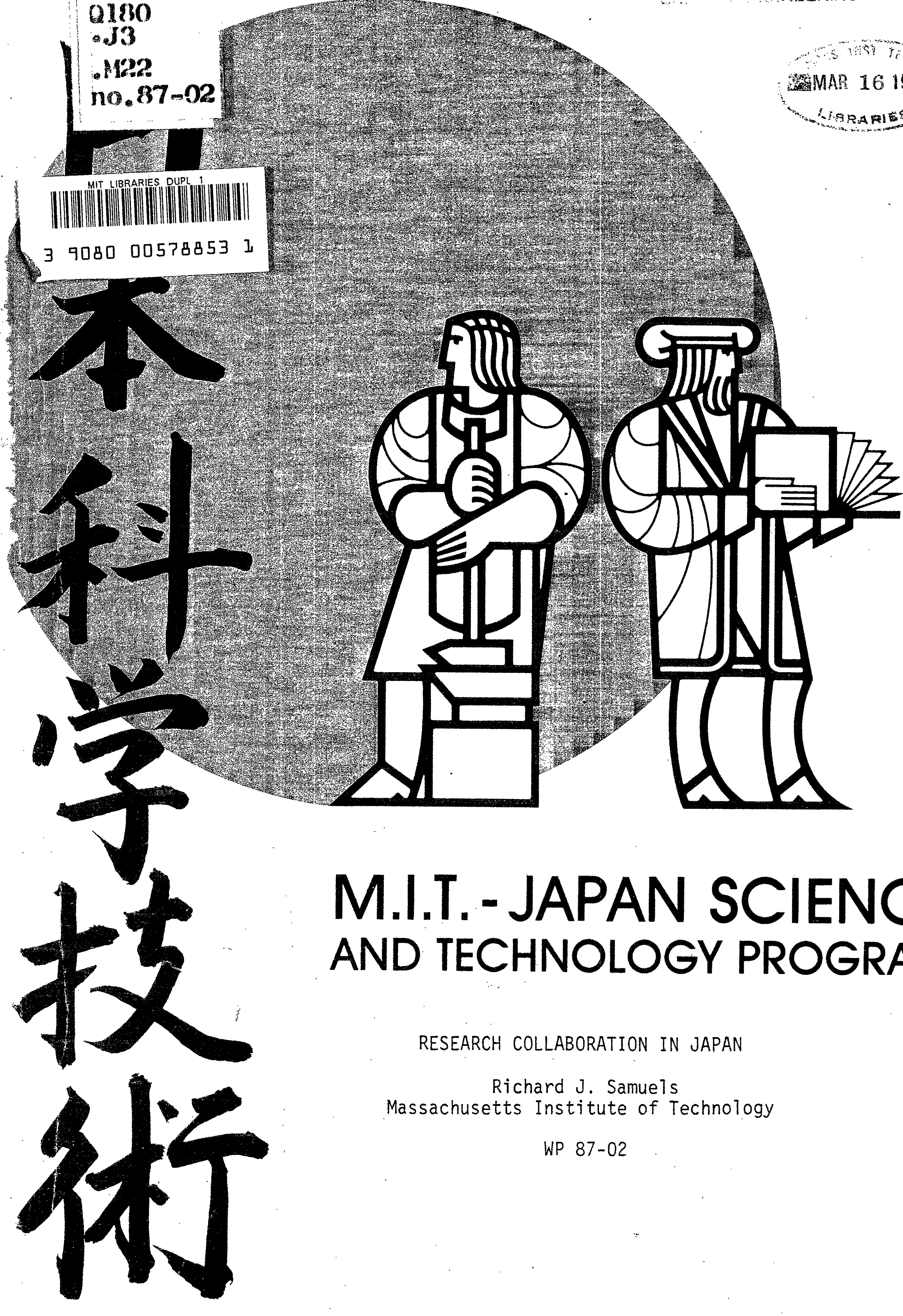

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RESEARCH COLLABORATION IN JAPAN

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+ *Kyōdō Zen de Aru* - "Collaboration is Everything" (Organizing slogan for the Japanese Research Program in Very Large Scale Integrated Circuits)

+ "The Japanese have the poorest spirit for cooperation." Nippon Oil President Naito referring to failed oil cartels in the 1920's.

I. INTRODUCTION

In 1934 Joseph Schumpeter theorized that the essential challenge for economic development is to appropriate benefits of research and innovation by simultaneously protecting and employing proprietary information. His model of innovation incorporates: insight (invention), organization (entrepreneurship), risk-taking (investment), and profits (rents) in a linear, staged relationship that ends with the diffusion of the innovation. The Schumpeterian notion that has long dominated economic thinking is simple: "proprietary information drives the capitalist engine."[1]

If Schumpeter is properly credited with identifying the link between invention and economic growth, Japanese industry is popularly credited with transforming that relationship. Japanese industrialists and policy planners have long recognized that the

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[1] Nelson (1984) p.10. Schumpeter (1934) stresses the role of the individual risk taker, the entrepreneur. Schumpeter (1942) addresses technology management in the modern corporation where specialized, bureaucratized, and captive R&D units provide firms with special powers to direct technological change in the marketplace.

potential for waste, duplication, and other misallocations of scarce resources is the hidden obverse of competition for control of proprietary information. The secrecy and patent protection that are the essence of Schumpeterian competition and that are required for the appropriation of innovation by firms can produce unneccessary as well as better mousetraps. Put differently, what benefits individual firms may not equally benefit whole economies. The broader economic impact of misallocated scare research resources can be profound, especially in an environment of escalating R&D costs and particularly in a nation like Japan, where "excessive competition" is an excessive preoccupation. As many have observed, antimonopoly law has never stood between Japanese industrial policy and the desire of firms to enhance their international competitiveness.[2]

It is not odd, therefore, that public and private cooperation in research would seem so important in Japan. In the realm of doing things together, "collaboration" in Japan was, until very recently, "collusion" in the United States. In the realm of doing things alone, "individualism," an idol of the Western tribe, often is in Japanese terms, mere "selfishness." Perceptions of Japanese successes achieved through what appear to be quite different fundamental assumptions about the nature of competition and the organization of research have stimulated reassessments of Western practices. This paper will attempt to map Japanese practices in a preliminary effort to explain them.

II. RESEARCH COLLABORATION

One looks in vain for analysis of interfirm collaborative research in the Western literature on research and development published before 1970. Leading texts often refer only to cartels and collusion, the costs of which were often too numerous to enumerate.[3] These costs were firmly embedded in theories of microecomic behavior and were enshrined in legal practice.

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[2] Yamamura (1984) is an excellent review of how Japanese patterns of research collaboration and lax antitrust enforcement are related. He notes, for example, that in sharp contrast to US experience, only four cases involving the Antimonopoly Act and the Patent Law have been filed in postwar Japan. See Patrick (1986) and Samuels (1987) for extended discussions of this general point.

[3] For example, see Scherer (1970), a standard text in which "collaboration" is not even mentioned. In its alphabetical and symbolic place in the index is "collusion," replete with cross-references to "cartels, and "price-fixing," totaling 26 pages.

To reconstruct the orthodox view, the disadvantages of cooperative research were both economic and legal; cooperation was as much a disservice to the firm as to the economy as a whole. For the firm, cooperation would limit the appropriation of innovative ideas. Shared benefits make investment in invention less attractive. Firms' investments in cooperative research and development would commit scarce funds and personnel and would entail concession and compromises with partners; collaboration could only dilute a firm's own technology strategy. Researchers would serve too many masters. Too much time would be spent on coordination, too little on generating useful (appropriable) knowledge.

In the broader economy, cooperation would stiffle competition, thereby retarding technological development. It would preclude (or at least severely limit) multiple paths to invention that would, through potentially multiple inventions, have the broadest economic benefit. It would dull the incentive to be creative. The total pool of independent innovative activity in an economy would be reduced, and the savings and efficiencies derived from avoiding duplication would accrue unequally to the largest and most powerful participating firms. Worse, collaboration might "spill-over" from the laboratory to the factory, thereby becoming anticompetitive and market distorting. Large, lazy research programs might be substituted for multiple leaner and more imaginative ones.

Yet, collaboration and competition may not be as incompatible as theory suggests; a paradox is suggested by several current developments: In some businesses, financial, economic, and managerial know-how have replaced embodied technology as a leading source of market advantage. In addition, fantastic reductions in product life cycles coupled with equally fantastic increases in front end costs, and longer, more uncertain product gestation periods,[4] often result in the enhanced technology intensity of manufactured products and manufacturing processes. In short, the emergence and strategic significance of entirely new commercial technologies with unprecedentedly short half lives have challenged planners and practitioners alike.

Their ideas and solutions have increasingly and consistently invoked new forms of institutional combinations -- and interfirm research collaboration in particular. Here is the paradox: Firms have responded to challenges for technology intensification not only with Schumpeterian emphases on proprietary activities, but in also with new linkages to external sources of ideas. Many established firms are measureably less self-sufficient in technology; they are less confident they can generate autonomously the innovations needed for growth, and they are unsure

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[4] The United States Department of Commerce estimates that only one out of twenty laboratory projects result in a positive cash flow for private firms. See Felker (1984).

they can capture the rent even from their own innovations. Increasingly it seems that the risks of non-collaboration are judged to be greater than the risks of collaboration. Schumpeter's model notwithstanding, large and small firms alike, needing to stay active in broader technical areas, have turned to what what Fusfield and Haklisch have called "the external reservoir of science and technology and to develop linkages with outside sources..."[5] and to a strategy that Mytelka calls the "delocalization" of research.[6]

Mytelka reports that in the United States industry-sponsored university and nonprofit research expanded two-thirds faster than in-house research between 1967-1977. By other accounts, moreover, this "de-localization" accelerated even more recently. Haklish has documented the sharp increase in the number of technical alliances outside the firm since 1981.[7] A separate survey of major American corporations also finds that although technology development has expanded both within firms and collaboratively, external sources of technology have grown in importance relative to (and at the expense of) internal technology development. No longer are there two distinct modes of technology strategy, the small, rifle-like entrepreneurial, "Silicon Valley" type and the large, diversified, shotgun-like corporation that can pursue several technological leads simultaneously. The two have become fused in what Horwitch calls a "post-modern" technology strategy.[8]

The rifle and the shotgun have become an automatic weapon and the Japanese have been embedded in these changes as both trigger and target. Fusfield and Haklisch (1985 p. 61) help us make this connection:

> "The dramatic Japanese export successes in fields across the industrial spectrum have had the greatest impact on US attitudes (toward research collaboration). The ability of Japanese firms to cooperate in carefully selected areas of microelectronics development, combined with Japan's greater emphasis on communication and planning between government and industry, has shaped the thinking of US companies."

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[5] Fusfield and Haklisch (1985) p.73. This group at New York University has completed several major studies of research collaboration in the semiconductor industry and more generally in industrial research.

[6] Mytelka, (1986).

[7] Haklisch (1986).

[8] Horwitch (forthcoming) Chapter 6.

European thinking has been equally affected by Japanese developments. Research collaboration traditionally has been viewed in Europe as "hardly more exciting than the work of the local post office;" it has been compared to a dog walking on its hind legs: "it is not done well, but you are surprised to find it done at all."[9] Yet, in the last five years the British government initiated its Alvey programme of cooperative research in computer science modeled directly upon the Japanese Fifth Generation Project, the European Strategic Program for Research and Development in Information Technologies (ESPRIT) was begun, and other collaborative research initiatives (such as Eureka and BRITE) were undertaken to fortify Europe's weakening technology base in the face of Japanese and American competition.[10]

Interfirm technical linkages can take different forms, some of which challenge the notion that competition and collaboration are zero sum strategies. Some, such as joint research ventures and university-based consortia, may be considered "precompetitive" while others, such as mergers and acquisitions, may be seen as "preemptive."[11] In the first instance, the exchange of research and technical information can be a very informal and inexpensive process of professional interaction. The currently proliferating licensing, cross-licensing, second-sourcing, and customer-supplier development agreements that are directed at the exchange of know-how are often more formal. When information does not yet exist and therefore when there is nothing yet to exchange, technical alliances may involve yet different types of formal arrangements, ranging from joint research ventures, and participation in large research consortia situated at neutral sites such as national laboratories or universities. These arrangements are "precompetitive" to the extent that they create or diffuse knowledge that is subsequently embodied in products. They are "preemptive" to the extent that this knowledge limits the number and range of products in the marketplace.

This essay will review several of these technology strategies in greater detail, especially in Japan. At this point, however, we note merely that both "preemptive" and "precompetitive" technology strategies can confer benefits upon participating firms and upon the economy more generally. The "precompetitive" case is the easiest to make. The sharing of risk and costs far upstream where these risks and costs are greatest and where personnel resources are scarcest are the most com-

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[9] Woodward (1965) p.38-9.

[10] For more on European research collaboration, see Mytelka (1986), Vernon (1974), DeForest (1986), Johnson (1972), and Alic (1986).

[11] The former term is from Fusfield and Haklisch (1985). The latter term is mine, and is related to the notion of technology oligopolies introduced below.

pelling among many rationales for joint research. Other arguments frequently cite such factors as the streamlining of the "lumpy" process of technical innovation and the avoidance of wasteful duplication that, by freeing engineering talent, make additional projects possible.

The challenge, of course, is to find a mechanism to allow participating firms to capitalize on each other's expertise and complementary capabilities without distorting makets and challenging the broad social and economic benefits of competition--such as lower costs, lower prices, better service, expanded consumer choice, and efficiency gains. This is why the case for "preemptive" strategic technical alliances is the more difficult to articulate. It seems more convincing when particular sectors in national economies are threatened by foreign competitors. It is therefore best understood as a technology conscious industrial policy.

Such a policy has modern origins in the engineering research association of Great Britain established during World War I. It has been refined by the Japanese, who argue that the central benefits of research collaboration are not economic efficiencies, but technology diffusion and enhanced flexibility and competitiveness on world markets. "Preemptive" alliances are excused (indeed, they have often been enshrined) in Japan, for their contribution to technology diffusion and to the "leveling-up" of the nation's technology base. In Japan, at least, the technology oligopolies currently replacing product oligopolies are understood as facilitators rather than as inhibitors of new businesses.[12] We will explore why and how these polices are adopted after first exploring the variety of factors that might potentially affect technology alliance strategies.

III. VARIATIONS ON THE THEME: GENERIC HYPOTHESES

In identifying the factors that influence these strategies it is useful to separate generic hypotheses about interfirm R&D from those that may apply unequally to different national systems. In the next sections we present the generic hypotheses and use them to inform the review of Japanese practices that follows.

1. Stage

The first factor is the stage of the research activity. Although research on research has rejected the idea of a linear

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[12] This distinction is owed to Mytelka (1986).

path from idea to product,[13] there are important differences between the most basic research and activities associated with the development of a specific product. It is easy to imagine that firms are more willing to cooperate when their shared objective is furthest from the marketplace. Disincentives for collective behavior should grow as projects become products.

A study of the British research associations in 1972 identified a slightly different pattern: Cooperative R&D was least attractive when the projects were both closest to and furthest from the product development stage.[14] The competitive concerns that inhibit technology cooperation downstream can be matched by a general lack of interest in outside linkages furthest upstream where there seemed no obvious application or near term benefits.

This suggests a critical distinction between what many refer to as "base" versus "key" technologies. Agreement among partners about where generic technology ends and proprietary knowledge begins seems essential for productive collaboration. Mytelka suggests that firms enter into sponsored or joint basic research in order to liberate internal resources for proprietary projects that enhance their competitiveness in the market. She notes that the difference between key and base technologies has been deeply affected by inverse trends toward compressed product lifecycles and technology intensification. Products that have the shortest life cycles, such as software, pharmaceuticals, or aerospace are those for which there is the greatest investment in research. Wood products, heavy chemicals, and tobacco are at the other extreme. These dual developments, she argues, have compelled firms to spend ever more for basic research, and as a result, firms seem more willing than previously to work harder to define clearly the "generic" technologies they can develop jointly.[15]

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[13] Allen (1977).

[14] Johnson, 1972. But note that Johnson's sample were research associations that were comprised only of firms in the same business or sector. A hypothesis developed below will account for the extensive inter-firm collaboration in product development.

[15] Mytelka (1986); Fusfield and Haklisch (1985) note that there is little collaboration in biotechnology but a great deal of collaboration in microelectronics in the United States. Their explanation posits a comparison of biotechnology in the 1980's to microelectronics in the 1960's, noting that each was then in a "highly competitive stage in which patentable processes and know-how are of great importance...In this stage companies may be unable to identify opportunities for cooperative activity..." This particular stage-based explanation becomes puzzling when one notes the proliferation in the mid-1980's of biotechnology research consortia in Japan.

Incentives for interfirm collaboration that vary by the stage of the research project are thus complicated by sectoral and structural considerations. Let us explore each briefly in turn.

2. Market Structure

Relations among firms and the ways in which they are individually and jointly related to specific markets can combine with the stage of research in three patterns of collaboration: horizontal, vertical, and cross-sectoral.

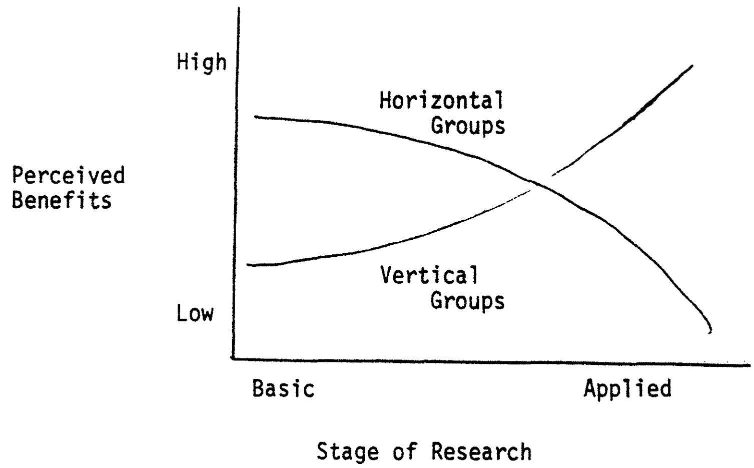
Horizontal research collaboration, projects undertaken by firms in the same business, are the most difficult to justify theoretically. Absent the national policy incentives referred to above and explored in greater detail below, we would expect direct competitors to combine only their most basic research activities. Under conventional assumptions, these combinations are more apt to be associated with large numbers of small firms than with small numbers of large, oligopolistic firms.

Vertical joint R&D, among firms in different parts of the same business (such as steel and automakers or ceramics and semiconductor manufacturers), is a more likely research combination. Its modal form should be in product or process development. Collaborative development of this kind, where each partner contributes expertise at different points along the innovation process, should broaden and stimulate competitive markets in ways that horizontal associations do not.

One might theorize, therefore, that as basic research becomes more applied, the attractiveness of joint research increases for vertically related firms, but decreases for horizontally related ones.

FIGURE ONE

ONE RELATIONSHIP OF MARKET STRUCTURE
TO THE TECHNOLOGY PROCESS



There is also cross-sectoral research collaboration, among firms in different industries. These combinations may portend the emergence of entirely new businesses. In the case of breweries and pharmaceutical firms, for example, contributions from each promise to revolutionize the manufacture of ethical drugs using fermentation technologies. Often labeled "strategic alliances" in the current management literature, these combinations are reportedly more common than before.[16]

Another way to consider the relationships among structure and stage is to theorize that joint basic research is more appropriate for (and perhaps even most common among) firms in the same business while joint applied research is the domain of firms in different businesses within the same industry. Firms from entirely different industries can be expected to enjoy the benefits of both applied and basic collaboration:

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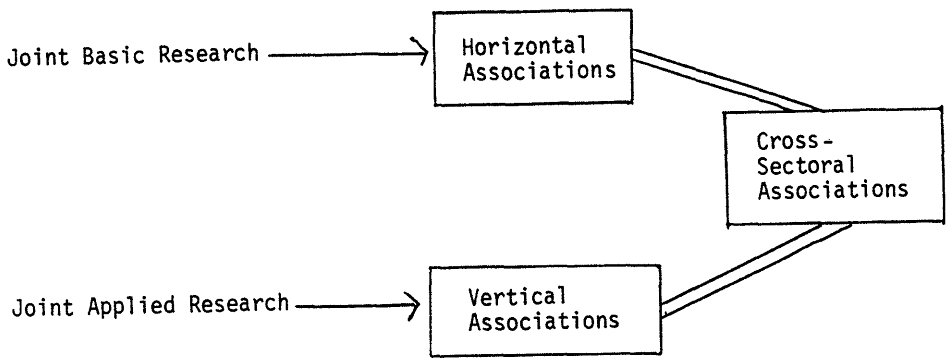
16 Haklisch (1986) p. 1-2 reminds us that even more significant than the "headline" projects in microelectronics, such as MCC, SRC, Eureka, VHSIC, VLSI, etc., are the many interfirm "technical alliances," the strategic partnerships that "constitute an intricate mosaic of both national and international technology transfer mechanisms." McKensie and Company is often credited with coining the term "strategic partnering."

FIGURE TWO

A SECOND RELATIONSHIP OF MARKET STRUCTURE
TO THE TECHNOLOGY PROCESS



Finally, it seems prudent to consider the nature of capital markets as well. In economies where equity and venture capital markets are well developed, it seems likely that incentives for interfirm collaboration are reduced. Where entrepreneurs with ideas can fund them readily, they will have less need to balance the benefits of cost sharing with the costs of benefit sharing.

3. Sector

The most common sectoral rationale for collaborative research is the "laggard" or "gap" hypothesis.[17] This holds that technological disparities among firms within and across sectors best explains patterns of joint research. Put simply, research collaboration should be more common among lagging firms and in lagging sectors than where firms and sectors are at the state of the art. Consortia of "laggards" are directed at normalizing and diffusing knowledge rather than at creating it. One might expect

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[17] This argument is widely articulated. See for example, OECD (1965), Sigurdson (1986), and Doane (1984). Woodward (1965) concluded that cooperative research is best suited to sectors with large numbers of competing firms where technology is not highly developed. Murphy (1982) p. 25 reports the view of one participant in Japan's VLSI project: "The weakest gained the most..."

technologically backward firms, sectors, and nations to engage in and to benefit from collaboration more than technologically advanced ones. This hypothesis is therefore limited to consortia for technology diffusion.

Consortia for technology creation are explained by a corrolary, what might be called the "state of the art hypothesis." Presumably, firms will come together when their collective technology base is at the frontier and needs to be pushed forward faster than any single firms could do on its own. Thus, we can expect laggards to participate in collaborative research where knowledge is diffused and leaders to participate in consortia where knowledge is created.

Another explanation for variations in patterns of joint research is related to the relevance of technology to a particular sector. As noted above, some businesses are more technology intensive than others. Traditional heavy industries, such as steel, automobiles, and chemicals are likely to be more <u>development</u>-intensive than electronics or biotechnology, where proprietary "key" technologies become generic "base" technologies with startling speed. Strategies for cooperative behavior, therefore, should vary by sector and by stage on the basis of the centrality of research, the nature of the collaboration, and rates of technological change, regardless of the distribution of technology within an industry. Leaders and followers alike will be more apt to collaborate in technology intensive sectors than in backward ones.

Finally, the centrality of a sector to national security is apt to affect patterns of collabortion. In the United States, for example, coordinated research and development has long been a feature of defense and space related businesses. It seems plausible to hypothesize that consortia proliferate in particular sectors not only because it makes business sense, but because it makes policy sense as well. Hence, we will be compelled to integrate business and government in the analysis of collaborative research and development.

4. Firm Size

First, however, we can entertain two different possibilities for the effect of firm size on patterns of interfirm research collaboration. On the one hand, large firms with large research staffs are presumably less likely to rely heavily upon external sources of technology. Put differently, it seems much easier to explain research collaboration among small and medium sized firms than among large firms in oligopolistic sectors, where collusion is more common downstream in markets than in research upstream. Haklisch, et al. (1984) conclude that "other things being equal" the share of an industry's total R&D conducted collaboratively will increase when the firms in that industry are smaller, when that industry's capital/labor ratio is higher, and when its exposure to foreign competitition is greater.

Yet, we have already noted that large firms rely extensively upon externally generated technology; the risks and the costs associated with research have escalated so rapidly in the past decade, that even the largest firms find themselves unable to cover all their technological bases. We may simply note that in the United States, the several initiatives in the 1980's for collaborative research in microelectronics involved virtually all of the largest firms.[18] Likewise, in Japan, thirty large firms account for about one-third of the membership of government-sponsored research associations. The five largest steel companies are together in seven of these and the six largest electrical machinery producers are together in twelve.

Even a small part of a giant firm's research budget spent on collaborative projects can dwarf a large percentage of a small firm's budget spent the same way. Many of the same American firms that have the largest absolute levels of in-house research are also the most active participants in university-based and other research consortia. Large firms may have the most to gain from joint research precisely because they also have the most sophisticated internal research apparatuses. This is suggested by historical studies that have determined in-house expertise, rather than making external projects unnessary, actually facilitates its use and enhances its desireablity.[19] Put differently, joint R&D is better viewed as a complement to, rather than as as a substitute for, internal corporate research. Other things being equal, therefore, bigger firms should be found engaging in more, and perhaps bigger, collaborative projects.

For these various reasons it is difficult to suggest an unambiguous relationship between firm size and the propensity to engage in joint research. Other factors explored above and below, such as exposure to foreign competition, the technology intensity of a given business, the diversification of specific firms, and the distribution of technology within an industry, all seem more relevant.

5. Labor markets

We can be reminded that individuals as much as institutions decide to collaborate and share technological information and

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[18] For merely the most recent example, note the role of IBM in stimulating a consortium of chip manufacturers, as reported in The New York Times, 6 January 1987. For a more detailed analysis, in this same sector, see Haklisch (1986).

[19] Mowrey (1983).

ideas. Incentives for them to do so will vary significantly, but one can imagine that where labor markets are fluid and where opportunities for professional advancement across firms are maximized, opportunities and incentives for informal exchanges will be particularly well developed. Professional associations may therefore play a particularly important role in the transfer of technology across firms and sectors (and one that is different from the role of trade associations noted above). Information networks ("invisible colleges") of professionals trained in the same graduate programs or formerly employed by the same firms are apt to become channels for sharing ideas. Von Hippel (1986) has explored this "informal know-how trading" in the United States and finds it a widespread, inexpensive, and flexible form of cross-licensing that goes far beyond the exchange of technical data.

Where labor markets are less fluid and where opportunities for this sort of cross-fertilization are less well developed, we can expect one of two outcomes. Either innovation will be stifled by the high institutional walls that separate researchers, or else researchers, recognizing the benefits of interaction and concerned with the consequences of not collaborating, will work harder than they otherwise would to create formal opportunities to collaborate. In short, where labor markets are fluid, informality should characterize collaboration, while formal forums should supplement existing networks where labor markets and professional mobility is constricted. Labor markets vary more considerably by national systems than by sectors within national economies; we are directed therefore toward examining national institutions and practices, particularly those in the public sector.

6. Public institutions and public policy

The Schumpeterian model of innovation and competition highlights proprietary technology, private institutions, and profit motives but fails to account for the public sector role in economic change.[20] This essay has likewise addressed interfirm research collaboration as if it exists in a policy vaccuum and as if firms and their strategies are all that matter. As we shall demonstrate in the Japanese case, public institutions and public policy can affect patterns of research collaboration in a great many ways.

The first is related to science education. Where universities serve as both a source of technical manpower as well as of basic research, they can add significant depth to corporate research programs. It is not difficult to imagine that university-firm research collaboration will be better developed

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[20] Nelson (1984) p. 13.

where universities have the best developed research capabilities, and where they encourage sponsored research. This will most likely obtain where universities, rather than firms, have the responsibility for the advanced training of technical personnel.

The second is economic and industrial policy. These policy environments are central to any discussion of research collaboration. Subsidies, grants, tax incentives, regulation, state enterprise, public procurement, and other programs designed to enhance the breadth and depth of a national technology base can both lead to and be lead by an active state bureaucracy. Of course, there can be no research collaboration absent relaxed anti-trust enforcement. In the first instance, however, the nature and extent of state transfer payments and other fiscal incentives for collaborative research will depend upon business-government negotiations. Often these negotiations will ratify and reward arrangements previously negotiated among the firms themselves. Analaysis of national policy projects and initiatives in research collaboration must first address these negotiations.

It must next address the nature and extent of state intervention in markets. Where the economic bureaucracy enjoys jurisdiction in markets, and where that jurisdiction can be separated from control of those markets, then the promotion of research collaboration can be market-conforming and will be welcomed by market players. Where the bureaucracy has neither control nor jurisdiction vis-a-vis research collaboration, firms are free to combine and distort markets on their own. In the most difficult case for business-government relations, firms are likely to resist and even to subvert public policy for research collaboration where state control and jurisdiction are fused.[21]

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[21] This argument is more fully developed in Samuels (1987).

IV. INTRODUCING JAPANESE FACTORS

To this point we have suggested six sets of generic hypotheses concerning the factors that should faciltitate or inhibit reasearch collaboration. The Japanese case can both inform and illuminate the relationships identified above.

1. Stage

There is no obvious reason why our general expectation that technology strategies will vary by the stage, or distance from the marketplace, applies differently in Japan than elsewhere. For example, Doane's study of Japanese joint research in electronics concluded that the extent of interfirm cooperation varies over time in the same project.[22] Likewise, there are no indications that the difference between base and key technologies is less central to Japanese technology strategies than elsewhere, even if the terms are used indiscriminantly in Japanese.[23] If anything, current research on Japanese technology policy suggests that Japanese participants in joint projects work longer and harder to identify where generic technnologies end and proprietary ones begin than do others. If Japanese patterns of research collaboration are different than those that obtain elsewhere, it is likely to be more related to questions of market structure, business-government relations, and to sectoral characteristics than to stage alone.

2. Market Structure

For quite different reasons, we can expect both horizontal and vertical patterns of interfirm research collaboration to be more highly developed in Japan than elsewhere.

Japanese firms, especially the largest ones, enjoy a disproportionate and oligopolistic voice in economic policy making. Industry and trade associations are formally represented in government councils, and their deliberations and preferences are routinely enshrined as public policy. Trade associations, comprised of horizontally-related competing firms, routinely exempt themselves from antirutust regulation in Japan. One result may be patterns of horizontal research collaboration that

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[22] Doane (1984) p. 141.

[23] Note that the word <u>kihon</u>, literally "base," "foundation" or "fundamental," is officially translated as "key" by the Japanese government when reference is made to the new semi-public Key Technology Center (See below and <u>Look Japan</u> September 10, 1986).

are exaggerated by Western standards.

We have different reason to believe that vertical combinati-tions may be equally exaggerated. It is widely appreciated that new products and processes arise from combinations of expertise and technologies broader than single firms (even large multi-divisional ones) and single sectors. Japanese finance and industry centered groups (*keiretsu*), with their interlocking directorates and through their routine interaction at the most senior level ("presidents clubs") should be a major influence facilitiating vertical research consortia.

This is directly related to the nature of Japanese capital markets in two ways. First, Japan's underdeveloped equity markets foster extensive corporate debt that may provide large banks and their finance centered groups with strategic information about a wider number of firms. This, in turn may enable Japanese banks to play a more significant role in bringing firms together for joint research than banks elsewhere. Second, as Saxonhouse (1985) and Yamamura (1984) convincingly argue, investment capital does not flow perfectly competitively in Japan's heavily regulated financial system. One result might be that "signaling" or "targeting" sectors for collaboration based upon extensive business-government discussion might be neccessary compensation for turgid capital flows.

3. Sector

Sectoral differences must therefore be factored into our explanations. The "laggard" and "state of the art" hypotheses articulated above may have special relevance, for Japan has had experience with both conditions within the recent past. In the case of the former, firms in technologically backward sectors relied heavily upon collaboration for technology transfer in the 1950's and 1960's. A conventional expectation is that as they matured and approached the technological frontier they would invest more in their own labs than in joint facilties. In such sectors as automobiles, steel, shipbuilding, and optical devices there should be fewer government sponsored research associations and joint national projects in 1987 than in 1957.

But apparently the reverse has obtained. One explanation is that the nature of joint research in Japan has shifted from the normalization of information to the creation of knowledge in Japan. Japanese firms have built upon their history of interfirm cooperation and have put their collaborative institutions and norms to new purposes. In short, we expect to find that research collaboration in Japan has increased because the nature of that activity has become more fundamental.

4. Firm Size

Two points about Japanese firm size seem relevant to explanations for patterns of research collaboration. First, the largest Japanese firms are often vertically integrated. Therefore, quite apart from their group associations, big Japanese firms are apt to be engaged in a greater variety of businesses than big Western firms. This is certainly true of certain leading high technology sectors, such as microelectronics, where Japan's largest chip makers are also Japan's largest computer and consumer electronics manufacturers. Deals and compromises made in collaborative ventures in one sector can be exchanged by these same firms in very different business areas. This alone should make the Japanese case different.

Second, Japan's many small, technology-intensive manufacturing firms cannot be ignored. In some sectors, such as machine tools and software, the small and unaffiliated firms are the technology leaders. The extent to which these firms collaborate in technology devlopment, with each other as well as with their larger competitors, will be very important for completing the conventional picture of centralized research collaboration in Japan.

5. Labor markets

Although interfirm labor mobility for technical personnel seems to be increasing rapidly in Japan, it remains the rare scientist or engineer who has worked for several unrelated firms.[24] This has several implications for explanations of the nature and extent of joint research in Japan. First, as Saxonhouse (1985) convincingly argues, the Japanese permanent employment system reduces opportunities for profession-based communications. More formal collaborative projects therefore become a potentially significant forum for the sorts of informal individual exchanges that take place in professional associations elsewhere. This need is made more urgent by the fact that firms, rather than graduate and professional schools, train the bulk of Japan's technical workforce. Hence the limited cross-firm contacts that do exist, such as undergraduate class *bonenkai* and joint research projects, are cultivated to compensate for Japan's comparatively underdeveloped professional labor market.

This might also explain the formal nature of interfirm collaboration in Japan. American firms, even when they do agree to participate in joint research, seldom release key personnel for the collaborative venture. Joint research ventures are

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[24] See the activities and publications of the Nihon Recruit Center, particularly Beruf, its magazine for engineers seeking new jobs.

typically responsible for hiring their own personnel from the general technical labor force. Technology is transferred to the "cooperating" parent companies in what might be called "stockholder collaboration," through site visits, publications, and other "hands-off" procedures.[25] Japanese collaboration seems to depend much more upon the circulation of engineers from parent firms to joint ventures. Technical personnel are rotated in and out, usually for 1-2 year periods, taking their contacts, know-how, and training back to the parent firm.

6. Public institutions and public policy

Understanding institutional continuity is essential for understanding Japan. Most of the leading Japanese research universities are national universities funded directly by the Ministry of Education, Culture and Science (Monbushō). Industry-university ties were quite strong in the interwar years and during the Pacific War, but the pacifism and anti-business ideologies of the first generation of postwar intellectuals discredited campus collaboration with industry.[26] One way to view interfirm research collaboration in Japan is to understand it as compensation for the relatively underdeveloped relations between leading research universities and the private sector.

The role of the Japanese government in nurturing research collaboration will be explored in detail below. Here we merely anticipate a paradox concerning government structure and patterns of research collaboration in Japan. Much sociological and political research on Japan has characterized public administration in terms of "sectional centralism" or "functional fragmentation" (*tatewari gyōsei*).[27] This refers to the ways in which the mutual insularity of and competition among administrative units contributes to duplicated and overlapping policy programs in Japan. Explanations for the success with which Japanese public policy facilitates and nurtures collaborative research must be reconciled with these centrifugal forces. We will not be surprised to discover multiple, overlapping, duplicative research consortia, each under the aegis of a separate ministry vying for control of its larger share of policy research funding.

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[25] Admiral Bobby Inman, former head of the Microelectronics and Computer Corporation, describes this as "sipping (the jointly developed technology) with a long straw." See his interview in The New York Times September 5, 1986.

[26] Inose, Nishikawa, and Uenohara (1982).

[27] See Nakane (1970) for the sociological model. See Samuels (1983) and Reed (1985) for its application to public administration.

It is entirely plausible that the Japanese government and industry promote research collaboration to compensate for rigidities in the labor market, for underdeveloped capital markets, for the loss of tariff protection, for the absense of military research and for the underdevelopment of university-based sponsored research.[28] Nonetheless, there seem to be an equally compelling set of factors facilitating Japanese research collaboration that exist quite apart from the need to take special compensatory measures. These include the nature of industrial and financial groupings, oligopolistic capital and product markets, sectoral variations, and bureaucratic politics. Let us therefore review what is known about Japanese patterns of research collaboration in order to evaluate these explanations more completely.

V. REVIEWING THE JAPANESE EVIDENCE

1. Stage

Doane corroborates the hypothesis above by concluding that: "The form and nature of (interfirm) cooperation for innovation changed as Japanese industries moved from catch-up to the original innovation stage."[29] When most technology was imported, cooperation was rather a simple matter. Early collaborative projects were designed merely to diffuse technologies and thereby to raise the technological floor of Japanese industry. Technicians and managers from different firms met as often as neccessary to monitor their separate progress; they were sometimes brought together by a central coordinating office within an industry association or a government ministry.

Collaboration to raise technological ceilings is more complicated, for it requires more than coordinated diffusion; it requires the setting of research goals themselves. Doane demonstrates that where interfirm (in this case horizontal) collaborative innovation has succeeded it needed to be some distance from the market. The establishment of clear goals and reliance upon a central, neutral coordinating mechanism by firms of relatively equal expertise were, in her view, made possible by the pre-commercial nature of the undertakings.

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[28] These "compensatory" explanations are best articulated by Yamamura (1984), Saxonhouse (1985), and Okimoto (1987).

[29] Doane (1984) p.125; See also Sigurdson (1986).

Yet, there is evidence that applied research and product development account for the bulk of research collaboration in Japan, and that these associations pay off in commercial markets. The ratio of joint applications in published Japanese patents doubled in electronics, and rose by 40% in industrial machinery between 1974-1982.[30] In high tech "fine" ceramics, it increased by nearly 50% in the two year period 1980-1982. A government survey found, moreover, that less than 14% of inter-firm collaboration was directed at basic research. One-third was defined as "applied" and over half was considered "development."[31]

One way to understand this is to remember that basic research is always the lowest priority for firms that need to generate profits. This is no less true for Japanese firms. The relevant comparison is not with applied and developmental research, but with basic research undertaken within single firms. Systematic data are not yet available.[32] But it seems reasonable to infer that the share of joint basic research is growing in tandem with proprietary basic research, as Japanese firms shift from being consumers to being producers of new technologies.[33] Unfortunately, we cannot yet determine which is growing faster. No studies beyond those cited offer systematic analyses of how these shifts in stage helped shape shifts in procedure and organization of joint research. More work, preferably longitudinal, is indicated here.

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30 Tomiura (1985) p.23. Note however, that in electronics, the level is very low: 2%.

31 Rokuhara (1985) p.40.

32 What does exist is anecdotal or firm specific. Tomiura (1983 p.26) classified 20% of Nippon Steel's 300 research projects as "basic." The largest category concerned research in manufacturing processes. Fourteen per cent of the total were "joint" research projects with other firms.

33 This pithy characterization is from Dore (1983) p.7.

2. Market Structure

The incidence of interfirm research collaboration is accelerating in Japan.[34] Earlier in this paper we proposed reasons why both vertical and horizontal alliances might be especially pronounced in Japan. Let us explore the data available on each.

Vertical joint research is more common. Four fifths of all cooperative research in Japan is conducted by firms in different businesses.[35] These firms are often related by historical and/or capital ties to the same industrial or financial group. Such affiliations are very common in certain business, such as nuclear power, synthetic fuels, oil exploration, telecommunications, and seabed mining. The result is the emergence of an oligopolistic set of six or fewer similarly structured technology projects. Several of the most recent of these arrangements are listed in Table One:

34 Rokuhara (1985) p.37. This report from the Japanese Fair Trade Commission's Office of Economic Analaysis includes a comprehensive survey of collaborative research practices, with data collected from more than 200 large and small firms across six sectors.

35 Suzuki (1986) p. 59. The case of Nippon Steel is illuminating. Tomiura (1985) reports that the ratio of joint applications in patents filed by Nippon Steel in 1984 reached 20% of the total. Of these, more than 90% were filed with firms in different businesses.

TABLE ONE

COLLABORATIVE RESEARCH PROJECTS
ORGANIZED BY JAPANESE INDUSTRIAL GROUPS
(1985-1986)

GROUP	PROJECT	# FIRMS	DATE
MITSUI	Bioreactor Research	9	8/85
	Electronic Shopping	2	10/85
	Hardened Concrete	2	10/85
	Bioengineering	25	3/86
MITSUBISHI	Synthetic Cable	2	10/85
	Industrial Robots	3	11/85
	Metal alloys	2	12/85
SUMITOMO	Industrial Robots	2	12/85
	Computer Chemistry	2	3/86
FUYO	Plating	2	n/a
DKB	Industrial Robots	3	6/85
	Banking Software	2	8/85
	Automated Steelmaking	2	11/85
	Fine Ceramics	2	12/85
	Radio Darkroom	2	4/86
SANWA	Auto Parts	2	8/85
	Biomaterials	3	11/85
	Bioreactor	3	4/86
	Artificial Intelligence	19	4/86
	Biotechnology	12	5/86

Source: Keizaichōsa Kyōkai, ed. *Keiretsu no Kenkyū* Vol. 27 (1986).

While interview data suggest that firms look first to members of same group for research partners, survey data tell a different story.[36] Group-centered joint projects may be preferred for Japanese business investment decisions, but they are much less prominent in research. More than four-fifths of vertically structured joint research (83%) is organized among otherwise

[36] See Doane (1984) p. 214 for interview data.

unrelated firms.[37]

There are also other indications of significant levels of intergroup, vertical and cross-sectoral research alliances. These may be created after the separate groups first try to consolidate on their own, but find costs prohibitive and efforts duplicative. One such example is in aerospace; in 1984 the major groups' trading houses, materials, and vehicle manufacturing firms separately established research committees for space utilization technologies, but with extra incentives provided by MITI and the STA in December 1985, they all came together under the aegis of the "Space Environment Utilization Center."[38]

But public sector incentives are not necessary to bring non-competing firms from competing groups together. There are many recent examples of such collaborative R&D projects. These cross-sectoral or "diagonal" strategic alliances represent an historically unprecedented combination of traditional group centered associations (vertical) and trade association arrangements (horizontal). Given the formal nature of vertical and horizontal associations in Japan, we might call these hybrids diagonal. Whatever their label, however, they are considered "shocking"[39] by a leading Japanese business data organization:

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[37] Kōsei Torihiki Iinkai Jimukyoku (1984) p.20.

[38] This Center is most likely the progenitor of the Spring 1986 Space Environment Studies Project, one of the first projects funded by the new "Key Technology Center" of MITI and the MPT. (See below and Appendix).

[39] Keizai Chōsa Kyōkai, ed. (1986).

TABLE TWO

RECENT EXAMPLES OF COLLABORATIVE R&D ACROSS JAPANESE INDUSTRIAL GROUPS (1985-1986)

Date	Structure Diagonal/ Horizontal	Mitsui	Mitsubishi	Sumitomo	Fuyo	DKB	Description
7/85	D	Toyota	Mitsubishi-Denki				Welding Technology
9/85	D	Mitsui Ship-building				Fuji Denki	Fishing Technology
9/85	H			NEC		Fujitsu	with Hitachi, NTT; Optical Communication System
9/85	D	Mitsui Bussan		NEC		C. Itō	with Hughes Communications; Satellite
10/85	D		Mitsubishi Rayon	Sumitomo Metals			Plastic Magnet
1/86	H	Toshiba	Mitsubishi Electric	NEC		Fujitsu Ishikawa-jima Harima	with Hitachi; Space Experimentatation Center
1/86	D		Mitsubishi Shōji			Shimizu Construction	with U. of Texas; Biotechnology Firm
2/86	H		Mitsubishi Electric	NEC		Fujitsu	with NTT; Optical Communication System
2/86	H	Toray		Sumitomo Electric Sumitomo Bakelite		Kuraray	Bio Materials
3/86	D	Toray	Mitsubishi Kasei	Takeda Pharmaceutical	Tōa-Nenryō	Kyōwa Hakko	Protein Laboratory
3/86	H		Mitsubishi Trust Bank		Yasuda Trust Bank		Banking Software
4/86	H		Mitsubishi Electric	NEC Matsushita		Fujitsu	with Hitachi, Tokyo University; "TRON Project"

Source: Keizaichōsa Kyōkai, ed., Keiretsu No Kenkyū Vol. 27, 1986.

Thus, there is mixed support for our hypothesis that a large amount of vertically organized joint research in Japan can be explained by the ologopolistic group structure. One explanation for the high and possibly increasing incidence of "diagonal" collaboration among unrelated firms may be related to the role of public policy in stimulating collaboration of this type. Group affiliation may be less important when alternative forms of financing and other incentives are available. We return to this below.

The remaining one-fifth of all joint research in Japan is conducted by competitors organized horizontally. There are three vehicles for this kind of collaboration. The first is the industry association. Japanese industry associations are extremely active in technology monitoring and diffusion. They are forums for collaboration and "know-how trading" of all sorts, and deserve much closer attention from researchers, especially because they are exceptionally influential in economic and research policymaking.[40] The second is the formal contract for project-specific alliances among firms. While some of these, such as the recent Hitachi-Fujitsu agreement to develop a 32 bit (and later a 64 bit) microprocessor will emerge from private initiative and without obvious government support, preliminary indications are that horizontal alliances seldom succeed without or beyond the government sponsorship.[41]

The third vehicle is the publicly supported engineering research association (See below). The five largest steel firms, for example, participate together in seven such associations, but very little of their private research is done collaboratively.[42] Likewise, the "big six" electrical machinery manufacturers have participated together in nearly a dozen of these associations, usually in very large scale and highly visible "national projects." But other horizontal research collaboration seems more limited. The evidence currently available suggests that horizontal joint research, long nurtured by government policy, has

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[40] See Lynn (1982) and Lynn and McKeown (forthcoming) for the best work in this area. Dore (1983) p.24 speaks of this in the context of "the guild tradition of competitor cooperation." Yamamura (1984) sees the industry associations as the critical link between the firms and MITI in the selection of participants for national projects.

[41] The Hitachi-Fujitsu deal demonstrates that in rapidly changing markets, joint development need not be vertically structured. They are sharing a $100 million development cost to establish their own (preemptive) standard for the industry. See The Wall Street Journal November 3, 1986.

[42] We need better evidence to argue this point without reservation, but see Tomimura (1985).

never quite weaned itself. When it succeeds, moreover, it seems to require a clear division of labor that includes an operating norm Doane refers to as "separate but together."[43]

3. Sector

There is clear sectoral variation in patterns of research collaboration in Japan. The Fair Trade Commission survey reported that the incidence of interfirm research has increased faster in chemicals and electronics than in automobiles.[44] This may be explained by the already extraordinary level of vertically related automotive product development projects. The automobile firms are not active members of the horizontally structured research associations although steel, electronics, and chemical industries are; this is likely because their joint research is conducted independently between manufacturers and parts suppliers up- and downstream. Parts manufacturers and steel companies regularly send personnel for 1-2 years to the auto manufacturers' research faciltities in Japan.[45]

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[43] Doane (1984) p.158. She also notes (p.143) that the government's role in faciltiating horizontal research collaboration began when the Ministry of Communications (Teishinsho) brought together NEC, Oki, Fujitsu, and Hitachi to back-engineer and improve imported equiptment. After the war, she reports, these same firms agreed with NTT that they would collaborate to design and build their own equiptment.

[44] Rokuhara (1985).

[45] Charts detailing the extent of this vertically organized network of joint development projects for two (unidentified) automobile manufactures are published in the Long Term Credit Bank Report No. 78 January-February 1985.

Data on joint patent applications tell a different story, however:

TABLE THREE

JOINT PATENT APPLICATION BY SECTOR (1982)

SECTOR	PERCENT OF TOTAL JAPANESE PATENT APPLICATIONS	NUMBER
ELECTRONICS/ COMMUNICATIONS	2.8%	73,392
AUTOMOBILES	1.6%	12,816
CHEMICALS	6.1	8,217
MATERIALS	8.5%	13,290
TOTAL	3.6%	107,715

Source: Rokuhara (1985) P.42.

Despite the extent of vertical interfirm research linkages, the automobile sector exhibits lower than average commercial benefit from joint research. The materials firms, while generating fewer joint patent applications in absolute terms, seem to focus more of their total research on collaborative projects.

Vertical interfirm collaboration is also very important for the rapidly growing fine ceramics industry. A 1982 industry association study revealed that ceramics firms have realized very little success from collaborating with each other.[46] Instead, they report fair success and much experience with collaboration with firms in entirely different businesses. Product application and the product manufacturers do seem to come from historically unrelated businesses:

[46] Cited in Rokuhara (1985) p.34-6.

TABLE FOUR

JOINT MATERIALS RESEARCH IN JAPAN (1985)

Materials Firm	Partner	Development Activity
Nippon Tokushu Tōgyō	Riken	Ceramic Diesel Engine
Hitachi	Nissan Diesel	" " "
Kyocera	Isuzu	" " "
Kyocera	Nippon Piston Ring	Ceramic Auto Parts
Nippon Kagaku Tōgyō	Tōyō Soda	PS-2
Kurosaki Yōgyō	Nippon Steel	Compound Ceramics
Asahi Glass	Nippon Steel	Refractory Bricks
Taki Chemical	Nippon Steel	Fireproof Structures
Shōwa Kōgyō	Kawasaki Steel	Fireproof Heterogenous Structures
Asahi Glass	Nippon Kokan	Silicon Iodide
Nichi Asu	Bōnā Intanashyonaru	Ceramic Fiber
Toray	Arusu Hamono	Cutting Devices
Kyocera	Shibaura Denshi	Heat Sensor
Toshiba Ceramic	Toshiba	Single Crystal Silicon Iodide
Kyocera	Honda Motors	Ceramic Engine
Toshiba	Toyota	Ceramic & Gas Turbine

Source: Rokuhara, 1985, p. 35.

At the present time, the industry is hampered by ceramics manufacturers without applications experience and by steel and other traditional materials firms that do not understand the new technologies well. Initiatives for research collaboration have come predominantly from the older, larger materials firms upstream, rather than from the users. As recent investments in silicon fabricating facilties in Japan and abroad reveal, these same steel and aluminum firms are also attempting to master the new materials technologies on their own.[47]

Collaborative research also characterizes the nascent biotechnology industry in Japan. More than one-third of Japanese biotechnology firms were engaged in collaborative research in 1982.[48] Many of these firms are much smaller than those in the automotive or ceramics industry discussed above, and most of their collaboration is conducted in horizontally structured government research consortia.

On the basis of the secondary literature concerning sectoral differences, it is difficult to confirm or reject hypotheses about the relationship of stage and structural variables. External research in mature industries, such as automobiles, and in emerging but commercially viable ones, such as ceramics, are each more apt to be vertically structured and development oriented; external research in emerging, but pre-commercial sectors, such as biotechnology is apt to be fundamental and horizontally structured.

It is difficult to have confidence in these generalizations for two reasons, however. First, the number of cases is small and the available evidence is very limited. Second, it seems likely that firm size and sectoral priority in national policy are better explanations for these variation than is stage. We turn next, therefore, to an examination of these explanations for joint research in Japan.

4. Firm Size

The evidence relating firm size to patterns of joint research is ambiguous. Between 1980-1982, there was a 60% increase in the number of interfirm contracts for joint research and development among firms smaller than 10 billion yen. Such contracts among firms larger than that rose by less than half

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[47] Note for example that Nippon Kōkan, the world's fifth largest steel maker, is building a silicon plant in Oregon in 1987, and that Kawasaki Steel entered the custom chip business in 1985.

[48] Cited in Hane (1986).

that rate (38%) in that same period.[49] It is possible that this growth is high because there is so little collaboration to begin with among small firms. A separate survey of numerically controlled machine tool manufacturers in Sakaki Village, where more than 300 small firms form the greatest concentration of such manufacturers in the world, found that 75% of the firms do not cooperate in R&D, and that the remainder do so only occasionally.[50]

Joint basic research, like basic research more generally, is far more common in large than in small firms.[51] But institutional forms of interfirm collaboration in Japan do not markedly vary by firm size. For small and large firms alike, more than 90% of joint research and development projects are undertaken through contracts, rather than through government consortia or formal joint venture arrangements. It is interesting to note that small firms are somewhat less active participants in engineering research associations than large firms. This is of interest because these associations were first established by law to raise the technology base of small and medium sized Japanese firms.

Although it is difficult to be confident about generalizations derived from these limited data, it seem that these associations have been transformed in Japan, and that our earlier hypothesis about the utility of joint research for larger firms remains viable. This is further supported by the finding that large Japanese firms contract for joint research at twice the rate of small ones.[52]

5. Labor Markets

Existing research on Japanese research collaboration neither confirms nor refutes the hypothesis that joint research is designed to compensate for underdeveloped labor markets. At best we have snapshots of particular projects and professional associations that provide forums for researchers from different firms to discuss technological developments or to advance a

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[49] Rokuhara (1985) p.37.

[50] Friedman (1986) Chapter Five.

[51] Rokuhara (1985) p.40-41 reports that 17% of joint research by firms larger than 10 billion yen is basic research compared to just 8% by the smaller firms in his survey. Overall, as reported earlier, "basic" research accounted for 14% of all research collaboration.

[52] Rokuhara (1985) p.36.

particular state of the art.

One such account reports significant differences between Japanese and American engineering professional associations. Eagar observed that extensive technical committee meetings, usually full-day, stand-alone conferences (rather than adjuncts to annual business meetings), were particularly effective mechanisms for "normalizing knowledge." He concluded that Japanese professional societies provided "the glue which holds Japanese universities, national laboratories, and industries together and contributes not only to excellent communication of new technology but also to considerable cooperative research."[53] Eto concurs. He argues that professional societies have played a "decisive role" in shaping interfirm research agendas in Japan.[54]

Lynn has reported that Japanese engineers are <u>more</u> apt to attend a greater number of professional mettings than are American engineers. His preliminary data contradict conventional wisdom, suggesting that one-fifth of his Japanese sample, but only one twentieth of his American one, attend more than five professional meetings per year.[55] These conferences surely play a different role than in America, where members are more likely to use these bodies as clearinghouses for job information and professional contacts. What is not yet clear, however, is the extent to which firms in Japan would rely less on these associations if engineering manpower was more flexible and less loyal to particular firms. Neither is it clear that these formal ties replace, rather than supplement the kinds of informal know-how trading that is so common among American engineers. In the absence of reliable cross-national data, we can only withhold final judgement about how labor mobility affects patterns of interfirm research in Japan. We do know rather more about the impact of public institutions and public policy.

6. Public Institutions and Public Policy

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[53] Eagar (1986) p.33 says that this process includes debriefings in which engineers who had been abroad report to the rest of the membership, and prebriefings in which drafts of papers for international conferences are circulated and critiqued before presentation. See also Chapter Seven of Lynn and McKeown (forthcoming) for a comparison of the role of trade associations and collaborative research in the US and Japan.

[54] Eto (1984) p.193-5.

[55] Preliminary data presented by Leonard Lynn at the 1987 annual meeting of thre American Association for the Advancement of Science, February 16, 1987, Chicago.

We have already noted that proactive Japanese government policy toward research collaboration offers sharp contrasts to more passive American policies which (at best and only recently) have moved to dismantle regulatory barriers. The role of Japanese public institutions in shaping and directing joint research must be understood in the context of the factors outlined above. But the truly "key" technologies may be political, organizational, and social: viz., the evolved capability of the Japanese state to respond flexibly with broadly acceptable measures to maximize social benefits without sacrificing private gains. Better yet, it is the capacity of the Japanese state to satisfy itself and private actors that private gains and public good are not incompatible. We explore these solutions and this process below.

6.1 The Process: An Overview

The process by which interfirm research collaboration becomes an object of public policy in Japan is not well understood. Far more attention is paid to a project after it is announced and after a technology is "targeted" for collaborative development, than is paid to the consultative process that creates it. On balance, however, announcement of a joint research project is better viewed as the beginning of the end of that project than as the end of its beginning in Japan.

The beginning of the beginning is always very informal, and is seldom well documented. In most cases, an industry association initiates discussions; less frequently, government officials take the lead.[56] But debates about whether this process is industry or government-initiated can be unproductive. Private researchers work hard to find ways to collaborate and their collaboration legitimately involves government officials at every stage. Protracted planning and exhaustive consultation ensure only that participants are committed to the success of a project. This participation is significantly facilitated by public incentives deserving closer scrutiny.

Most accounts stress three distinctive features about

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[56] Pepper, etal. (1985) p.220 sketch the process by which R&D consortia are created in Japan. They also describe the creation of the Biotechnology Research Association and its origins in an industry "roundtable" (*kondankai*). Doane (1984) argues that with the exception of NTT's procurement-based collaborative development programs, most joint research in Japan is "industry initiated." (p.159). Yamamura (1986) stresses MITI's "open leadership" of joint research projects. See also the accounts by Dore (1983), who stresses the role of junior officials, and an excellent report by the US Congressional office of Technology Assessment (1983).

cooperative research in the public sector. The first, noted above, is the extraordinary time and effort invested in front end planning and consultation. This investment, apparently repaid, is facilitated by the oligopolistic structure of Japanese markets as described above, and by the interdependence of state and market actors. Public officials need not concern themselves with assessing the commercial prospects for a technology they have agreed to champion, because they can be confident that these choices were derived from industrial deliberations. The second is the way in which these deliberations result in public support to facilitate rather than to direct industrial research.[57] Here is the distinction made above between state jurisdiction and state control. It seems that public incentives for joint research in Japan succeed when they involve state actors as neutral arbiters, not as forceful leaders. Not every project succeeds, of course, but by most accounts the most visible failures are those imposed upon participants.[58]

The third speaks to the intersection of bureaucratic politics and consensus-building in Japan. Collaborative research is typically multiple and parallel. A reasonable metaphor for this is a "hive" in which many participants work separately for a common product. Very rarely do firms come together under the auspices of a publicly funded project to work side by side in a common laboratory on a daily basis. Instead, tasks are finely divided, and frequently two or more firms are expected to explore different experimental paths to the same goal.[59]

There are two (not mutually exclusive) explanations for why collaborative research in Japan is rarely undertaken comprehensively. The first casts the process in a positive light. In this view, because every effort is made to preserve proprietary possibilities while harvesting collaborative benefits, divisions of labor are preferred. They are the logical result of the way consultative process is embedded in organizational practice, and often, in law. The second possiblity is that the multiple jurisdictions of Japanese public administration produce a "noise" in the system which prevents the participants from completely trusting and cooperating with each other. In fact, it is possible that private firms that reach a modus vivendi find intrabureaucratic rivalries the greatest obstacle to the smooth and efficient implementation of their programs. Although inter-ministerial collaboration in science and technology is not

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[57] See Alic (1986) for a balanced appraisal of this point.

[58] Dore (1983) p.22 makes this important point. See also Doane for an examination of the relationship between failed projects and intrusive public officials.

[59] Doane (1984) p.140 and Nagao (1985) p.9 provide details about divisions of labor for the Super High Speed Computer Project, PIPs, and Fontac.

unheard of (note the 1967 creation of JIPDEC by MITI and MPT), duplication may actually be modal.[60]

6.2 Finance

The budget process imposes a significant degree of discipline on joint research in Japan. On balance it seems that the centrifugal forces of bureaucratic politics that encourage and sustain multiple projects are offset by the centripetal forces of centralized budgetmaking requiring comparative evaluations of projects and annual justification by public champions. Checks and reviews of joint R&D projects are conducted annually, and are measured against current progress and final objectives. Accompanying documentation is awesome in scope and detail.

Japanese government R&D budgets, raised from special accounts, general revenues, and from legal gambling, are spent two ways. The first is in the form of institutional overhead for government laboratories and national universities. The other, more relevant to interfirm research collaboration, is in the form of transfers to private firms entrusted with assigned research. These transfers, in turn, take two forms. They may be loans or they may be subsidies.

Of course, neither public subsidies nor loans are postwar innovations. The Japanese government has been subsidizing industrial research since the early Meiji period. While outright grants remain significant, especially for basic research that firms would not otherwise undertake, it is widely known that the Japanese government directly funds a smaller portion of private sector research than does any other major industrial state. It is less widely known that this public sector share of Japanese research spending dropped below 20% in the mid-1980's.

A "conditional loan system" was first instituted during the 1930's (*Kōkōgyō Gijutsu Shiken Kenkyū Hojokin*). Loans were not repaid unless profits were shown. By 1955 these funds comprised more than one-third of all private firm spending on research in Japan. At that point firms began to invest their own funds in proprietary research, and the government's conditional loan program was redirected to support collaborative research. In 1955, less than ten percent of all conditional loans supported

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[60] One example was the reaction of at least three other ministries to the 1981 MITI announcement of a ten-year biotechnology research consortium. The STA, MAFF, and MHW each responded with a cooperative research project of their own. Two of the leading sociologists of Japanese science discount the importance of these bureaucratic politics. Dore (1983 p.26) argues that they matter only "at the margin." For Lynn (1986), they are mere "turf battles" and are insignificant in comparative perspective.

collaborative R&D; by 1963 this increased to 41%. In 1983 a new system (*Sangyō Kasseika Gijutsu Kenkyū Kaihatsu Hojokin*) was established to support joint R&D exclusively. It cannot be distributed to single firms or individuals. Since the "conditions" attached to repayment are so (purposely) under-specified, "success conditional loans" (*hojokin*) should be considered as no different than subsidies.[61]

Today four fifths of all Japanese government loans (about one-fifth of the research budget for MITI's AIST laboratories plus an equal sum from the Japan Development Bank) are extended to joint projects. In 1987 these loans are pegged at 6.8% and allow up to 15 years for payback. The ratio of government loans to government subsidies is actually greater than unity when the special accounts budgets are included.[62] Since firms must be members of designated non-profit research consortia to qualify for these conditional loans, it is clear that the Japanese government subsidy system is disproportionately generous to joint research projects. These collaborative projects are by definition in the "public interest," hence they receive priority in budgeting. Thus, the Japanese government does not merely encourage firms to do joint research, it pays them to do it.[63] These direct and indirect payments are justified by the MITI estimate that a successful product developed with government support will generate ten times that amount in tax revenues. This seems a handy justification for the government's relative disinterest in forcing repayment of "success conditional loans."[64]

The tax system also provides incentives for ordinary corporate research in Japan; tax benefits seem less overtly skewed than loans to favor collaborative research. There are numerous tax benefits for corporate research spending: Firms may elect to reduce their taxes by 20% of their total R&D expenditures less their highest R&D expense in the previous year (small and medium sized firms have an additional option here). In addition, after 1986 they began to enjoy a 7% property expense reduction for R&D in "key" (targeted) technologies. The most explicit tax benefit for collaborative research allows firms to depreciate capital equipment used in joint projects by a full 100% in the first year of a project. Each research consortium may own its own equipment nominally valued at one yen, and fixed property taxes for joint research ventures are reduced to 75%

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[61] Interview, MITI official (June 22, 1987).

[62] Suzuki (1986) offers a systematic review of public funding for joint research in Japan.

[63] This point is Spalding's (1985).

[64] See Sakakura (1984) for these arguments from MITI's perspective.

after three years. Donations made to such ventures can be taken as a tax loss.[65]

Public support for collaborative research does not stop with subsidies, grants, or tax benefits. Research in national laboratories can also involve the participation of researchers from private firms. In 1986 two new programs were introduced to enhance cooperation between MITI's Agency for Industrial Science and Technology (AIST) laboratories and neighboring private firms. A total of almost 500 million yen was set aside to provide these firms access to AIST equipment and to introduce commercial themes to the government laboratories.[66] Individual AIST laboratories had already initiated these activities. MITI's Electrotechnical Laboratory (ETL), for example, already supports a small number of (usually corporate) research internships each year under the aegis of its "Cooperative Research Program." More important, however, are the "Technical Guidance Internships" funded by private firms for collaborative reseach done at ETL. In 1984 there were 140 such visitors, mostly Japanese corporate researchers, who were working at ETL for 1-3 years.[67] The use of public facilities is often as important as the use of public funds or the deferral of public taxes in stimulating research collaboration in Japan.

6.3 Intellectual Property

As one might expect, this extensive pattern of collaboration in Japan raises difficult questions about intellectual property rights. All government commissioned research, joint or otherwise, is the property of the government. However, by most accounts, licenses are widely available to firms on a non-discriminatory basis. Government funds loaned to private laboratories that result in patentable discoveries require only repayment, and even then only if commercially successful. In these cases, the property rights belong to the firms themselves. But since, as noted above, these success conditional loans are used predominantly for joint research, there is the complication of determining which firm within a consortium, if any, owns the

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[65] These tax benefits are outlined in *Kōgyō Gijutsu* Volume 27, Number 4 (1986).

[66] The AIST is the research arm of MITI. It supervises sixteen national laboratories in a variety of applied fields, including the Electrotechnical Laboratory, the Mechnaical Engineering Laboratory, The Fermentation Research Institute, and the National Chemical Laboratory for Industry. For details on these programs see *Kōgyō Gijutsu* Volume 27 Number 4 (1986). For an overview of the AIST laboratories, see Anderson (1984).

[67] Strauss (1986) p.75.

patent. Fiscal austerity and administrative reform in Japan even further complicates this problem. After 1981 the Ministry of Finance (MOF) tightened requirements for "success-conditional loans." They continue to prefer outright "contract research" under the terms of which all equipment and patents become the property of the state. But analysts say that patent ownership is negotiated on a "case-by-case" basis to accomodate the private partners.[68]

6.4 Institutional Arrangements

The Ministry of International Trade and Industry (MITI)

Collaborative research has significance for bureaucratic politics as well as for economic competitiveness. MITI's role, is best characterized in three ways. First, it acts as cheer-leader vis-a-vis the Finance Ministry for industrial research. Firms that want additional resources need MITI to make their case. Second MITI is a champion vis-a-vis the Fair Trade Commission and the courts. Collaborative research is an area requiring MITI's special attention because exemptions from antitrust laws must be obtained for the participating firms. Third, MITI is a coordinator of industrial (and now increasingly more basic) research. Its "national projects" uniformly require the neutral, credible, and authoritative forum that only the leading economic and industrial policy bureaucracy can provide.

With the exception of technical staff at AIST labs, senior MITI officials are nearly all trained in law and economics. They do not have sufficient technical expertise to pick projects and target technologies without extensive collaboration with industry and academic experts. Although the first formal stage in the creation of a research association are requests for proposals tendered by MITI, this typically comes well after MITI and the relevant industry groups have negotiated the terms of a new joint venture. Each bureau within MITI routinely commissions these groups, for example, to report on research in progress and to identify particulary attractive prospects. This report is thereupon circulated and amplified in formal consultative hearings of adhoc and permanent advisory committees, including the influential Industrial Structure Council.[69] The process may

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68 There is little comprehensive analysis of changing government policy in this area. See Dore (1983), Suzuki (1986), Saxonhouse (1985), and Nagao (1985) for some details.

69 Dore (1983) provides case studies. Nagao (1985) and Sigurdson 1986) outline the RA creation process. Sakakura (1984) is a MITI official's view of "picking winners."

take as long as three years. MITI formally selects participants in joint research projects, but participation is voluntary, not coercive. No firm participates unwillingly, and few willing ones can be easily excluded.

Indeed, cases of non-collaboration deserve special attention beyond what is now available in the secondary literature. Contrary to much of what is written about consensus and cooperation in Japan, it is not uncommon for the leading firm in a particular sector to shun joint research. Saxonhouse (1985) notes that although all the major Japanese chemical firms participate in government funded collaborative research, they tend <u>not</u> to join projects in their own areas of technological leadership. There is evidence that this is true in other sectors as well. Showa Denko, for example refused to participate in an AIST polymer conductivity research association, choosing instead to proceed with its own research on polymer batteries. Tanabe Pharmaceuticals did likewise in bioreactors. When MITI established its interfirm project to develop flexible manufacturing systems, it invited Mitsubishi, Toshiba, and Hitachi to collaborate on a $60 million eight year high power CO_2 laser design project. Hitachi, judging itself to be well ahead of its competitors, refused. MITI then helped fund Toshiba and Mitsubishi, and today all three firms have comparable laser technology. An effort by MITI to engage the cooperation of pharmaceutical firms in a recent chemical technology project resulted in so many refusals that AIST funds had to be assigned to each firm separately.[70] To be sure, MITI is not powerless to induce firms to participate. But it is <u>inducement</u>, rather than compulsion that is the key to understanding the process and structure of MITI support for collaborative research. Without extraordinary incentives, often structured by the participants themselves, MITI research collaboration would be far more limited.

The engineering research association (ERA) administered by MITI is the most common instrument for government-supported interfirm collaborative research. ERA's today account for 6% of all joint research conducted among Japanese firms.[71] Virtually all collaborative research that involves five or more firms is organized as a research association. These research associations are established as non-profit legal entities for specific projects. Ordinarily, funding is shared between private firms

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[70] The Showa Denko case is from Dore (1983). Saxonhouse (1985) mentions Tanabe and bioreactors. The laser case is from Eagar (1986). The Chemical case is from Suzuki (1986).

[71] Suzuki (1986). This figure seems low because, as reported above, 90% of all interfirm research collaboration in Japan is undertaken by private agreement between two firms. Once the number of firms increases, however, so does reliance upon government funding and the ERA formula in particular.

and the government, although participating firms can enjoy significant tax and other benefits from ERA membership even if there are no government financial transfers. Once the specified business of an association is completed, it is either dissolved or its by-laws are ammended to redirect the members firms toward a new project. Research associations have the same legal status as trade associations.

Like many Japanese institutions, the ERA was borrowed from abroad.[72] Dr. Masao Sugimoto, Director of MITI's Mechanical Engineering Laboratory (*Kikai Shikenjo*) in the late 1950's, was impressed by a British system of cooperative research associations that had been created after WWI out of concern that Britain was losing its technological leadership.[73] Of particular interest to Sugimoto (and to the Japan Auto Parts Industry Association that lobbied for new public research initiatives) was the support provided by the British government through ERA's to small and medium sized firms. These were precisely the firms most in need of technological assistance in Japan as well. The first research associations were ad hoc, subsidized by Sugimoto's lab and supervised by the Japan Auto Parts Industry Association. Not one of the 47 firms that participated in the first four ERA's in filters, suspensions, radiators, engine parts had research facilities of their own. The lab and the industry association collaborated to provide central facilities for the collection of data and for shared equipment.

The ERA system was legally established in 1961 under the Research Association for the Promotion of Mining and Industrial Technology Act (*Kōgyō Gijutsu Kenkyū Kumiai Hō*). Small and medium sized firms remained the primary target and the purpose remained applied rather than basic research. Between 1961-1965 twelve RA's were established and their sectoral composition began to broaden. Their average life was nearly fifteen years. None were created between 1965-1970.

This hiatus requires further investigation, but if our generic hypotheses above are correct, we can presume that it was related to two converging trends. The first was the coming of age of small and medium sized manufacturing firms in Japan. They

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72 Westney (forthcoming) is a comprehensive study of foreign organizational borrowing. This account is from Sigurdson (1986).

73 Sugimoto had worked for Hitachi before WWII. He returned to Hitachi in 1964 after a distinguished career at MITI and after serving as the Director of the Science and Technology Agency. Sigurdson (1982) and (1986) is a more complete account of the history of Engineering Research Associations in Japan. See Kōgyō Gijutsuin ed., (1985a) for compete details on the legal, financial, and administrative regulations guiding the operation of Japanese ERA's.

had less need in 1965 for horizontal collaboration than they did in 1955; they also probably had less interest in diffusing technology to their competitors, since by this time it was likely to be their own technology. The second was that the larger, technically sophisticated firms had not yet begun to turn their resources toward basic research. As these firms approached technological frontiers by the early 1970's, they were apt to discover the value of collaboration for the purpose of technology creation, and they were apt to find the ERA a convenient vehicle to implement new collaborative associations.

In fact, an ERA "boom" came between 1971-1983 when Japan's largest firms began to participate in earnest. Fifty-nine research associations were established in that period (twenty-five between 1981-1983 alone), representing fields as diverse as polymers, aircraft jet engines, microelectronics, fine ceramics, and biotechnology.[74] Average membership and the average size of member firms both grew. The smallest among the thirty firms that had participated in five or more ERA's by 1983 had sales of more than 200 billion yen. The average sales of these most active participants was nearly one trillion yen.

At the end of 1985 fifty-two of the seventy-nine ERA's established under the 1961 law were still operating, but their raison d'etre and the nature of their participants has now been transformed. Small and medium sized firms still participate in these ERA's (136 firms belong to only one association), but eight firms are active in ten or more, and thirty firms account for nearly one-third of the memberships. Sigurdson points out that:

> "Engineering Research Association objectives have shifted from generating specific technical results to that of broadly influencing certain industries or a whole industrial sector."[75]

This has been abetted by a shift in MITI policy that encourages the use of ERA's for broadly based, basic research oriented "national projects." Among these have been the successful VLSI Project among others in microelectronics, materials science, and biotechnology.[76] Government support for engineering research association doubled between 1977-1982. Today Japanese firms seldom use the ERA system unless government funds are introduced to support it; rarely do they conduct research at a common site any longer. This has led some to argue that they have become mere "recepticles" for government funds, and that their "main role" is

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[74] See Appendix A for a full list.

[75] Sigurdson (1986) p.10.

[76] Fourteen firms joined the MITI Biotechnology Research Association in late 1986. Twenty joined the Bioreactor Research Association.

the distribution of government funds rather than as a vehicle for research per se.[77]

There are several other important institutional foci for MITI-supervised joint research. One is the public corporation. Administrative reform and fiscal austerity in Japan have made the creation of these off-line "public policy companies" more difficult in recent years. Nevertheless, several of the most important "national projects" involving collaborative research among firms with public support are organized this way. One is the New Energy Development Organization, directed equally by MITI officials and by senior private sector leaders; another is ICOT, administrative home for the well-publicized Fifth Generation Computer Project. Another alternative to the Research Association is the research cartel invoked under the Structurally Depressed Industry Law. Here firms in a designated sector are encouraged to collaborate in order to qualify for specially earmarked research funds as part of the government's overall effort to rationalize industry structure.[78]

Much of MITI's jurisdiction in facilitating research collaboration followsfrom previous successes and failures. Research associations are sometimes created only after more ambitious efforts to consolidate or otherwise restructure an industry collapse. This was the case of the VLSI and other computer technology development projects.[79] Frequently, whole

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[77] Rokuhara (1985) p.50-1 mentions the gasohol and alumina powder research associations in this context. See also Suzuki (1986) p.43. While most RA's are involved in basic or applied research, several, such as the super high performance computer and VLSI projects have been directed at the development of products for the marketplace. See Yamamura (1984) for details on the former and Sigurdson (1986) Doane (1984), and Sakakibara (1983) for details on the latter.

[78] See Johnson (1979) for an overview of the public corporation in Japan. Samuels (1981) details the New Energy Development Organization. Feigenbaum and McCorduck (1983) and Strauss (1986) provide details on ICOT and the Fifth Generation Project. See Young (1985) for more on this law and Samuels (1983) for more on the research cartel in aluminum.

[79] Nelson (1984) reports that MITI designs for a "national champion" to compete with IBM met the same fate as previous efforts to consolidate the automobile industry. The set of three collaborative research groups was merely the resulting "compromise" between MITI and the manufacturers. Doane (1984) offers a more detailed summary of MITI's failure to consolidate Japanese computer firms by pairing them. She recounts the case of Hitachi and Fujitsu, brought together by MITI, who reached a tentative division of labor that each violated almost immediately. See also Murphy (1982) p.14.

sectors find themselves in difficulty that they attribute to MITI policy. Problems such as excess capacity in aluminum or petroleum refining that MITI policy had abetted, and trade frictions in businesses such as steel or textiles, whose export drives MITI nurtured, have led policy planners to consider an enhanced upstream role for the economic bureaucracy.

One initiative of this sort was the 1981 "Next Generation Base Technologies R&D Program" through which MITI established a jurisdiction further from the market than it had earlier ventured. Initially, twelve projects were identified in the areas of a) new materials (fine ceramics, high efficiency separateion membranes, conductive polymers, highly crystalline polymers, high grade alloys under crystal growth control, and composite materials), b) biotechnology (bio-reactors, large scale stable cell culture, recombinant gene engineering), and c) electronic devices (super lattice elements, 3-D integrated circuits, and fortified integrated circuits). Research was organized in five new research associations involving 28 government laboratories, 80 private firms, and 134 universities. Total spending by the AIST, the supervisor of these projects was anticipated to be 100 billion yen over ten years (the average life of these projects was projected to be 9.6 years). In 1986 6.5 billion yen was budgeted.[80]

Other MITI initiatives are even more recent and are closely related to complex bureaucratic politics of research funding and shifting jurisdictions for industrial policy. This is best uderstood by introducing a second institutional focus for public funding of collaborative research, the Ministry of Posts and Telecommunications and the Nippon Telegraph and Telephone Corporation.

The Ministry of Posts and Telecommunications (MPT) and the Nippon Telegraph and Telephone Corporation (NTT)

MPT does not share MITI's status as a "policy agency." Yet, MPT enjoyed extraordinary powers as the prewar Ministry of Communications (Teishinshō) that supervised posts, maritime shipping, railroads, civil aviation, and Japan's only experiment with a national electric utility.[81] MITI (then the Ministry of Munitions) began encroaching on these powers during the war, capturing the responsibility for electric power and aviation policy that it still enjoys today. MPT's industrial policymaking powers were further limited by Occupation reforms establishing

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[80] This account is from Dore (1983) and *Kōgyō Gijutsu* Volume 27 Number 4 (1986).

[81] See Samuels (1987) Chapter Four.

NTT as a public monopoly, institutionally distinct (and administratively distant) from the parent ministry. Even if reduced in power, MPT's responsibility for administering Postal Savings and for nominally supervising NTT throughout most of the postwar period make MPT an important player in the bureaucratic politics of telecommunications and research policymaking.

NTT conducts basic research in three laboratories that together comprise its Electrical Communications Laboratory (ECL), one of the most prestigious research institutes in Japan. Like the Bell Labs of AT&T, three times its size, the ECL is engaged in a wide variety of telecommunications research, including optical communications, digital switching, large-scale integration, and integrated information systems. And like Bell Labs (before divestiture) ECL long served a single, monopolistic master.

This is the most important distinguishing characteristic of the MPT/NTT research system. Unlike MITI but very much like the US Department of Defense, NTT can procure products developed to its own specifications. It has no production facilties, but provides a final market for the products conceived in its labs. While MITI benefits indirectly (through the maintenance of a stable and growing Japanese economy) from supporting industrial research, NTT is actually an extensive (and until recently monopolistic) market for its client firms. Products are developed by a stable "family" of contract suppliers that have long enjoyed special benefits from this special relationship. Whereas MITI subsidizes research before it is undertaken, NTT pays its contractor/family members only <u>after</u> their goals are reached. These firms: NEC, Fujitsu, Oki Electric, and Hitachi, therefore find additional incentives for collaborative research and development activities.

A second distinguishing characteristic of NTT-funded collaborative research is the "value added" NTT provides to these firms. NTT not only procures their product, but engages directly in the basic research that makes these products possible. This research often involves family members, but as we have seen in the case of MITI-sponsored research, even NTT "family" members prefer to conduct their collaboration separately. Firms do not approach NTT to propose a project, NTT initiates projects that will meet its product needs, and will choose participants accordingly. Once chosen, however, the benefits of research collaboration can great. NTT may prefer to support parallel, competing paths to the same product, but guarantees that when one of its family members succeeds, the others are provided the technology for its manufacture. The best example of this process was the case of the facimile machine, developed in the ECL.[82]

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[82] This is based upon Doane's (1984) account of the organization and management of NTT research. See her analysis of the DIPS case in particular. There is also limited evidence that

The MITI-MPT relationship grew tangled and acrimonious in the early 1980s; their "Telecom War" (in which NTT was deeply embedded) produced the most recent and ambitious government program for collaborative research to date, the Key Technologies Research Promotion Center, created by the 1985 Act for the Facilitation of Research in Key Technologies.[83] Several converging developments lead to this bureaucratic war and to these political solutions.

The first development concerned international trade frictions. The special relationship between NTT and its associated firms was assaulted by American trade negotiators in the 1980's. They resented efforts to shelter NTT's $3 billion procurement program from Japan's promises to liberalize trade, and believed (incorrectly as it turned out) than an agreement for open NTT bidding and procurement would result in American high technology telecommunications equipment sales and reduce the bilateral trade deficit. Complicating this was the expiration in 1985 of the 1978 "Temporary Special Measures Law for Specific Machinery and Information Industry Promotion," known colloquially as the *Kijōhō* in Japanese and as the "Targeting Law" in English. American and European trade negotiators objected to "unfair" advantages this law provided Japanese firms in businesses the foreigners felt they could compete. MPT, for reasons associated with the NTT procurement issue, and MITI, for reasons associated with the Targeting Law, each had special incentive to finese the intersection between research promotion and trade policy.

The second development had to do with fiscal austerity. By this time, the Second Provisional Commission for Administrative Reform, *Rinchō*, was gathering momentum. Senior LDP leaders, MOF officials, and business leaders had long been engaged in negotiations to reduce government spending and to relieve the public treasury of financial responsibility for some of its most inefficient operations, such as the National Railways. It occured to private sector leaders that the NTT monopoly might also be challenged. *Rinchō* Chairman Doko Toshio, engineered the

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other Japanese government agencies require firms awarded procurement contracts to subcontract portions of the award to their competitors. See the case of the National Space Development Agency (NASDA) and the No. 1 Earth Resources Satellite contract awarded to Mitsubishi Electric. NASDA asked Mitsubishi Electric to "use those parts in which Nippon Electric and Toshiba are strong." (<u>Nihon Keizai Shimbun</u> December 18, 1985).

[83] The term "Telecom Wars" and much of this account is from Johnson (1986). Readers interested in a thoroughly compelling and deftly nuanced account of relations between MPT and MITI are urged to read his essay. Note that NTT was supervised directly by MPT until it was reorganized as a joint stock company in 1986.

NTT presidency for his former colleague, Shinto Hisashi in 1981, placing a powerful voice for privatization within NTT for the first time. Industry wanted a competitive presence in telecommunications. "Adminstrative reform" also affected research budgets. The government share of R&D spending was already lower in Japan than in any other industrial democracy when, in 1984, the Finance Ministry instituted its "zero minus ceiling" budget system. MOF announced that it would disallow any budget requests larger than the previous year's allocations. As noted above, this reduced government R&D funding to the lowest level among the industrial democracies.

Fiscal austerity could not have come at a worse time for MITI, which was trying vigorously to redefine its industrial policy mission and to enhance its role in industrial research. MITI not only proposed increased research funding for the AIST, but also sought approval to establish a new Basic Technology Promotion Center for telecommunications, materials technology and biotechnology in the fiscal 1985 budget. MOF and *Rinchō* stood in MITI's path. MITI resorted to political pressure. In August 1984, for example, it gathered all former MITI Ministers to publicly renew committments to basic and applied research. This group, comprised of the LDP's most influential and senior leaders, included three former prime ministers and six major faction leaders.[84]

MPT was lobbying just as vigorously to maintain and to enhance its own administrative jurisdictions. Its problems were far more menacing than MITI's. First, even though MPT had not fully controlled NTT for most of the postwar period, the NTT privatization would further dissipate MPT powers. To make matters worse, MPT was threatened with loss of control of the lucrative Postal Savings Program, "the world's largest financial institution."[85] The private banks and MOF were each eager to wrest control of these funds from MPT. Taken together these developments could cripple MPT and snuff out aspirations that MPT could again become a "policy agency" equaly to MITI or MOF.

Changes in the very nature of the telecommunications industry aided both MIT and MPT. Bureaucratic redivisions of labor followed close behind the extensive transformation and fusion of traditional telecommunications businesses. The emergence of a hybrid "information industry" out of the computer industry (MITI's traditional jurisdiction) and a newly competitive communications industry (regulation of communications circuits is indisputably MPT's job) gave both ministries legitimate claims for policy jurisdiction in the new hybrid, high growth telecommunications business.

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[84] *Shūkan Tōyō Keizai* September 1, 1984.

[85] Johnson (1986).

At first, MITI and MPT each stood in the other's way. Each ministry supervised separate and uncoordinated research in its national laboratories; each stimulated and supported interfirm research collaboration in telecommunications designed to establish it as the national telecommunications policy champion. In 1983 each initiated a separate regional information network system: MPT's "Teletopia" and MITI's "New Media Community." In the summer of 1984, each submitted separate draft bills outlining a research and telecommunications research and regulatory program that would secure its own policy jurisdicition.[86] But it was clear that neither MOF nor the private firms would put up with the duplication and competition for long.

The privatization of NTT provided opportunities for reconciliation of MITI and MPT aspirations, a reconciliation achieved only after extensive bureaucratic infighting and only at significant political costs. Once it became clear that NTT shares would be sold, MPT (fearing the loss of its research infrastructure) proposed that a special Telecommunications Research Promotion Center (Denki Tsūshin Shinkō Kikō) be established with funds from the sale of shares (*genbutsu shusshi*). MOF preferred to use the funds to offset the fiscal deficit, a movbe that would would have separated MPT from the NTT funds. Senior LDP politicians intervened between MOF and MPT, and induced MITI to redirect its own proposal for a new research center.

Their reconciliation required three sets of compromise. The easiest was the name. MPT deferred to MITI here, and the MITI proposal for a Key Technology Promotion Center was accepted. MPT preferred that the new Center focus only on telecommunications technology, while MITI sought a broader mandate. MITI again prevailed. But MITI's effort to have unilateral control of the center was rebuffed by the LDP, MOF, and business leaders. The new Center would be controlled jointly. In the final compromise, MITI had its financial windfall and MPT had its policy windfall. As Johnson aptly puts it:

> "The center is a typical Japanese hybrid: the product of bureaucratic competition, funded from public but not tax monies, and incorporating private sector supervision and participation."[87]

The Key Technology Promotion Center was established by the Key Technology Research Facilitation Law of June 1985. It is

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[86] The MPT program was embodied in its draft bill:" Denki Tsūshin no Kiban Seibi Hōan." MITI's was in its "Jōhō Sangyō Kyūgo Kiban Hōan." See *Shükan Tōyō Keizai* September 15, 1984; *Asahi Shimbun* July 31, 1984. *Shūkan Tōyō Keizai* August 11, 1984. *Tsūshō...(1985a)*.

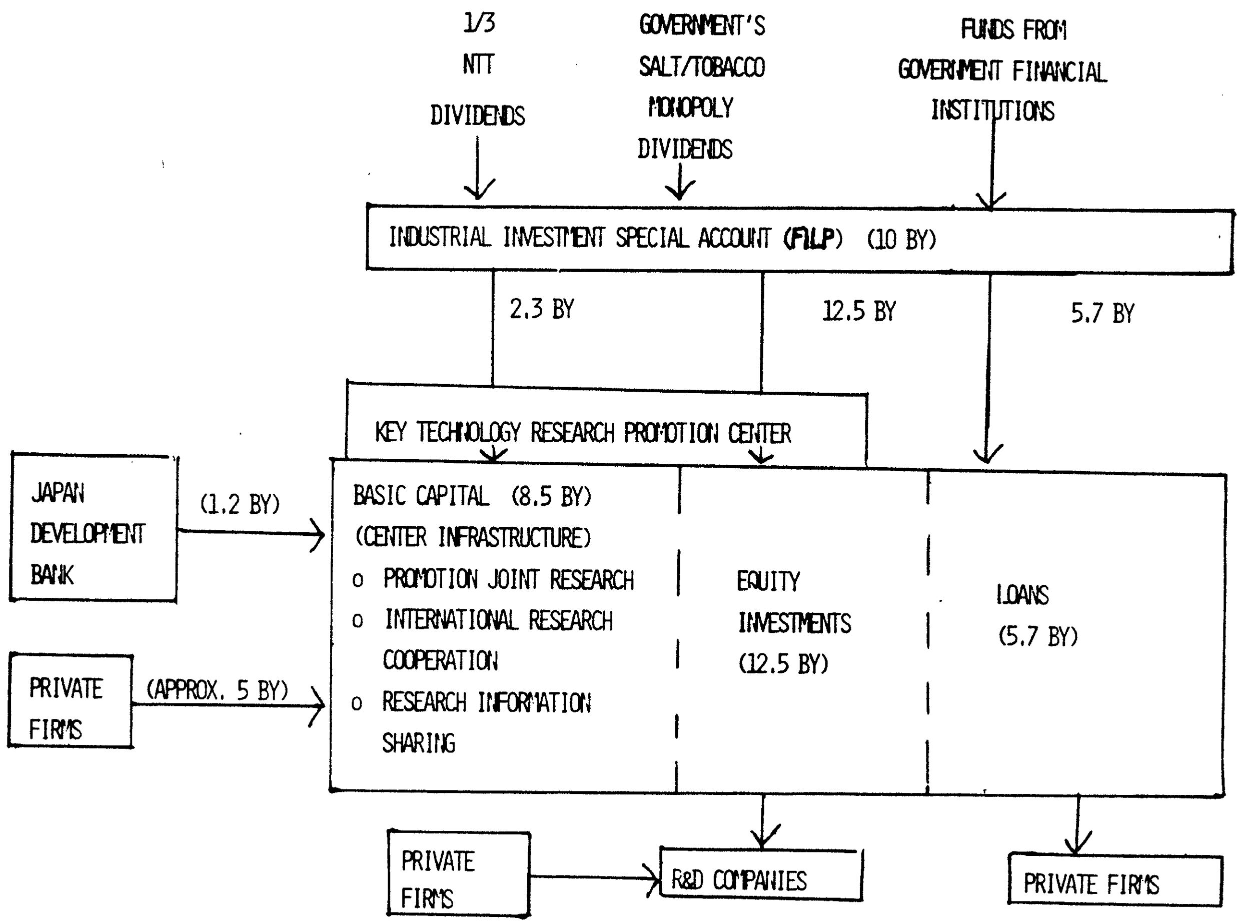
[87] Johnson (1986); also *Shūkan Tōyō Keizai* January 19, 1985.

engaged in three categories of activities, providing: 1) equity for research and development companies comprised of private firms engaged in joint research, 2) loans to private firms (interest repayment is conditional), and 3) basic infrastructure to collect and diffuse scientific and technical information, to promote international research cooperation, and to facilitate other forms of joint research. One-third of government dividends from NTT shareholdings are earmarked for the Center. In addition, it receives funds directly from the Japan Development Bank, other government financial institutions, and private firms.

Promotion of joint research is at the core of the new Center. In order to entice private firms to spend more on basic research, the Center provides up to 70% of the costs for the creation of new research companies comprised of at least two private firms. The firms are permitted to retain all patent rights. The first group of twenty-five projects were interesting for what was and what was not listed. On the one hand, thirteen percent of the Center's first 2 billion yen was distributed to local and regional governments to promote "Teletopia" projects, MPT's term for regional information systems. This suggests that MITI may have been induced to compromise its own "new media community" regional policy program. On the other hand, there was no mention of support for a project in advanced turboprop engines undertaken by the five major aerospace companies. These firms announced in the Spring of 1986 that their joint development program would be supported by Center funds. This suggests that Center funds, like others administered by MITI, provide a significant degree of flexibility and possibilities for diversion. The Center may be best seen as yet another "recepticle" for private firms. (For a full list of the first group of Center Projects, see the Appendix B). The distribution of these finances and activities in fiscal 1986 are depicted in Figure Three below:

FIGURE THREE

THE KEY TECHNOLOGY PROMOTION CENTER
(1986)



Source: *Kōgyō Gijutsu* Volume 27 Number 4 (1986) p.16.

<u>The Ministry of Education, Science, and Culture</u> (Mombushō)

MITI's ambitions in basic research and the promotion of research collaboration also encroaches upon the jurisdiction of Mombusho, which supervises most of Japan's scientific research. In addition to direct responsibility for the scientific research conducted in Japan's prestigious national universities, Mombushō supervises the research activities at ten national research institutes, six of which are engaged in basic scientific research, and all of which are encouraged to stimulate collaboration.

Collaboration in the basic sciences in Japan presents special problems. Only four percent of firms responding to a government survey reported that they sponsored research or engaged in collaborative research with Japanese universities. Similarly, university scientists particpated in only very limited ways in the government-supported cooperative R&D programs described in a separate study.[88]

There are several varieties of disincentives for university-based researchers to collaborate with others outside their faculties. First, there is the rule of "non-additionality" by which grants from goverment ministries other than Mombushō automatically reduce Mombushō support by the same amount. The second problem is structural. It is widely believed that the insular research groups of the science and engineering faculties of Japan's leading universities inhibit the interaction with industry and other research institutes. These "chairs" (*koza*) are remnants of Germanic borrowing that government and industry both hope the universities will discard. Third, many argue that the low level of industry-sponsored research at leading Japanese universities is derived from the antipathy of Japanese scientists toward applied research and toward industry in particular.

Nonetheless, there have been significant changes. In 1973 Mombushō, concerned with the lack of effective coordination in Japanese basic research, established its National InterUniversity Research Institutes (NIURI) to centralize these activities and to promote joint research in the basic sciences. Funds were made available for collaboration across the government research institutes that would also allow industry participation.[89] In 1986 legislation was introduced to further facilitate cooperation between government and university researchers and industry. Several impediments to collaboration, such as the 50% reduction in pension allowances for visiting researchers, and restrictive

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[88] Rokuhara (1985) p.38-9; Inose, Nishikawa, and Uenohara (1982) p.55.

[89] Eto (1984); Abe, et al. (1982); Anderson (1984) p. 89-101.

patent ownership regulations were removed. Formal civil service restrictions on consulting by researchers at national universities are still commonly circumvented. They receive loans of equipment and utilize corporate research facilities quite commonly; there are several reports that such arrangements have often been an important source of basic research for major industrial projects.[90] Thus, despite the prevailing view that university research is isolated from industry and despite the hand-wringing of Japanese industry and university professors about their lack of interaction, there is evidence that their collaboration is both important and increasing.

The Science and Technology Agency (STA)

The STA was established in the mid-1950's to coordinate government research and to assume jurisdiction in areas not already controlled by existing ministries. This has never been accomplished without substantial difficulty. Bureaucratic rivalries with MITI over nuclear power and with Mombushō over space technology have become permanent parts of the STA environment. The formal division of labor with MITI has always been defined by the distinction between basic and applied research, with MITI assuming responsibility for the latter, and STA for the former. However, in Japan as elsewhere, this distinction has neither been easy to identify nor to enforce. The STA has always been frustrated by Mombushō's "natural rights" to university-based research and by MITI's claim to suzerainty over industrial research. It has been difficult for the STA to "coordinate" what it does not actually control.

As noted above, MITI authored and Diet passed the enabling legislation for engineering research associations in 1961. The STA responded that same year with the Japan Research and Development Corporation (JDRC), a special public corporation under its supervision. The objective of this new entity was to transfer the results of government research to private industry and to promote commercial development of government-funded basic research. This has often involved the provision of "success-conditional loans" from the STA to private firms. Likewise, in apparent response to the 1981 "Next Generation" MITI initiative, the STA's Institute of Physical and Chemical Research (RIKEN) launched its own "Frontier Research" program in 1986. Frontier projects focus on 15 year basic research in biological and materials sciences, and are designed to attract foreign

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[90] Doane (1984) p.127; Inose, Nishikawa, and Uenohara (1982); Anderson (1984).

researchers.[91]

Like the other government agencies mentioned above, the STA has taken recent initiatives to promote joint research and better collaboration between industry, national laboratories, and the universities. In 1981 the STA, through the JDRC, established the Exploratory Research for Advanced Technology Organization (ERATO), as its own instrument to promote basic collaborative research. ERATO's mission, to engage and combine the expertise of researchers from firms, universities and government labs, is limited to small groups for five year projects. No bricks and mortar funding is available, and as the JRDC has no facilities of its own, research is conducted in rented space, often at nearly three dozen geographicaly dispersed company and university labs. ERATO stresses individuals over organizations. Indeed, ERATO selects scientists for their creativity, youth (they must be younger than thirty-five), and (often) foreign research experience. Many are seconded from private firms. By early 1985 the ERATO projects had produced 260 professional papers and (despite being limited to basic research) 170 patent applications. Patent rights are shared equally by the JRDC and the inventor. (A list of current ERATO projects and participants is in Appendix C.)

Reviewing the Japanese Policy Context

This review of public institutions and public policy suggests that in Japan it may be more difficult to persuade <u>ministries</u> than to persuade <u>firms</u> of the advantages of cooperation. Given the value of proprietary information in competitive markets, this is more than a little surprising. But bureaucratic politics can be overwhelmingly inertial and narrow in Japan, and this may provide additional research strategies to firms. For firms, generic technologies are a resource cost, while proprietary ones are a resource generator. Bureaucracies, on the other hand, have only costs, especially under conditions of austerity. They can spend, but they ordinarily cannot generate resources. Thus, competition among ministries cannot be differentiated in the same way as competition among firms. Success is measured only by budget share and jurisdiction. While we anticipated that the functional fragmentation of the Japanese bureaucracy might affect patterns of institutional support for interfirm collaboration, the opportunities it provides firms suggests a more general problem for policy analysis.

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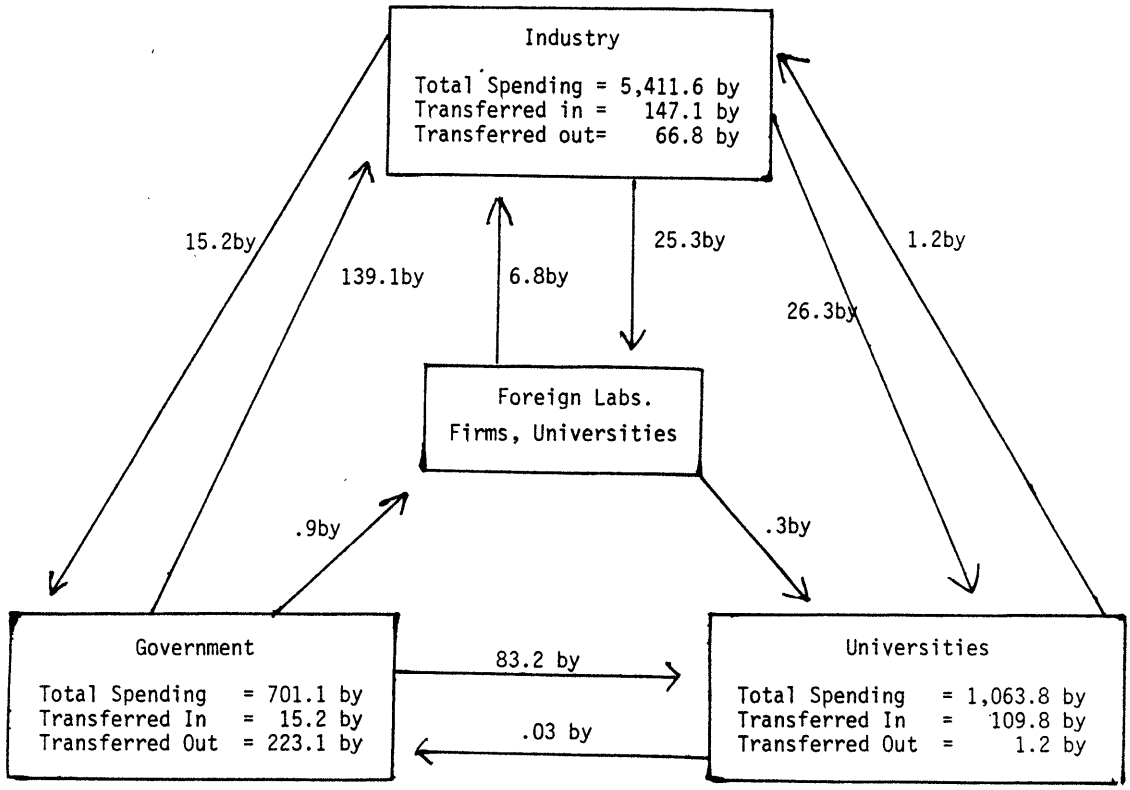
[91] Note that this project is not to be confused with the "Human Frontier Science Program," an initiative in the biological sciences undertaken by MITI in 1987 with the support of the Prime Minister.

The best data available on the actual flow and disbursement of research funding in Japan shows that industry is the big winner in every respect (See Figure Four). Total industrial research spending is greater than that for universities or government laboratories, and industry receives a greater flow of external research support than either of the other two. Moreover, Japanese industry funds nearly as much <u>foreign</u> as domestic research. In sum, just as there can be no understanding of collaborative research in Japan without understanding the basic process of industrial research, so too there can be no understanding industrial research without seeing how it is embedded in the broader policy and institutional environment:

FIGURE FOUR

THE FLOW OF JAPANESE SCIENTIFIC AND TECHNICAL RESEARCH SPENDING (1984)
unit = billion yen



Source: Kōgyō Gijutsu In, ed., 1986a, P.61.

VI. CONCLUSIONS

Research collaboration in Japan is well fabled, but is not yet well enough studied. Some perspective is in order. For all the talk about how national projects and cooperative ventures dominate Japan's research agenda,[92] interfirm research collaboration remains the lesser part of Japanese research efforts. Although collaboration is found in all major industrial sectors, and although government-funding can be involved, firms' most important research is not done in joint facilties. Proprietary research still accounts for the largest share by far of Japanese research spending. Two-thirds of all research projects are conducted by firms alone. Half of the remaining one-third is interfirm research. The rest is collaboration between firms and national labs, universities, and other research institutes.[93]

Dore (1983) raises important questions about nationalism and Japanese culture that cannot be ignored:

> "Information is perhaps more readily shared in Japan than in most countries...This is partly a function of nationalism and a sense of the need to catch up. It is also partly a reflection of the ...guild tradition of competitor cooperation in industry associations."

In his view, the facility of information flows and an underlying collective nationalism combine with a neutral and respected public institutions to enhance the willingness of firms to collaborate. Does the evidence reviewed here suggest that models of Japanese consensus and collaboration are outdated? Or conversely, do approaches that devalue cultural explanations of Japanese collaboration miss the fundamental causal relationships? We have seen that even nominally collaborative projects are structured to protect the proprietary interests of the participating firms. Thus, while it is quite clear that the Japanese have never been burdened with the idea that cooperation upstream

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[92] See, for example, references to joint research as a "Japanese trademark" in the Federal Government's JTECH Telecommunications Report of January 1986. Note also, however, that the Japanese do not see their cooperative research practices as particularly well advanced. Rokuhara (1985) is an example.

[93] Rokuhara (1985) p.32. The Sakakibara and Otaki (1984) survey of more than 300 Japanese firms found that research and sales/marketing groups were far more important sources of technical information than were other firms in the same business, academics, or suppliers. In their list of how research is activated, "confidential communications with in-house research labs and with other parts of the firm," "foreign study," and other mechanisms were most important. Joint research was not even on their list.

in research is incompatible with competition downstream in markets, it is far from clear that models of consensual, harmonious, cooperative Japanese practices permit us the fully nuanced interpretation we are seeking. Nationalism is important, but it is not enough.

Although the image may be one of cooperation implemented through shared tasks leading to synergies and innovation, the reality is more commonly one of cooperation implemented through divided tasks; innovation is probably derived from economy. We can be sure that the Japanese work hard at finding ways to economize and streamline the technology process. We can be equally sure that their solutions protect °cooperative separation' as much as they encourage genuinely integrated collaboration. Just as oligopoly and competition coexist in (and indeed define) the Japanese economy generally, so does their balance define the Japanese technology process. It is no surprise that as the Japanese increase their investment in innovation that they do so in culturally comfortable and historically consistent ways- by ignoring antitrust concerns and by reinforcing oligopolies. It is left for the bureaucracy to ameliorate the worst effects of the transformation of product oligopolies into technology oligopolies. On the basis of our limited evidence, it seems that this concern is less important to bureaucrats than is the protection of their own jurisdictions. To repeat, in Japan it is arguably more difficult to get bureacrats to collaborate than to get firms to do so.

To the extent that there is genuine collaboration, evidence is mixed about motives and causality. The Office of Technology Assessment has evaluated Japanese joint microelectronics research and concludes that:

> "...the actual extent of interaction among participating firms was limited...It appears that the organizational form involved a compromise between attempts to encourage individual interactions- with objectives such as stimulating personnel development- and the more concrete technical goals."[94]

This speaks perceptively to the influence of labor markets and firms size on patterns of research collaboration. It plausibly suggests that government support may be neither necessary nor sufficient for some forms of interfirm research collaboration in

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94 Office of Technology Assessment, ed., 1983 p.418. Note that Yamamura (1984), citing a *Chūō Kōron* essay (Fall 1981), argues persuasively that joint research is as important to the Japanese for stimulating researchers competitively as for exchanging technological information. As well, Okimoto (forthcoming) argues that the real contribution of collaborative research in Japan remains the circulation of information and the overall boost they provide research budgets.

Japan.

There is some evidence that speaks to the role of Japan's industrial and financial groups in promoting collaborative research. The OTA reported that, based on patterns of contracting in microelectronics, once participants in a joint project complete their basic research and move toward product development, interfirm cooperation declines in Japan. Our somewhat broader evidence allows a slightly revised interpretation. Clearly, interfirm collaboration for product development is common in Japan; indeed it is the modal form of joint research. We conclude not that interfirm cooperation declines as products move to market, but that it shifts from horizontal to vertical forms. While the secondary evidence on this point does suggest that this shift is facilitated in Japan by the nature of the *keiretsu* groups, it also points to a significant intergroup and cross-sectoral, or "diagonal" collaborative dynamic.[95]

The possibility that "signaling" by the Japanese government of a particular high technology area through the creation of a well publicized joint research project is a functional substitute for underdeveloped equity markets remains intriguing. It must be tempered by our observation, however, that firms seem to deploy sufficient resources for research, and even for joint research, when they are determined to do so. The creation of formal "recepticles" to receive public funds is not evidence of compensation or functional substitution. Admittedly, more research remains to be done.[96]

Finally, the Japanese case suggests several points of considerable comparative interest. First, we observe a successful transition from collaboration for technology diffusion to collaboration for technology development. Instruments designed to facilitate this diffusion among small and medium sized firms are transformed into powerful, centralized instruments for

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95 We cannot rule out MITI as an important facilitator of these "diagonal" associations. Note its role in the formation of the Aircraft Core Technology Center in October 1985. Shimadzu, Teijin Seiki, Toshiba, NEC, Toray, and Kobe Steel joined to facilitate international joint development of aircraft parts and materials.

96 The best statement of the "compensatory" explanations for joint research in Japan is Saxonhouse (1985). More work also needs to be done on the "free rider" problem. There is little systematic analysis of the extent to which technology, collaboratively developed, is diffused to non-participants. Saxonhouse looks at data from seven government research consortia and concludes that there is very little relationship between participation and change in market share. Non-participants seemed to do just as well as participants.

technological development serving giant firms. Standard objections to research collaboration, including high management costs, free riders, diluted benefits, and reduced technological options are each finessed in Japanese practice. Japan may be a singular case in which competition is stimulated, rather than inhibited by joint research and extensive conversation among competitors. We are reminded that above all else, Japanese competitors are pragmatic. The stability of their positions in markets allows them to consistently weigh the negative, restrictive effects of collaboration against potential new efficiencies, and to learn how to live with the costs while capturing considerable benefits. Collaborative science may indeed be a Japanese art, but it seems as much related to economic and administrative structure as to culture.

APPENDIX A

Engineering Research Associations (Gijutsu Kenkyū Kumiai) in Japan, 1961-1986

ERA No. and topic/ name in Japanese	Firm No.	Period	Firms
1. High polymer materials (Kōbunshi genryō gijutsu kenkyū kumiai)	23	10/61-4/77	Asahi Kasei, Asahi Glass, Aginomoto Kureha Kagaku, Shōwa Denko, et al.
2. High grade industrial alcohol (Kōkyū alcohol kōgyoka gijutsu kenkyū kumiai)	3	11/61-2/72	Maruzen Oil, Hitachi, Nippon Soda
3. "Wool yarn" laboratory (Gijutsu kenkyū kumiai amachi kenkyūjo)	7	2/62-4/77	Daido Keori,Daido Bomo et al.
4. Creep testing (Creep shiken gijutsu kenkyū kumiai)	22	3/62-5/69	Yawata Steel
5. Optical engineering (Kōgaku kōgyō gijutsu kenkyū kumiai)	45	6/62-1/81	Asahi Kogaku, Cannon Camera
6. Preferential refining (Yūsen seiren gijutsu kenkyū kumiai)	3	9/62-3/64	Fuji Steel, Daido Steel
7. Electronic computers (Denshi keisanki gijutsu kenkyū kumiai [FONTAC])	3	9/62-11/72	Fujitsu, NEC, Oki
8. Solvent dyeing of wool (Yōmō seihin yōzai senshoku gijutsu kenkyū kumiai)	4	10/62-2/67	Kataoka Keori, Asahi Denka kōgyō
9. Casting technology (Naniwa imono gijutsu kenkyū kumiai [Rōsoku] - Osaka)	18	1/63-11/74	Small Casting Companies in Osaka
10. Shock absorbing packaging (Kanshōzai gijutsu kenkyū kumiai)	6	4/64-4/79	Koku Kikaku Konpō, et al.
11. Aluminum electrolysis (Arumi hyōmen shori gijutsu kenkyū kumiai)	33	2/65-5/83	Shōwa Koki, Kobe-Northrup

12. Coal calcination (using heavy oil) (Sekkai jūyu shōsei gijutsu kenkyū kumiai)	38	8/65-5/80	Calcination firms
13. Car components (pollution and safety research) (Jidōsha kōgai anzen kiki gijutsu kenkyū kumiai)	7	2/71-	Hitachi, Jidōsha, Denki Kōgyō, Hanshin Electronic, et al.
14. Car components (Sōgō jidōsha anzen kōgai gijutsu kenkyū kumiai)	6	12/71-	Mitsubishi Electric, Nippon Air Break, Mikuni Kōgyō, Mitsuba Denki, et al.
15. Light metal composite materials (Keikinzoku fukugōzai gijutsu kenkyū kumiai)	26	12/71-7/76	Nippon Light Metals, Sumitomo Chemical, Shōwa Denko, et al.
16. Super computers (Chō kōseinō computer kaihatsu gijutsu kenkyū kumiai)	5	8/71-3/84	Fujitsu, Fujitsu Lab., Hitachi, et al.
17. New computer series (Shin computer series gijutsu kenkyū kumiai)	5	8/72-5/84	NEC, Toshiba, Nippon Business Automation, et al.
18. Super computers (Chō kōseinō denshi keisanki gijutsu kenkyū kumiai)	3	8/72-5/84	Mitsubishi, Mitsubishi Research Institute, Oki Denki
19. Medical instruments (Iyō kiki anzen gijutsu kenkyū kumiai)	11	4/73-5/85	Shinazu Seisakujo, Toshiba, Nippon Kōden, NEC
* 20. Nuclear powered steel making (Gensyhiryoku seitetsu gijutsu kenkyū kumiai)	13	5/73-12/81	Nippon Steel, Nippon Kōkan, Kawasaki Steel, Mitsubishi Heavy Industires, Ishikawajima Harima, et al.
21. Nitrogen oxide prevention (sintering) (Tekkōgyō chisso sankabutsu bōjo gijutsu kenkyū kumiai)	9	3/74-3/80	Nippon Steel, Nippon Kōkan, Kawasaki Steel, Sumitomo Metals, et al
22. Software for management planning (Keieikanri software module gijutsu kenkyū kumiai)	5	3/74-	Nippon Computer System Kinki Computer Consultant, James A. Systems, et al.

	23. Software for administrative processing (Jimushori software module gijutsu kenkyū kumiai)	14	3/74-	Nippon Denshi Kaihatsu Nippon Time Share, Computer Service, Jimu Keisan Center, et al.
	24. Software for design and and computation (Sekkei keisan software module gijutsu kenkyū kumiai)	5	3/74-	Kozo Keikaku Kenkujo Kaihatsu Keisan Center Fuyo Joho Center, et al.
	25. Software for operations research (Operation research keisan software module gijutsu kenkyū kumiai)	8	3/74-	Kyoei Keisan Center, Computer Engineers, Techno System, Tochiku Software, et al.
	26. Software for automatic control (Jidōseigyō software module gijutsu kenkyū kumiai)	4	3/74-	Kanri Kogoku Kenkyujo, Software Research Assoc., Nippon Automation System, et al.
	27. Automatic measurements (Jidōkeisoku gijutsu kenkyū Kumiai)	7	5/74-	Ando Electric, Adachi Electric, Iwasaki Tsushinki et al.
	28. High temperature structural safety (Kōon kōzō anzen gijutsu kenkyū kumiai)	24	9/74	Asahi Kasei, Kawasaki Heavy Industries, Toshiba, Hitachi, Mitsubishi Heavy Industries
*	29. Traffic control system (Jidōsha sōgō kansei gijutsu kenkyū kumiai)	10	11/74-4/80	NEC, Hitachi, Tateishi Electric, Toyota, et al.
	30. Vinylchloride safety (Enka Vinyl kankyō gijutsu kenkyū kumiai)	21	4/75-6/83	Asahi Glass, Kureha Chemical, Shinetsu chemical, et al.
*	31. Olefins from heavy oil (Jūshitsuyu kagaku genryōka gijutsu kenkyū kumiai)	6	7/75-11/83	Idemitsu-Kōsan, Shōwa-Denko, Sumitomo-Kagaku
*	32. Jet engine (Kōkūkiyō Jet Engine gijutsu kenkyū kumiai)	3	3/76-	Ishikawajima Harima, Kawasaki Heavy Industries, Mitsubishi Heavy Industries
	33. VLSI (Chō LSI gijutsu kenkyū kumiai)	7	3/76-	Computer Sōgō Kenkyūjo NEC, Toshiba, Jōhō System, et al.

	34. High capacity, low cost medical instruments (Gijutsu kenkyū kumiai iryō fukushi kiki kenkyūsho)	43	8/76-	Asahi Kasei, Toshiba, Hitachi, Nippon Kōden Kurare, Takeda Pharm., Sanyo, et al.
	35. New housing supply systems (Shin jūtaku kyōkyū System gijutsu kenkyū kumiai)	11	2/77-11/79	Takenaka Kōmuten, Nippon Steel, et al.
*	36. PIPS pattern information processing system (Pattern jōhō shori system gijutsu kenkyū kumiai)	5	3/77-5/82	Toshiba, NEC, Hitachi, et al.
*	37. Electric car (Denki jidōsha gijutsu kenkyū kumiai)	11	2/78-	Daihatsu, Mazda, Hitachi, Nippon Denchi
*	38. Undersea oil production (Gijutsu kenkyū kumiai kaitei sekiyū seisan system kenkyū)	18	3/78-9/85	Arabian Oil, Ishikawajima Harima, Nippon Steel, Hitachi Shipbuilding
*	39. Flexible manufacturing system (Laser ōyō fukugō seisan system gijutsu kenkyū kumiai)	20	4/78-	Toshiba Machinery, Aida Engineering, Mitsubishi Electric, et al.
	40. High efficiency gas turbine (Kō kōritsu Gas Turbine gijutsu kenkyū kumiai)	14	9/78-	Asahi Glass, Ishikawajima Harima, Central Electric Power Research Institute, et al.
	41. Heavy oil technologies (Jūshitsuyu taisaku gijutsu kenkyū kumiai)	31	6/79-	Shōwa Shell Sekiyu Ishikawajima Harima, Idemitsu Kōsan, Kashima Sekiyu Kawasaki Steel, et al.
	42. Fifth Generation Computer (Denshi keisanki kihon gijutsu kenkyū kumiai)	10	7/79-	Computer Sōgō Kenkyujō Fujitsu, Hitachi, et al.
	43. New fuel oil technology (Shin nenryōyu kaihatsu gijutsu kenkyū kumiai)	22	6/80-	Mitsubishi Oil, Ajinomoto, Idemitsu Kōsan, Kansai Paint, et al.
	44. Polymer applications (Kōbunshi ōyō gijutsu kenkyū kumiai)	8	7/80-7/85	Asahi Kasei, Asahi Glass, Teijin, Toray, et al.

	45. Residential area waste disposal (Teijukenyō haisuishorikikai system gijutsu kenkyū kumiai)	8	7/80-	Ebara Infilco, Kurita Industries, Takenaka Kōmuten, et al.
*	46. Carbon monoxide as a raw material (C, kagaku gijutsu kenkyū kumiai)	16	10/80-	Mitsubishi Kasei, Ube Kōsan, Daicel, et al.
	47. Optical applications for measurement and control systems (Hikari ōyō system gijutsu kenkyū kumiai)	15	1/81-	Hikari Sangyō Gijutsu Shinkō Kyōkai, Fujitsu, Mitsubishi Electric, et al.
	48. Small system gas powered air cooling (Kogata gas reibō gijutsu kenkyū kumiai)	15	7/81-	Tokyo Gas, Osaka Gas, Matsushita Electric
	49. Synthetic dyes (Gōsei senryō gijutsu kenkyū kumiai)	5	7/81-	Nippon Chemical, Mitsubishi Kasei, Sumitomo Kasei, Hodogaya Chemical
**	50. Fine ceramics (Fine ceramics gijutsu kenkyū kumiai)	15	8/81-	Toshiba, Asahi Glass Kyocera, et al.
**	51. Biotechnology development (Biotechnology kaihatsu gijutsu kenkyū kumiai)	14	8/81-	Mitsubishi Kasei, Kyowa Hakko, Sumitomo Chemical, et al.
**	52. Polymer technology (Kōbunshi kiban gijutsu kenkyū kumiai)	11	8/81-	Toray, Mitsubishi Kasei, Asahi Glass, et al.
*	53. High speed computers for science and technology (Kagaku gijutsuyō kōsoku keisan system gijutsu kenkyū kumiai)	6	12/81-	Fujitsu, Oki Electric, Toshiba, NEC, Hitachi, Mitsubishi Electric
*	54. Manganese nodule mining (Gijutsu kenkyū kumiai Manganese dankai saikō system kenkyūjo)	20	1/82-	Ishikawajima Harima, Osaka Syosen, Kinzoku Jigyodan Mitsui Senpaku
	55. Industrial furnaces (Gijutsu kenkyū kumiai kōgyōro gijutsu kenkyūjo)	7	9/82-	Ishikawajima Harima, Isorait Kōgyō, Chino Seisakujo et al.

	56. Basic refining technology (Seiren shinkiban gijutsu kenkyū kumiai)	16	9/82-	Nippon Steel, Nippon Kokan, Kawasaki Steel, Sumitomo Metals, et al.
	57. Oxygen burning for high quality polymers (Sanso fukamaku nenshō gijutsu kenkyū kumiai)	7	9/82-	Asahi Glass Teijin, Tōyō bōseki, Toray, et al.
	58. Paper production (Seishi gijutsu kenkyū kumiai	26	9/82-	Oji Paper, Jūjyo Paper Honshu Paper, Mitsubishi
	59. Crude oil refining (Genyu Ni-sanji kaishū gijutsu kenkyū kumiai)	11	11/82-	Arabian Oil, Imperial Oil, Nippon Kokan, et al.
	60. Energy development (Energy kaihatsuyō kaimen kasseizai gijutsu kenkyū kumiai)	6	11/82-	Daiichi Kōgyō Seiyaku, Kaō Soap, Lion, et al.
*	61. Automatic sewing system (Jidōhōsei system gijutsu kenkyū kumiai)	29	12/82-	Aishin Seiki, Asahi Chemical
	62. Coal extraction and mining equipment technologies (Sekitan Rotenbori kikai gijutsu kenkyū kumiai)	11	3/83-	Kawasaki Heavy Industries, Hitachi, Bridgestone Tire, et al.
	63. New aluminum refining process (Aluminium shin seiren gijutsu kenkyū kumiai)	7	4/83-	Nippon Light Metals, Showa Light Metals, Mitsui Aluminium
	64. New uses for light oil (Keishitsuyubun shinyōto kaihatsu gijutsu kenkyū kumiai)	21	5/83-	Asahi Chemical, Kōa Oil, Idemitsu Kōsan
	65. High efficiency synthetic fibers (Kō kōritsu gōsen gijutsu kenkyū kumiai)	8	9/83-	Asahi Chemical, Kanebō, Teijin, et al.
	66. New production of chemicals using biotechnology (Seitai kinō riyō kagakuhin shin seizō gijutsu kenkyū kumiai)	7	9/83-	Ajinomoto, Kaō Soap, Mitsubishi Chemicals

67. Electricity conducting inorganic compounds (Dōdensei mukikagōbutsu gijutsu kenkyū kumiai)	5	9/83-	Sumitomo Denki Kōgyō, Nihon Ita Glass, Hitachi, et al.
68. New production methods for high quality resins (Kōseino jushi shinseizō gijutsu kenkyū kumiai)	5	9/83-	Mitsui Sekiyū Kagaku Mitsubishi Chemical, Kurare
69. Aluminum powder metallurgy (Aluminium funmatsu yakin gijutsu kenkyū kumiai)	9	9/83-	Kobe Steel, Shōwa Aluminium, Sky Aluminium
70. Shape memory alloys (Keijō kioku gōkin gijutsu kenkyū kumiai)	6	9/83-	Furukawa Denki, Dōwa Industries, Tohoku Metals, et al.
71. Development of alcohol for fuel use (Nenryōyō alcohol kaihatsu gijutsu kenkyū kumiai)	7	11/83-	Kannan Paint, Kirin Beer, Suntory, et al.
72. Industrial robot (Kyokugen sagyō robotto gijutsu kenkyū kumiai)	20	2/84-	Ishikawajima Harima, Oki Electric, Kawasaki Heavy Industries
73. Alkali battery (Arukari kandenchi gijutsu kenkyū kumiai)	6	9/84-	Sanyō Duracell, Toshiba, Tōyō Takasago Denchi
74. Remote sensing system for resources (Shigen remotto sensingu skisutemu gijutsu kenkyū kumiai)	13	1/85-	Mitsubishi Electric, Toshiba, NEC, Hitachi
75. Super heat pump energy accumulation system (Supā hīto ponpu enerugī shūseki shisutemu gijutsu kenkyū kumiai)	17	4/85-	Ebara Seisakujo, Kobe Steel, Maekawa Seisakujo Mitsui Shipbuilding, Ishikawajima Harima,
76. New material and equipment system for apartment development (Shūgō jūtauyō shinzairyō kiki shisutemu kaihatsu gijutsu kenkyū kumiai)	30	7/85-	Asahi Glass, INAX, Osaka Gas, Ōbayashi Gumi, Kashima, Ebara Seisakujo, Kyushu Matsushita Denki

77. Next generation equipment for nuclear power (Gijutsu kenkyū kumiai genshiryokyō giseidai kiki kaihatsu kenkyūjō)	29	10/85-	Tokyo Electric Power, Kobe Steel, Nippon Mining, Hitachi, Mitsubishi Heavy Industries
78. Toyama Prefecture regional system development (Toyamaken chiiki shisutemu kaihatsu gijutsu kenkyū kumiai)	13	10/85-	Saito Seisakujo, Intech, Silver Jushi Kōgyō, et al.
79. Water purification and energy recovery systems (Akua runesansu gijutsu kenkyū kumiai)	22	12/85-	Ebara Seisakujo, Orugano Kubota Tekko, Karita Kōgyō, Kobe Steel, et al.

* = Designated Large Scale National Project

** = Designated Part of Next Generation Basic Technology Program

Sources: Kōgyō Gijutsu In, 1986;
Sigurdson, 1986

APPENDIX B

INITIAL JAPAN KEY TECHNOLOGY CENTER PROJECTS (1986)

Project	No. Firm	Center Funding (million yen)	Members
1. Non-Oxide Glass	2	35	Nippon Sheet Glass, Hoya
2. Second Generation Opto-Electronic Integrated Circuits	13	100	NEC, Oki, Sumitomo Electric, Toshiba, et al.
3. Space Environment Studies	6	75	Ishikawajima-Harima, Toshiba, NEC, Hitachi, et al.
4. Coherent Light Communication Measurement Technologies	5	90	Yokogawa Hokushin Electric, Advantest, Ando Electric, et al.
5. Gene Technologies and Peptide Synthesis	2	30	Meiji Seika and Daicel Chemical
6. Protein Engineering	5	200	Mitsubishi Chemical, Kyowa Hakko Kogyo, Takeda Chemical, et al.
7. Video Information System	3	80	Sumitomo Electric, Fujitsu, Matsushita
8. Synchotron Radiation Application Technologies	13	150	Mitsubishi Electric, Toshiba, NEC, Hitachi, et al.
9. High Performance Surface Metals	17	35	Nippon Kokan, Nippon Steel, Kawasaki Steel, et al.
10. Electronic Dictionary for Natural Language Processing	8	200	Fujitsu, Toshiba, Hitachi, Oki, et al.
11. Human Audio and Visual Sensor Mechanisms	41	130	ATR International, NTT, KDD, Kansai Electric Power, IBM Japan, et al.
12. Automatic Interpreting	41	210	ATR International, NTT, KDD, Sumitomo Metals, IBM Japan, et al.
13. Intelligent Communications System	41	110	ATR International, NTT, KDD, Sony, IBM Japan, et al.

14. Optical Microwave Telecommunications	41	105	ATR International, NTT, KDD, Toshiba, IBM Japan, et al.
15. Integrated Information/ Communication Systems for Buildings	3	64	Fujitsu, Shimizu, Taisei
16. Voice Activating Associative-Type Information Storage and Communication Systems for Personal Computers	4	20	Carry Laboratories, MAC (Japan) Ltd., Crystal Soft, T&E
17. Joint Backup Communications Systems	5	105	Seibu Information Center, System Brain, Dai Nippon Computer Systems, et al.
18. Information System for Wholesale Dealer Complexes	8	5	Takasaki City, Takasaki Wholesalers Assoc., Gunma Bank, et al.
19. Kumamoto Information and Guide System	42	10	Kumamoto Prefecture, Kumamoto City, NTT, et al.
20. Regional Information Systems	9	70	Shimane Prefecture, Matsue City San-in Godo Bank, et al.
21. Integrated Information System for Greater Suwa Teletopia	38	70	Six Cities and Towns in Suwa District, Nagano Prefecture, Seiko-Epson, et al.
22. Yamaguchi Triangle Teletopia Information System	19	40	Tamaguchi Prefecture, Tamaguchi City, NTT, et al.
23. INF Integrated Information Systems	162	20	Fukushima Prefecture, Fukushima City, NTT, et al.
24. Kurume Teletopia Information System	43	30	Kurume City, Saga Bank, NTT, et al.
25. Kagoshima Videotex System	29	16	Kagoshima Prefecture, Kagoshima City, Minami Nippon Shimbun, et al.

Source: US National Science Foundation, Tokyo Report, Memorandum 98, April 23, 1986

APPENDIX C

EXPLORATORY RESEARCH IN ADVANCED TECHNOLOGY ORGANIZATION PROJECTS

(1986)

Project	Subgroups	Participants
Ultra-Fine Particles	Basic Properties	Meijo University
	Physical Applications	Stanley Electric
	Biological/Chemical Applications	Stanley Electric
	Formation Process	ULVAC
Amorphous & Intercalation Compounds	Basic Properties	Electric and Magnetic Alloys Research Institute
	Amorphous Compounds	Otsuka Chemical
	Amorphous Thin Films	Gakushuin University
	Special Ceramics	Furukawa Electric
	Intercalation Compounds	Electric and Magnetic Alloys Research Institute
Fine Polymers	Molecular Design	Sophia University
	Selective Functional Materials	Mitsubishi Chemical Industrial
	Organic Electronic Materials	Matsushita Research Institute
Perfect Crystal Project	Fundamental Structure	Semiconductor Research Institute
	Super High-Speed Element	Mitsubishi Electric
	Perfect Crystal Growth	Mitsubishi Metals
	Optical Function Element	Hamamatsu Phototonics Co.
Bioholonics Project	Basic Design	
	Self-Control	Teikyo University
	System Construction	
Bioinformation Transfer Project	Bio-Transmitters	Osaka Medical College
	Neurotransmission	Nippon Shinyaku
	Neuropharmacodynamics	Nippon Shinyaku
Superbugs Project	Fundamental Works	Riken (Institute of Physical & Chemical Research)
	Metabolisms and Production	Riken
	Tolerance Introduction	Hamamatsu Photonics
Nano-Mechanism Project	Basis Analyses	Tsukuba Research Consortium
	Measurement and Control	Tsukuba Research Consortium
	Processing	Nippon Kogaku

Solid Surface Project	Basic Properties Reactivities Functional Structures	Tsukuba Research Consortium Tsukuba Research Consortium Toray
Quantum Magneto Flux Logic	n/a	n/a
Molecular Dynamics Assembly	n/a	n/a
Biophoton	n/a	n/a

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