry	100	98	65	55	41	51	55	70	67	74	86	78	79	83	88
NTT[a]	28	33	32	21	19	20	18	22	21	19	20	17	16	14	15
Remainder	72	65	33	34	22	31	38	48	46	55	65	61	63	68	73
Central government[b]	n.a.	1	4	3	3	3	2	2	3	4	2	1	2	2	1
Private research institutions[b]	n.a.	*	1	*	51	40	37	23	25	15	8	16	14	10	7
Public research institutions[b]	n.a.	*	31	41	*	*	*	*	*	*	*	*	*	*	*
Universities and colleges[b]	n.a.	n.a.	n.a.	n.a.	5	5	4	5	5	7	5	4	4	4	3
								MITI subsidies							
Millions of U.S. dollars	7	7	24	76	84	74	79	58	75	67	53	58	59	65	59
As percent of information R&D	8	6	14	25	27	21	20	13	12	9	7	6	6	5	4

Source: Data taken from appendix table D-1. Yen are converted to dollars at current exchange rates.
n.a. Not available.
* Positive but less than 0.5 percent.
a. NTT information R&D estimated as one-half of total NTT R&D budget. All information technology R&D performed in "transportation and communications" is assumed to be included in the NTT budget.
b. No data available for universities and colleges in 1970–73, or for government and research institutions in 1970.

have spent much more on computer-related research and development than MITI.[20] While MITI may have received more publicity than NTT for supporting the development of Japan's computer industry, NTT appears to have been considerably more important in supplying resources for technology development.

Universities and colleges have generally accounted for about 4 to 6 percent of Japan's computer effort. The national universities typically account for between two-thirds and four-fifths of this total, the private universities for the remainder.[21] Almost all of this research is funded by government. There have been few direct links between university research and corporate development in recent decades.[22] But as the industrial R&D effort has matured, support for basic research in universities has grown in relative terms, while government aid to private research associations has become proportionately less important.

Figure 5-1 illustrates the importance of various forms of public support for computer R&D in Japan. Since the early 1970s, funds transferred by MITI to the cooperative research associations (assumed to equal 40 percent of their expenditures) have been its major instrument for funding new technology, trailed by R&D within its own labs. NTT's support has vastly exceeded MITI's.

A Fourth Transition?

The overall importance of MITI research support for information technology rose and fell precipitously between 1970 and 1983 (see table 5-3). From under 10 percent of the total in 1970 and 1971, MITI subsidies

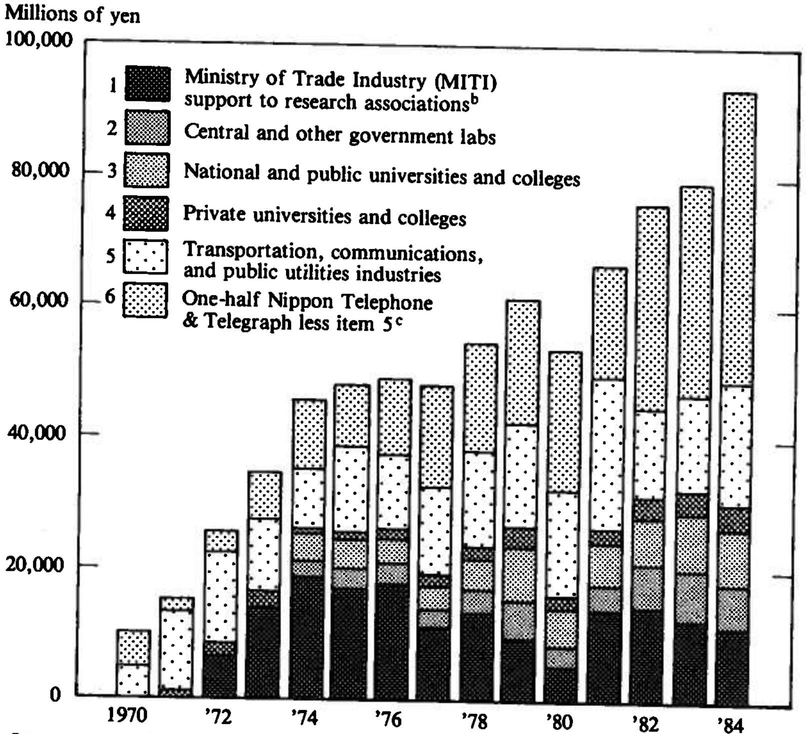
by procurement contracts or conducted jointly with private firms within NTT itself. See H. J. Welke, *Data Processing in Japan*, Information Research and Resource Reports, vol. 1 (Amsterdam: North Holland, 1982), pp. 44–45.

20. This is based on the assumption that half of NTT's R&D budget (which includes much work on electronic components) is related to computers. If only funds specifically earmarked for information technology (and excluding much component work) are counted, the total is roughly the same size as MITI's spending.

21. In 1983, for example, computing facilities at private universities received a subsidy of about 1.5 billion yen. New computing facilities at public universities accounted for almost 8 billion yen that same year. Because Japanese R&D statistics include capital expenditures (unlike American statistics), these kinds of expenditures may be included in the aggregate computer R&D statistics. See JECC, *Konputa Noto, 1983*, p. 168.

22. In 1983, for example, private universities received 133 billion yen in research funds from government and over 5 billion yen from other sources. See Statistics Bureau, *Report on the Survey of Research and Development, 1984*, p. 162.

Figure 5-1. *Public Support for Information Technology R&D in Japan, 1970–84*[a]



Source: Calculated from appendix table D-1.
a. Except for NTT budget, all figures include only R&D classified as "information technology."
b. Estimated as 40 percent of total R&D in public and private research institutions and associations.
c. In other words, additional funds up to one-half total NTT research and development budget.

climbed to over one-quarter of the total in 1973 and 1974. They hovered at 20 percent in 1976, the last year of the adjustment program. MITI subsidies to private computer research usually run between 40 and 50 percent of the budget of the private research associations. In 1981, for example, 40 percent of the R&D performed in private research institutions (or about 6 percent of information R&D) corresponds almost exactly to a program-by-program inventory of MITI subsidies. MITI funding fell to roughly its 1971 share of the total by 1981.

Computer research in private Japanese firms has soared since 1978, while funding of joint research associations has remained about constant. The figures on MITI funding of computer research in table D-2 portray a similar situation, with current yen funding levels remaining roughly

constant through the early 1980s. This has led to computer R&D within private corporations rising from 40 percent of the total, at the peak of the restructuring effort in 1974, to over 80 percent of the total by the mid-1980s. Private research associations, which accounted for more than half of computer R&D in 1974, accounted for only 16 percent of the total in 1981, 7 percent in 1984.

The steep climb in corporate spending on information processing R&D in recent years is evident in table 5-3, as is the declining role of public funding. MITI subsidies accounted for 4 percent of Japanese R&D in 1984, NTT spending (with half of total R&D assumed to relate to computers) another 15 percent. After adding the budgets of government and university research laboratories, roughly 10 percent of all Japanese computer R&D was paid for by direct public funding. With NTT included, the total rises to 25 percent.

The marked rise in the corporate share of Japanese computer R&D is mainly the result of rapidly expanding R&D budgets in the private sector. MITI subsidies remained roughly constant in current yen terms, at around 15 billion yen per year through the early 1980s, and the NTT R&D budget actually declined somewhat during this period. Japanese firms seem to have shifted toward a more research-intensive corporate strategy. In 1984 Fujitsu, Hitachi, and NEC were three of the five large companies in Japan spending over $500 million on research and development, and together they accounted for roughly $2.2 billion in R&D.[23]

As was true in the United States in the late 1950s and early 1960s, the rapid expansion in commercial sales of Japanese computers, rather than cutbacks in R&D subsidies, seems to be the main reason for the overall decline of government's role in pushing the development of computer technology. The bulk of the increased private effort in Japan, as in the United States, went into applied research and development. The Japanese computer industry has matured into a healthy, competitive sector capable of pursuing independent development of its new products.

But MITI, NTT, and the Ministry of Education still seem to be disproportionately important in sponsoring basic research and individual firms in supporting development (see table 5-4).[24] Because the MITI and

23. See Robert Neff, "Japan Polishes Creativity Image," *Electronics*, August 11, 1982, pp. 96–97; and Berger, "Japanese Firms Boost Spending," p. 34. The activities of IBM Japan's research laboratories are included in these figures for Japanese industry.

24. See D. Brandin and others, *JTECH Panel Report on Computer Science in Japan* (La Jolla, Calif.: Science Applications International Corporation, 1984), pp. 1-3, 1-4,

Table 5-4. *Types of Research and Development Performed, by Sector, Fiscal Year 1983*

Sector	*Basic research*	*Applied research*	*Development*
Companies			
Electrical machinery	4	18	79
Communications equipment and electronic components	3	20	77
Transportation, communications, and public utilities	4	28	67
Special corporations, such as NTT	6	28	66
Research institutions and associations	13	31	57
Central government	31	39	30
Private	9	31	60
Universities and colleges	56	36	8

Source: Statistics Bureau, *Report on the Survey of Research and Development, 1984,* pp. 119, 148, 160.

NTT research support tends to be skewed toward speculative, long-term research, it is a highly levered commodity. In addition to the dollar or so that is matched with every MITI dollar in the private research associations, firms typically have another one or two dollars invested in related internal projects.[25] The more basic, least appropriable research seems to be what is done cooperatively, while efforts to commercialize these results are pursued internally.

The most visible large-scale national R&D project by MITI in the 1980s was the so-called Fifth Generation project, a ten-year effort begun in 1981 after two years of preliminary studies.[26] Financed, like other national projects, by consigned research grants from MITI, it cost about 7 billion yen per year by the mid-1980s. In a novel approach nine private companies, including the big three computer makers (Fujitsu, Hitachi, and NEC) joined together to finance a private research institution, ICOT (the Institute for New Generation Computer Technology),

3-15, 3-57, 3-58; Edward K. Yasaki, "R&D in Japan," *Datamation,* vol. 29 (July 1983), p. 94; Cohen, "Japan Pushes IC Research"; and Berger, "Japanese Firms Boost Spending."

25. See Brandin and others, *JTECH Panel Report,* p. 1-5; and Miroslav Benda, "Trip Report: Industrial Study Mission to the Fifth Generation Computer Project, Tokyo, November 3–18, 1984" (Boeing Computer Services, 1984), p. 4.

26. See Barry Hilton, "Government Subsidized Computer, Software and Integrated Circuit Research and Development by Japanese Private Companies," *ONR Far East Scientific Bulletin,* vol. 7 (October–December 1982), p. 17.

which is responsible for undertaking the research. ICOT is headed by Kazuhiro Fuchi, who left the Electrotechnical Laboratory to direct the project.

The Fifth Generation project is focused on new computer architectures for symbolic computing and artificial intelligence themes. It builds on the foundations laid by the PIPS project. The public announcement of the Fifth Generation program in 1981 provoked widespread reaction in the United States and Europe. It led to the formulation of the strategic computing program in the United States, the Esprit program in the European Community (EC), and the Alvey program in the United Kingdom. The research agenda for all these projects is quite similar.

Procurement

Japan's promotion of computer technology has extended beyond direct funding of R&D. Measures to promote sales of Japanese computers have played a significant role in developing the Japanese industry. Although Japan has not had the strong military demand for computers that played such a crucial role in the early days of the U.S. industry, the government market has been important nonetheless. Technically not regarded as part of the government, NTT has traditionally directed its large volumes of equipment purchases to the NTT family of qualified Japanese suppliers.

Government procurement represented a considerable share of the market for Japanese computers in the 1960s—probably one-half, with the other half sold internally by computer divisions within their parent corporations.[27] In those early days of the industry, Japanese machines fared poorly in open competition with foreign products.

Computer purchase decisions were largely decentralized in the Japanese government.[28] The "buy Japanese" policy, observed in govern-

27. See Joseph C. Berston and Ken Imada, "Computing in Japan," *Datamation,* vol. 10 (September 1964), p. 27.

28. See Julian Gresser, *High Technology and Japanese Industrial Policy: A Strategy for U.S. Policymakers,* Committee Print, Subcommittee on Trade of the House Committee on Ways and Means, 96 Cong. 2 sess. (GPO, 1980), pp. 37–38. MITI has, however, periodically appealed to government organizations to "promote the introduction of domestic computers to foster the domestic computer industry and to expand its share." Such an appeal, for example, was made in 1976 by the MITI minister and later made public. Ibid., p. 68.

ment (and NTT) computer purchases throughout the 1970s, was mainly the result of informal attitudes and practices, not a formal edict issued by some central authority. Japan is a party to the Government Procurement Code of the General Agreement on Tariffs and Trade (GATT), in effect since 1981. Nevertheless, complaints of informal barriers persist among foreign competitors.

Japan's informal procurement policy was highly effective in influencing the purchase of government computers. In September 1975, 93 percent of the value of computers installed in government offices was domestic, as was 96 percent in government-related offices, 88 percent in local public organizations, 68 percent in cooperative societies and miscellaneous organizations, and 90 percent of the value of computers in universities. This compared with an overall average of 56 percent of the value of domestic origin for all Japanese users, 25 percent in financial institutions (perhaps the greatest user of foreign computers), and 23 percent in public utilities.[29] Japanese products continued to hold this favored position in the government market through the late 1970s. Statistics for 1977 show the same or even greater shares for Japanese manufacturers in these markets, while in other, nongovernment markets (financial institutions, for example) their share slipped somewhat.[30]

Quite unlike the case in the United States, the Japanese government's share of the overall computer market has grown over time. In 1968 government agencies accounted for about 5 percent of installed value.[31] As the result of the accelerating computerization of government operations, however, this share kept pace with the private sector. In 1976 installations in government and government agencies stood at 12 percent of the installed computer base; if educational institutions and cooperatives are included, the portion is closer to 20 percent. Roughly the same portion (19 percent) of the value of Japanese installations was accounted for by these same users in 1982.[32] Public authorities in Japan have remained a major force in the general purpose computer market.

Another primary instrument used to stimulate the sales of Japanese computers has been the Japan Electronic Computer Corporation

29. Ibid.

30. Japan Information Processing Center, *Computer Market in Japan* (Tokyo: JIPDEC, 1979), cited in The Futures Group, *The Impact of Foreign Industrial Practices on the U.S. Computer Industry* (Glastonbury, Conn.: The Futures Group, 1985), table 8.2.

31. James K. Imai, "Computers in Japan—1969," *Datamation*, vol. 16 (January 1970), pp. 149–50.

32. See *Japan Electronics Almanac 1983* (Tokyo: Dempa Publications, 1983), p. 39.

(JECC), established back in 1961 when the Japanese computer market was effectively closed to foreign imports and serious promotion of the industry began. JECC has close ties to MITI, which set it up and made key appointments, and to the Japan Development Bank (JDB), which has supplied much capital to the corporation at below-market interest rates.[33]

JECC finances the lease of Japanese computers by Japanese computer users. Participating Japanese computer producers periodically contribute fresh equity capital to the JECC, but subsidized loans from the Japan Development Bank (roughly one-third of its capital) and a pervasive MITI presence effectively make it a quasi-governmental body.

JECC played a very important role in financing computer sales in the early days of the Japanese industry. Its computer purchases accounted for roughly 40 percent of annual installations of computers through most of the late 1960s (see appendix table D-3). But by the mid-1970s JECC's share of the computer market had dropped below 20 percent. These measures are somewhat misleading, however. Japanese computer installations, especially in the 1960s, depended heavily on foreign imports. Japanese computer production statistics include the local operations of IBM Japan (as well as Nippon Univac, Burroughs, and NCR Japan), which represent a major portion of these sales. Products of firms not meeting rigorous domestic content requirements were ineligible for purchase by JECC.

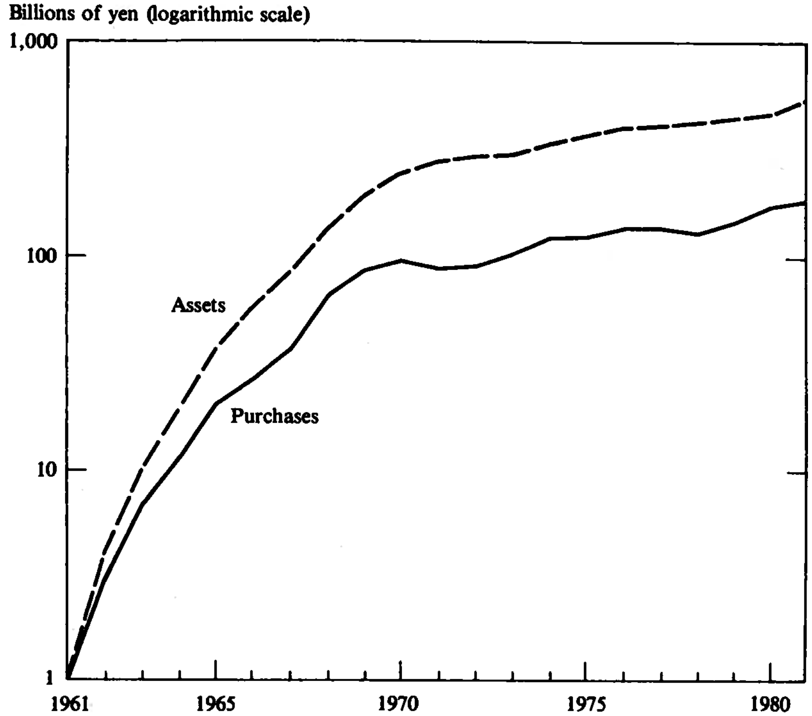
If only "Japanese" computers shipped within the country are considered, JECC played a far more influential role in sealing off a major market for Japanese producers. If deliveries of foreign computers are excluded, JECC generally bought at least half, and it often accounted for as much as 80 or 90 percent of Japanese shipments in the 1960s. If production is considered, JECC accounted for perhaps 40 percent of Japanese output in the mid-1970s.

By late in the decade, however, JECC's share of "Japanese" output slipped to 20 percent of production. Computer purchases by JECC began to level off in the early 1970s, while production continued its steady rise (see figure 5-2).

JECC's access to cheap capital effectively provided a subsidy to Japanese users who purchased Japanese computers. Given comparable prices for machines of roughly equal power, the subsidized leasing terms were an incentive to buy a Japanese machine. As the principal force in

33. See Chalmers Johnson, *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925–1975* (Stanford University Press, 1982), p. 247.

Figure 5-2. *Computer Purchases and Assets of the Japan Electronic Computer Corporation, Fiscal Years 1961–81*



Source: Japan Information Processing Development Center, *Computer White Paper, 1982* (Tokyo: JIPDEC, 1983), p. 17.

the market, JECC had considerable power over prices. Some claim it used this leverage to fix prices at relatively high levels, dampening price competition. Fujitsu and Hitachi, in fact, are said to have increasingly turned to use of their own internal leasing operations in order to offer large customers better prices than those fixed by JECC.[34]

Perhaps the greatest testimonial to JECC's effectiveness in building a market is the establishment in 1980 of JAROL, the Japan Robot Leasing Corporation. JAROL is essentially a JECC for industrial robots.

34. See Leslie Donald Helm, "The Japanese Computer Industry: A Case Study in Industrial Policy" (M.A. thesis, University of California, Berkeley, 1981), p. 31; *High Technology and Industrial Policy*, Committee Print, p. 26; and Ira C. Magaziner and Thomas M. Hout, *Japanese Industrial Policy*, Policy Studies Institute 585 (London: PSI, 1980), p. 85.

Tax and Loan Policies

In addition to funding research and development and promoting the purchase of domestic products, Japan has made explicit and concerted efforts to offer indirect financial support to favored industries, like computers. For example, special tax breaks have been given to computer producers, and favored activities receive low-cost, low-interest financing from government banks. Table 5-5 summarizes two groups of tax breaks for computer producers: those available to all industries and those specifically for producers and consumers of computer hardware and software.

Tax benefits for all producers favor R&D and exports, both key factors in the competitiveness of a high-technology industry. Measures to encourage research include an R&D tax credit, not unlike that implemented in the United States, and accelerated depreciation for R&D capital. Special deductions for expenses related to overseas trade and investment are designed to promote exports.

Similarly, dual objectives are followed in tax breaks focused specifically on computers. Some programs effectively cheapen their cost to users; others favor producers. For example, users enjoy special depreciation deductions applicable to high-performance computer systems and reductions in local taxes on fixed assets. In 1976 over 50 percent of the acquisition cost for a computer could be written off in the year of purchase.[35]

An extensive system of income tax deductions for producers of computer hardware and software increases returns to investment in those favored lines of business. The most significant of the targeted, computer-specific measures is probably the *repurchase reserve allowance*, which allows computer manufacturers to deduct from income a fixed percentage of sales as a reserve against the repurchase of obsolete computers from leasing companies (JECC and others). The rapid decline in JECC's role in the early 1970s, accompanied by sharp decreases in deductible income, lessened the tax benefit of these provisions.

Allocation of financial resources controlled by government authorities has also been a major indirect instrument of national technology policy in Japan. The most important program has been lending by the Japan

35. Japan Information Processing Development Center, *Computer White Paper, 1976* (Tokyo: JIPDEC, 1977), p. 33.

Table 5-5. *Selected Tax Measures Favoring the Japanese Computer Industry*

Years in effect	*Measure*	*Details*
General measures		
1967–	R&D tax credit	25 percent of incremental R&D; 20 percent after 1981
n.a.	Accelerated depreciation of R&D capital, hardware	Up to 60 percent deduction in first year
1959–	Deduction for overseas sales of technical services	Part of income deductible
n.a.	Accelerated depreciation of assets used in connection with activities of research associations	100 percent first-year depreciation deduction
1964–	Special reserve for overseas investment	Tax-free reserve of 15 percent income (12 percent, 1980); large firms exempted after 1972
Measures targeting computers		
1961–66	Qualification for special tax treatment law	Partial exemption from income tax
1968–	Computer repurchase reserves	Fixed percent of sales set aside in tax-free reserve (10 percent, 1968; 15 percent, 1970; 20 percent, 1972; 5 percent, 1978; 2.5 percent, 1980)
1972–	Program guarantee reserve	Fixed percent of software sales set aside in tax-free reserve (2.0 percent, 1972; 0.5 percent, 1979; 0.25 percent, 1980)
1979–	General-purpose software package registration system	50 percent of revenues deferred in tax-free fund for four years
1970–78	Special depreciation for large computers	Additional first-year depreciation (20 percent, 1970; 25 percent, 1972; 20 percent, 1976)
1979–	Special depreciation for on-line computer systems	For high-performance systems, additional first-year depreciation deductions (25 percent, 1979; 13 percent, 1980; 10 percent, 1982)
1971–	Reduction of local fixed-asset taxes on computers	Reduction for large computers (33 percent, 1971; 20 percent, 1976)
n.a.	Tax deduction for computer personnel training	20 percent of incremental training expenditure

Sources: Welke, *Data Processing in Japan*, pp. 29, 35; JECC, *Konputa Noto, 1983*, pp. 96–97; JIPDEC, *Computer White Paper, 1982*, p. 4, *1981*, p. 5, *1980*, p. 43, *1976*, p. 33, *1972*, pp. 36, 42; United States International Trade Commission, *Foreign Industrial Targeting and Its Effects on U.S. Industries, Phase I: Japan*, USITC Publication 1437 (Washington: USITC, 1983), pp. 76, 109; Ira C. Magaziner and Thomas M. Hout, *Japanese Industrial Policy*, Policy Studies Institute 585 (London: PSI, 1980), pp. 78, 86; Eugene S. Kaplan, *Japan: The Government-Business Relationship* (U.S. Department of Commerce, Bureau of International Commerce, 1972), pp. 87, 89; and *Corporation Income Tax Treatment of Investment and Innovation Activities in Six Countries*, PRA Research Report 81-1 (Washington: National Science Foundation, 1981), p. 102.

Development Bank to computer manufacturers, mainly through JECC. Significant funds have also been made available through a program of government loan guarantees to Japan's three quasi-public industrial development banks and the government-run Small Business Finance Corporation. Both the JDB and the industrial development banks have subsidized the computer industry to some extent through preferential interest rates and elimination of the compensating balance requirements normally imposed by private banks.[36] Private loans for these same types of products in the 1960s implicitly enjoyed a government guarantee that lowered costs below market rates, some argue. Such "administrative guidance" by government authorities in effect directly rationed cheap capital to favored industries.[37]

Table 5-6 charts the growth of such new lending to the computer industry and estimates the implicit value of the subsidy to the computer industry in the largest group of these loans from the Japan Development Bank. To provide a contrast, estimates of the tax expenditures involved in the most important tax breaks to computer producers are also shown. Since the mid-1970s when data became available, the JDB loan subsidies (mainly to JECC) have amounted to about 3 to 4 billion yen per year or about 2 percent of total computer R&D. Over this same period each of the major tax breaks for producers has been of approximately the same size: 2 to 5 billion yen for the repurchase reserve, about 3.5 billion for the R&D tax breaks (in 1976, the only year for which information was available). Thus from the mid-1970s on, these three items together may have provided an additional 10 billion yen per year in net earnings for producers, perhaps 4 to 8 percent of total computer R&D.

The direct support to computer R&D provided by the large NTT and MITI technology projects was much greater. Interestingly, these fiscal measures may have been considerably larger just before the transition to large-scale government support for research in 1973. The year before, even as the importance of JECC declined, tax expenditures on the

36. See USITC, *Foreign Industrial Targeting . . . Phase 1: Japan*, apps. B and C.

37. See, for example, Comptroller General, *Industrial Policy: Japan's Flexible Approach*, Report to the Chairman, Joint Economic Committee, United States Congress (General Accounting Office, 1982), pp. 8–11, 60–61; Gardner Ackley and Hiromitsu Ishi, "Fiscal, Monetary, and Related Policies," in Hugh Patrick and Henry Rosovsky, eds., *Asia's New Giant: How the Japanese Economy Works* (Brookings, 1976), pp. 203–05; and Yoshio Suzuki, *Money and Banking in Contemporary Japan: The Theoretical Setting and Its Application* (Yale University Press, 1980), pp. 166–81.

Table 5-6. *Fiscal Measures Benefiting the Japanese Computer Industry, 1972–81*
Billions of yen unless otherwise specified

Measures	*1972*	*1973*	*1974*	*1975*	*1976*	*1977*	*1978*	*1979*	*1980*	*1981*
New lending to computer industry, subsidized loans										
Japan Development Bank (JDB)	15.0	21.5	32.5	46	47	52	56	50	48	46
Long-term credit banks[a]	14.5	13.3	9	12	13	11	8	7	5	n.a.
Small Business Finance Corp.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.5	3	3	n.a.
Subsidy value of investment and tax measures										
JDB lending	n.a.	n.a.	n.a.	n.a.	n.a.	2.6	2.49	3.13	3.41	4.04
Japan Electronic Computer Corporation (JECC) repurchase reserve	10	6	3	5	5	3	0	3	2	2
R&D tax credit and accelerated depreciation R&D capital	n.a.	n.a.	n.a.	n.a.	3.4	n.a.	n.a.	n.a.	n.a.	n.a.
Chamber of Commerce computer repurchase	n.a.	n.a.	n.a.	n.a.	.04	n.a.	n.a.	n.a.	n.a.	n.a.
R&D as percent of production	13.3	19.1	17.1	20.8	20.5	17.8	16.1	15.8	14.5	16.4
Subsidy as percent of R&D										
JDB lending subsidy	n.a.	n.a.	n.a.	n.a.	n.a.	2.2	1.9	2.0	2.1	1.9
Repurchase reserve	19.6	7.3	3.3	4.8	4.2	2.6	0.0	1.9	1.2	0.9
R&D credit and accelerated depreciation	n.a.	n.a.	n.a.	n.a.	2.89	n.a.	n.a.	n.a.	n.a.	n.a.

Sources: Welke, *Data Processing in Japan*, p. 34; JIPDEC, *Computer White Paper, 1982*, p. 4, *1976*, pp. 30, 32; USITC, *Foreign Industrial Targeting: Japan*, pp. 110, 134; and Magaziner and Hout, *Japanese Industrial Policy*, pp. 83, 85–86.
a. Includes the Industrial Credit Bank of Japan, Nippon Credit Bank, and the Long-term Credit Bank.

repurchase reserve amounted to almost 20 percent of computer R&D. Thus the shift away from indirect fiscal and financial subsidies to producers coincided exactly with the increased use of direct payments to promote research and development. Since the early 1970s investment in technology has been selected over investment in other kinds of assets as a social priority.

It is worth noting that the Japanese have used the tax system as an explicit instrument of industrial policy. As table 5-5 makes clear, every two to five years new rates were set under existing tax measures and entirely new menus of benefits created even as old ones were wiped out. This incessant fine tuning of fiscal incentives across industries would be unthinkable in the United States, because of the lack of a political consensus about what sectors to favor and because of the willingness of special interests to use any revision of the tax system as an opportunity to push their narrow sectoral interests.

Market Structure

Joint research, a major element in the rapid development of Japanese computer technology, has created a unique mix of cooperation and competition. In general, Japanese authorities have worked to preserve competition in "downstream" applications and commercialization of new products. But the results of more basic, precompetitive joint research have been shared quite widely to eliminate wasteful duplication and increase productivity of R&D spending.

In the early 1970s under MITI's direction, the three groups of Japanese computer producers (Fujitsu-Hitachi, Mitsubishi-Oki, and NEC-Toshiba) shared costs and product lines but remained in direct competition with other companies. A similar structure was used with the very large scale integrated circuit (VLSI) project of the late 1970s. Fujitsu, Hitachi, and Mitsubishi formed one group, NEC and Toshiba another.

There has been little obvious propensity for these firms to join together to restrain competition. In fact, fierce competition among them has sometimes wrecked experiments in collusion (the disintegration of MITI's plans for the "rationalized" computer industry is an obvious example). But when cooperation has occurred, MITI has generally played an important role in brokering the transaction, usually sweetening it with substantial financial incentives.

Although private cooperative research associations operate under exemptions from Japan's antimonopoly law, they have remained fairly open to public scrutiny. Scientists and research directors, for example, are often posted to the associations from MITI or its laboratories. As noted earlier, ICOT, the institute conducting the Fifth Generation project, is headed by Kazuhiro Fuchi, a former ETL scientist. Research at the Future Electron Device Research Association also has been directed by ETL scientists on leave.[38]

Technology developed under contract from MITI generally belongs to the government and is available under MITI license to all; technology developed in a cooperative research association (even if funded partially by conditional loans from MITI) belongs to the association for license to its members and sale to outsiders. In 1985 IBM signed a widely publicized agreement with MITI that gave it access to the MITI-owned computer patents but *not* to those coming out of research funded by conditional loans.[39] IBM had long had access to computer patents of large computer producers as a result of cross-licensing of its patent portfolio with Japanese companies. The 1985 announcement came at a time of sharp friction between the United States and Japan over trade in high-technology products. Historically, however, patents have had only slight influence on competition in computers.

Trade Policy

Although not strictly a technology policy, trade policy was an essential element in early efforts to foster a Japanese computer industry. Tariffs were first boosted in the early 1960s when the decision to make the computer industry a national priority was made. Perhaps more important, quotas were placed on imports of selected items, including computers and integrated circuits. MITI approval was required on a case-by-case basis to import these items. Foreign investments and technology licensing agreements in the computer industry, like other Japanese industries at the time, were carefully controlled. These restrictions on trade and investment were used as bargaining chips in negotiations with foreign firms over the terms of entry into the Japanese market and to secure Japanese firms' access to foreign technology.

38. See USITC, *Foreign Industrial Targeting . . . Phase I: Japan*, p. 115; Magaziner and Hout, *Japanese Industrial Policy*, p. 41; and Cohen, "Japan Pushes IC Research," p. 96.

39. See Leslie Helm with Alison Leigh Cowan, "IBM Wins the Key to Japan's High-Tech Labs," *Business Week*, August 19, 1985, p. 48.

The decision in the late 1960s to liberalize access to the Japanese economy was the nominal reason for the funding of the 3.5 Generation program. Beginning in 1972 quotas and restrictions on foreign investments and technology transfer were gradually relaxed. By 1976 trade and investment in computers were completely liberalized. Tariff rates were also lowered. Today Japanese computer tariffs are slightly higher than U.S. rates but lower than European rates. Appendix table D-4 portrays the gradual liberalization of Japanese tariff rates on computers and related products since the mid-1960s.

Technology Policy in Europe

European governments have been much less successful than the Japanese and U.S. governments in nurturing national computer industries. One fascinating and absolutely critical difference between Japan and Europe can be seen in their respective responses to the key events of the mid-1960s. The technological lead of America's computer firms, built on its rapid development of integrated circuit technology, widened. At roughly the same time the first IBM System 360 was delivered, and an export license for a Control Data 6600 ordered by the French nuclear program was denied.

In response, European governments in the late 1960s plunged into crash programs to revive the sagging competitive fortunes of domestic computer producers. The Japanese, however, largely relied on technical links between national and foreign producers to keep their producers competitive. The first national computer research project in Japan, begun in 1966, was mainly an exercise in tilling the technological soil. The program developed the technical expertise, particularly in components and circuitry, that allowed national producers to refine and improve their largely imported technology. Not until 1970, when some of these foreign partners began to drop from the scene, did a crisis atmosphere develop. Talk of restructuring began to preoccupy MITI, and expensive crash technology projects were developed.

While the Japanese opted for a program of cooperative research, superimposed on a highly competitive national market, the European governments instead chose to sanction sheltered national favorites. Competition was reduced as government policy chased after size and its perceived advantages. Small firms were encouraged to merge into the

West Germany, and the United Kingdom have general tax incentives encouraging R&D investments.[69] All allow the current deduction of expenses for R&D investments. France and Britain have special depreciation allowances for investments in R&D-related assets. West Germany has a graduated system of R&D tax credits for incremental investments in R&D, and France in 1985 announced that it, too, would establish an R&D tax credit.[70]

Cheap, subsidized capital has been available to computer producers from government sources. The mechanisms vary: direct regulation of bank loan portfolios and interest rates in France; use of state-controlled investment banks in Germany; equity, loan guarantees, and low-interest loans provided by government organizations in Britain. These are not industry-specific programs, however. They are available to any firms that meet criteria for government interest. Germany and Britain also have programs to encourage the use of new, technology-intensive equipment produced by specific sectors, including computers. In Germany small sums are spent to subsidize the use of computer software and microelectronics. In Britain limited government funds subsidize the use of new equipment incorporating computers in selected applications.[71]

In Europe, where the national champion model was selected early on, antitrust has generally not been an important issue in computers. Its main application, in fact, has been against foreign competitors. The Commission of the European Community has brought various actions against IBM to limit its market power. As a result IBM agreed in 1984 to disclose technical details of new products, shortly after announcing them, to Common Market firms.

Summary

"Targeting" policies that funnel public resources into private industry to create a competitive advantage have been widely used to favor national computer producers. Table 5-10 attempts to summarize some

69. See National Science Foundation, Division of Policy Research and Analysis, *Corporation Income Tax Treatment of Investment and Innovation Activities in Six Countries*, PRA Research Report 81-1 (NSF, 1981), pp. 46–49, 69–72, 121–25.

70. David Dickson, "New French Law Boosts Industrial R&D," *Science*, May 31, 1985, p. 1071.

71. USITC, *Foreign Industrial Targeting . . . Phase II: European Community*, pp. 59–64, 73–82, 87–89, 100–12.

Table 5-10. *International Comparison of Industrial R&D in Computers, Selected Years, 1965–83*[a]
Millions of 1982 dollars

	United States		Japan			
Year	Includes Bell Telephone Laboratories	Excludes Bell Telephone Laboratories	Includes Nippon Telephone and Telegraph	Excludes Nippon Telephone and Telegraph	France	United Kingdom
1965	n.a.	>1,391(32)	n.a.	n.a.	>75(12)	99(13)[b]
1972	n.a.	3,131(n.a.)	257(67)	135(20)	n.a.	147(33)
1975	4,305(32)	3,744(22)	353(72)	225(36)	323(33)	190(15)
1979	4,767(21)	4,089(8)	794(36)	593(11)	410(4)	380(16)[c]
1981	5,578(27)	4,711(13)	894(29)	701(7)	n.a.	340(21)
1983	6,929(28)	5,966(16)	1,110(23)	920(6)	n.a.	n.a.

Sources: Tables 4-3, 4-4, 5-3, 5-8; and OECD, *Electronic Computers*, p. 135. Figures are converted to 1982 dollars by using the GNP deflator in *Economic Report of the President, January 1987*, p. 248. Industrial R&D in Japan includes information R&D performed in industry and research associations; public funds are approximated by MITI computer subsidies (and NTT funds when included).

a. Numbers in parentheses are the percentage of public funds.
b. For 1967.
c. For 1978.

of the data on research in computers presented in this and earlier chapters in a consistent and comparable way. The data on research in industry are available for the United States, Japan, France, and Great Britain.

The figures for the United States and Europe refer to research and development expenditure in the computer industry; those for Japan include R&D on computer hardware and software (since most Japanese computer production is in integrated industrial conglomerates) plus private research institutions (since most of the public funding of industrial computer research has gone to cooperative research associations). Because the Japanese figures include the large research program of NTT, an attempt to separate out the NTT expenditure (half of the budget of NTT is assumed to be computer related) has been made for purposes of comparison. Similarly, because NTT's American counterpart, the Bell Telephone Laboratories, has been a major force in U.S. computer technology, half of its R&D budget has been added to the U.S. figures for purposes of cross-country comparisons.

A popular view is that Japanese industry is the most dominated by government targeting, European industry somewhat less so. The United States is seen as the least interventionist of the major industrial countries. But even in terms of industry R&D, the United States is *not* notably less inclined to fund industrial investment in technology directly out of the public coffers. With the enormous growth of the commercial market in the United States from the mid-1960s to the late 1970s, government influence lessened considerably, reaching its nadir in 1979. The rhythm of support picked up in the early 1980s, and U.S. government funding of industrial computer R&D now assumes only a little less prominent role than in Europe and a considerably greater role than in Japan.

If the picture is widened to include R&D outside of industry, the government influence is even more important. In all the countries examined in this chapter, basic research is largely performed outside of industry. In the United States, academic institutions are the primary locus for this activity; in Japan and France, the national laboratories, although Japan has been increasingly supportive of academic research in recent years. West Germany and Great Britain are at intermediate points on this scale, splitting their basic research between public research institutions and academia. This is not particularly surprising. Basic research is perhaps the least appropriable and therefore the most in need of public funding.

The ups and downs of national targeting efforts reflect a cycle of action and reaction. A widening U.S. lead in computer technology in the 1960s stimulated the first government interventions in Europe and Japan. The upheaval in the U.S. computer industry in the early 1970s provoked a major escalation abroad, as countries debated how to replace the fallen U.S. partners upon which their companies had depended for crucial infusions of new technology. Expenditures in Europe and Japan zoomed, as efforts were made to create an indigenous technological base. The budgetary distractions of Vietnam coupled with a wide American lead in computer technology reduced U.S. investments in research. It was not until the late 1970s, when Japanese research investments noticeably began to pay off in narrowing the U.S. lead, that the United States again invested heavily in new computer technology. The 1981 announcement of the Japanese Fifth Generation program fanned the smoldering embers of worry into a raging blaze. Both the U.S. government and industry reacted with heavy new research investments in the early 1980s. In Europe the Japanese announcement, and perhaps equally important the U.S. response, also accelerated research spending.

The perception of Japan's success by foreign competitors acted not only as a catalyst for overall increases in their expenditure but also as an incentive to reexamine the structure and organization of their research programs. As table 5-10 makes evident, Japan's success cannot be attributed to the sheer magnitude of the resources that nation has invested

in developing computer technology. The United States spends vastly more, and certainly the combined R&D spending of Great Britain, France, and West Germany exceeds that of Japan. The good health of the Japanese computer industry must be attributed instead to other factors: the careful maintenance of competition in the domestic market, the joint nature of national industrial research projects, the emphasis on viewing national industry in the framework of an international market. Japan's subsidies for computer research are not unique; conditional loans and grants have been used in Europe since the 1960s. But the focus on joint, precompetitive "generic" research is. U.S. and European research programs' new emphasis in the 1980s on cooperation and sharing in basic research represents a radical departure from past practice. By implication, much of Japan's success is attributed to the way in which it has rationalized its subsidy to R&D and encouraged shared use of the more fundamental elements of industrial technology.

There are other noticeable international differences in the policy instruments used to target computers. Tax incentives to stimulate investment within the favored industry and to expand use of computers in other sectors have played a much more important role in Japan than in other countries. Nearly every year tax measures to accomplish these ends have been modified. Such incessant tinkering would be almost unthinkable in a different political system. Infusions of subsidized capital into the industry have been important in Europe and Japan but not in the United States, where intervention in capital markets is, with few exceptions (notably housing), not viewed as an acceptable instrument of economic policy.

Semiconductors are the cornerstone in the technological base upon which computers rest. Recent efforts by European firms to develop state-of-the-art semiconductors emphasize this critical role. Development of integrated circuits, the top priority in Japan in the 1970s, was absolutely essential to the emergence of Japanese firms as serious competitors in computers. Realization of this fact led to major investments in integrated circuit research in France in the late 1970s, the founding of Inmos with government assistance at roughly the same time in Great Britain, and heavy new investments in West Germany. Roughly half of Britain's Alvey program investments have gone to develop integrated circuit technology.[72] The United States' lead in this area has

72. See "Chips Take Lion's Share of Alvey Cash," *Financial Times*, June 26, 1985.

slipped, prompting renewed American investments in new component technologies. Wafer-scale integration, exotic (nonsilicon) materials, rapid turn-around "silicon foundries" and associated design tools, and the very high speed integrated circuit (VHSIC) program are all areas in which large new public investments are being made with an eye leveled on the foreign competition.