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—日本の西欧への挑戦—

GOVERNMENT–SPONSORED COLLABORATIVE RESEARCH TO PROMOTE INFORMATION TECHNOLOGY：JAPAN'S CHALLENGE TO THE WEST?

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◇ 本資料はＴｉｍ　Ｒａｙ氏が１９９２年４月より当研究所特別研究員として研究した成果の概要を取りまとめたものである。

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Abstract

To many Western observers, it has seemed that collaborative research schemes organised by Japan's Ministry of International Trade and Industry (MITI) have played an important role in the country's rapid development of its computer and semiconductor component industries. Japan's 1981 announcement of its Fifth Generation Computer Systems initiative prompted a number of Western attempts to match Japan's competitive performance by using "Japanese-style" collaboration to support research in the various constituent areas of information technology (IT). However, there is evidence to suggest that many of these Western schemes failed to take full account of a number of special features associated with the Japanese environment.

The present paper considers why governments intervene to support IT and presents a classification of different types of support policies. This model is used to assess the changing role that collaboration has played within the development of Japan's computer and related industries. Comparisons with Western versions of collaboration are then used to help identify factors that affect the relative success of collaborative research projects as mechanisms for promoting increased competitiveness.

A central message that follows from these comparisons is that the use of collaboration as a "market modifying mechanism", should take appropriate account of the complex nature of market structures and the ways in which these structures vary between different national environments. Japan's collaborative schemes evolved gradually and their development has been shaped by many factors that are specific to Japan. If these factors are ignored, there is a strong possibility that attempts to transplant the collaboration model to different national environments will suffer from adaption problems and a failure to function in the way that was intended.

Section 1: Introduction

The motivation behind the present paper is derived from the author's experience with the evaluation of a major government-sponsored initiative which was designed to promote Britain's competitiveness in the information technology (IT) sector by supporting "Japanese-style", "pre-competitive" collaborative research. This five-year British initiative, known as the "Alvey Programme", was a direct response to Japan's 1981 announcement of its government-sponsored collaborative project to develop "fifth generation" computer systems. At that time, the apparent success of previous initiatives sponsored by Japan's Ministry of International Trade and Industry (MITI) had given the concept of "collaborative research" a high degree of credibility in the West.

During the 1980s, collaborative research experienced a rapid growth in popularity among Western countries struggling to maintain a competitive position in evolving IT markets. Yet, while many of these schemes have made important contributions to the "national innovation systems" of the countries concerned, improvements in competitive advantage have often failed to match Western perceptions of the achievements made by Japanese initiatives. With this problem in mind, the present discussion considers the nature of MITI's collaborative IT initiatives and the way in which they functioned in the Japanese environment. The argument is based on interviews with members of Japanese firms, government officials, researchers that have been involved with MITI's collaborative research schemes and published sources. On the basis of this information, it is proposed that a deeper understanding of Japan's research initiatives provides a useful basis for re-appraising attempts to imitate these policies in the West. The West's use of Japanese-style collaboration to compete with Japan should take careful account of the context in which Japanese schemes were developed and use this as the basis for considering how a similar initiative might interact with the national innovation system in question.

With regard to assessing the nature of Japanese-style collaboration as a "policy challenge" to the West, Alvey is of special interest in that it embodied key features that were subsequently adopted by a number of other attempts, in both Europe and the United States, to use collaborative research to pursue enhanced competitiveness. It is used as here as a case-study of a government-sponsored European response to Japan's Fifth Generation Computer Programme. Mention is also made of the rise of collaborative research in the US since the early-1980s. The development of these US initiatives may be traced from private sector collaborative schemes which were instrumental in securing a relaxation of the Anti-Trust Laws: thereby paving the way for an expansion of private sector ventures and the launch of federally-funded collaborative ventures.

One message that appears to follow from attempts to imitate Japan's collaborative schemes is that collaboration, as a "market modifying mechanism", should take account of the complex nature of market structures and, also, the fact that there are significant variations in the way that these structures operate in different national environments. If the West fails to recognise the significance of contextual factors that have shaped the evolutionary development of Japan's collaborative schemes, there is a strong possibility that attempts to transplant this collaboration model to different national environments will suffer from adaption problems and a failure to function in the way that was intended. The following quotation relating to a failure by the West to understand the Japanese corporation, or "kaisha" provides a convenient analogy for summarising the shortcomings that can be associated with many Western perceptions of Japanese collaborative research schemes.

> But now there is a danger of the strengths of the kaisha being overestimated just as these companies were for so long underestimated. Some Japanese firms do well; others do badly. The strengths and tactics of the kaisha need not be surprising to those who analyze their behaviour and who

> develop plans for effective competitive response.
>
> (Abegglen and Stork: 1985 p17)

A central theme of the present paper is that, in the early-1980s, the strengths of Japanese collaborative research schemes seem to have been overestimated in the same way that they were previously underestimated. In reality, Japanese schemes have included failures as well as successes and their strengths and tactics are best understood by looking closely at how they have functioned within the context of Japanese industrial development in the IT sector.

The case of Alvey can be used to illustrate a scheme which was largely justified in terms of enhancing UK competitiveness, but produced achievements were seen in mainly in terms meeting technological research targets and a "structural" broadening of the UK research base, which was supported by the formation of extensive "networks" within the IT community (Guy, Georghiou, Ray et al: 1991 pii-iii). This gave the UK IT research base increased coherence and created new channels of communication between industry and academia. Nevertheless, the evaluators final report on the initiative noted that the intended boost to national competitiveness did not occur on the scale that was hoped for:

> The major disappointment (of the programme) concerned the goal of enhancing competitiveness. All the major indicators of the programme show declining competitiveness in the UK IT sector during the lifetime of the programme; market shares declined and major firms passed wholly or partially into foreign ownership.
>
> (Guy, Georghiou, Ray et al: 1991 p xviii)

The apparent failure of British industry to capitalise on the research outputs produced under the Alvey Programme raises questions about the extent to which it is realistic to expect that pre-competitive collaborative research will promote national competitiveness. Prior to Japan's Fifth Generation announcement, the competitive instincts of Western companies tended to restrict collaborative research to a very limited range of circumstances where the advantage of sharing the costs and uncertainties of research outweighed the disadvantage of having to share that knowledge with other parties. The European system of Industrial Research Associations provides an example of research funded jointly, by firms and the governments, which has been described as "worthy" but "hardly more exciting than the work of the local Post Office" (Woodward: 1965 p38). As the Director of a well-known British Research Association remarked:

> Sir, running a Research Association is like a dog's walking on its hinder legs. It is not done well but you are surprised to find it done at all.
>
> (Woodward: 1965 p39)

This image of collaborative research as a rather peripheral activity makes the West's apparent conversion to the paradoxical principle of "collaborating to compete" all the more remarkable. Moreover, even though there is evidence to suggest that the extent of increased competitiveness brought about by these schemes is questionable, pre-competitive collaborative research has become more prominent in Europe and the United States.

Structure of the Paper

Section 2 considers the significance of Japan's announcement of its Fifth Generation System Computer Systems Project and presents an overview of the principal issues which are addressed in subsequent sections. These cover three main areas: general perspectives on IT support policies; a case-history of government-orchestrated collaboration in the Japanese IT industry, and; Western responses to the "Japanese Model".

The perspectives on government policies to support IT presented in Section 3 serve to locate collaborative research within a broader range of policy options. This subject is approached by considering why governments should support IT and the nature of different types of IT initiatives. The section closes with a classification of schemes.

Section 4 focuses on Japan's development of policy initiatives to support IT. It shows how collaboration emerged as only one of four basic types of IT support policies. MITI's schemes in the computer hardware and semiconductor components sectors are reviewed to identify various steps in the process by which Japanese firms gradually closed the gap with IBM and other leading Western producers. It is argued, that while government-sponsored collaboration has provided a mechanism for accelerating the pace at which Japanese firms could "capture" and exploit best-practice technology, this was done in a distinctly competitive (as opposed to cooperative) environment. Japanese firms preserved their competitive identities and generally managed to avoid sharing knowledge associated with near-market technology. In addition to competition between firms, it is noted that there were conflicts between the industrial ambitions held by companies and MITI's view of its policy objectives; not to mention rivalry between MITI and other ministries. MITI's Fifth Generation project is then contrasted with previous schemes as a "new direction" to the established trajectory of collaborative research ventures. Finally, Section 4.2 contrasts the success of hardware support schemes to the much more problematic history that has been associated with collaborative research in software.

In section 5, the Alvey Programme is used as an example of a leading European response to the Fifth Generation "challenge". By contrast with the preceding Japanese schemes, this was mainly focused on research that was some distance from the market and was designed on the assumption that firms would engage in the sharing and joint production of knowledge. It featured a major input from the academic sector and served to consolidate and restructure the national IT knowledge base through the creation of new communication networks and an expansion in the number of researchers.

A perspective on the rise of collaboration in the US is provided in Section 6. This provides a further dimension to the picture in that pressure for increased collaboration may be traced from the private sector. A relaxation of the country's Anti-Trust Legislation, which had been a major distinguishing feature of the US "national innovation system" followed and there have since been federally-funded collaborative schemes to promote competitiveness.

Finally, Section 7 presents conclusions that follow from the study. These serve to highlight the complex nature of market structures. While national innovation systems are generally concerned with translating knowledge into commercially exploitable technology, there are significant variations in the way in which they do this. The use of collaboration as a "market modifying mechanism" should take careful account of these variations. Japanese-style collaboration emerged in the Japanese environment and was shaped by a number of factors that are specific to that environment.

2 An overview of the Issues

During the 1970s, developments in computer and communication technologies converged to create a new arena of competition: information technology (IT). The combination of computing power with the message-sending capability of telecommunications redefined traditional boundaries between the gathering, processing and distribution of information. At the same time, advances in microelectronic technology paved the way for spectacular improvements in the performance-to-cost ratio of computing, thereby fuelling the rapid expansion of IT markets and the diffusion of the technology into new areas of economic activity. The pervasive nature of IT helped to ensure that it was quick to emerge as an essential ingredient in the economic development of industrial economies.

Japan's government policies to support its computer and semiconductor industries during the 1960s and 1970s have often been cited as an important element in its ability to exploit opportunities created by the "IT revolution". As the 1980s unfolded, many countries looked to Japan as a prime example of the apparent benefits that could be derived from pursuing appropriate policies to support the constituent elements of IT. There was a growing realisation that a vibrant IT sector embodies enormous potential for stimulating significant growth in employment, together with enhanced overall competitiveness arising from performance improvements in a whole host of downstream user industries. A number of governments also view access to state-of-art IT as being of crucial importance to the maintenance of an effective defence capability. To a greater or lesser extent, governments have been forced to take note of IT and a proliferation of policies to promote national capabilities in this sector has followed.

Western awareness of Japan's role as a leading exponent of effective IT policies increased dramatically during the late-1970s. At that time, there were signs that Japan had started to draw level with the United States in certain areas of computer hardware and semiconductor component technologies. To many Western observers, it seemed that close cooperation between the state and private industry had fostered the development of a highly-effective "national innovation system". Respect for the apparent achievements of this system was a major factor in causing Japan's 1981 announcement of its Fifth Generation Computer Project to send shock waves of concern reverberating around competitor IT industries. It seemed that Japan's national innovation system was about to be trained on a new target: advanced research.

Whereas previous policies had been concerned mainly with transferring existing technology to Japanese firms, progress towards "fifth generation" computing was to be research-driven. The project was directed towards uncharted territory, beyond the prevailing forefront of international best practice research. Fifth generation computers were intended to understand spoken instructions, emulate human reasoning and explain how conclusions are reached: thereby providing a practical realisation of sophisticated artificial intelligence (AI). The programme was regarded widely as a bid by Japan to lead international best-practice technology in this sector. Although estimates of the ultimate tractability of this ground involved considerable uncertainty, the West's fear was Japan might be able to use its "national innovation system" to create an ability in an area of AI which had suffered a credibility crisis in the West caused, in part, by the over optimistic claims of enthusiasts for the discipline. Irrespective of the its eventual outcome, the fact that Japan was prepared to launch such an initiative was acknowledged widely as being a clear signal that the country had reached a position where it could mount a serious offensive on the very frontier of international best-practice, advanced IT research. The Fifth Generation programme was used extensively by Japan's competitors as a justification for adopting a more interventionist approach to IT policy. Ferné has noted that some 20 other national programmes followed in the wake of the Fifth

Generation announcement (Ferné: 1989 p10).

Although Japan had implemented a range of different policies to support different aspects of IT, the model that captured the West's attention was the system of Engineering Research Associations (ERAs), organised by the Ministry of International Trade and Industry (MITI). These ERAs, which were initiated in the early-1960s, involve government support for "horizontal" collaborative groupings that allow competing firms to pursue a specified agenda of research on a temporary basis. During the late-1970s, the widely-acclaimed success of collaborative initiatives, such as the Very Large Scale Integration (VLSI) project, helped to reinforce the idea that MITI's ERAs had a major role to play in helping Japanese firms to become more competitive. It seemed as if the government had conspired with industry to exploit the paradoxical notion of "collaborating to compete". Japanese firms appeared to have become competitive by colluding in government-sponsored initiatives to suspend the concept of competition during the development phases of technology life-cycles. Arguments to the effect that this sort of policy would only bring short-term gains became hard to sustain in the face of Japan's record of continued increases in its share of world markets for semiconductor components and computer hardware. There was growing support in the West for the diagnosis that Japanese collaborative research "worked", although details of the design and implementation of these schemes received rather less attention. While the exact extent of MITI's contribution to increased industrial competitiveness is a matter for debate, it did appear that MITI's "vision" for the computer and semiconductor components sectors had coincided with dramatic improvements in "revealed industrial performance". MITI's computer-related ERAs had become synonymous with success. The fact that the Fifth Generation project was also going to be collaborative raised the spectre of extending this momentum of sustained progress into a new area of basic research.

Suddenly, it seemed that the West's view of collaborative research had changed. Instead of being seen as a rather peripheral activity, collaborative research became "fashionable" and emerged as a key ingredient in a number of European and US ventures to promote competitiveness. However, many Western-style attempts to imitate the perceived success of Japan's cooperative schemes ("fighting fire with fire") do not appear to have taken full account of several key points relating to the practical operation of "Japanese-style" collaboration. Little importance seemed to be attached to the fact that the structure and objectives of MITI's ERAs evolved gradually and were continually redefined as a consequence of a "push-me-pull-you" dialogue between the government and participating firms. There was no standard "blueprint" for designing ERAs. Over the years, modifications were introduced as part of an evolving process to correct past problems and react to changes in technological and market environments. Structural variations have included shifts in the respective level of government and industry funding; differences in the duration of projects and shifts in the mechanisms for knowledge sharing. At different times, the Japanese models of collaboration have varied between a clear division of labour, based on self-contained "modular" work programmes, and the joint creation of knowledge in a central research laboratory staffed by researchers seconded from collaborating firms. This has reflected a shift away from "near market", application-oriented schemes (where commercial sensitivities necessitated a degree of modular organisation) and towards the more basic research of the type conducted under the Fifth Generation Computer Systems project.

Japan's collaborative schemes have evolved against the background of simultaneous shifts in the relative ability of Japanese firms to operate effectively in the global arena of competition. This, in turn, has had implications for the extent to which MITI can act as an "honest broker" and "legitimate" agent for mediating between rival firms. In this respect, it could be argued that improvements in the international competitiveness of Japanese firms undermined the significance of MITI's role of providing support at the national level. At the same time, there does not seem to be any industrial consensus about the shape and direction of a "new role" for MITI. Catching-up with the West removed the "technological signposts" that had assisted in the formation of a government-industry consensus for the design of past, "application-oriented" schemes. Basic research is typically concerned with fostering long-term "creativity" and is often prone to drift away from the more rigorous disciplines that are imposed by firms' "current commercial commitments". Companies that are actively involved in the conduct and exploitation of basic research find it hard to generate accurate "visions" for the future. The need to cover the "technological waterfront" means that much of the research work will eventually lead to benefits that are only of limited or indirect value. It is difficult to produce sharply-focused research agendas that are capable of close correlation with the future evolution of "user requirements". Such a task is even more difficult for government agencies.

The question of the justification for governmental intervention to support IT is assessed in Section 3. Attention is drawn to the nature of government views on the "ideological acceptability" of support for collaborative research as part of an attempt to answer the question: "why should governments be involved in IT?". It is argued that, while government support for basic research has long been justified on the grounds of "market failure", a case for supporting research as a means to enhance industrial competitiveness in IT started to become increasingly more prominent during the 1980s. Attempts to promote competitiveness through IT research lead on to the question of "what constitutes IT policy?". As IT has become more closely connected with economic growth, policies that affect IT have become more closely inter-twined with broader measures, designed to regulate trade and enhance competitiveness. The theoretical model proposed relates government-sponsored research and development to the overall range of policy options. Japan's development of collaborative research and Western responses are considered against the background of this model in Sections 4, 5 and 6.

Japanese policies for the development of "targeted" industries have been mainly shaped by a brand of pragmatism which has a long history. The state has played a significant role in structuring economic development in Japan since the country started to industrialise in the late-1800s. At that time, the fear of colonisation by the United States or a European power helped to establish the principle of the state acting to manage the market economy. Intervention to manipulate the "invisible hand" of capitalism subsequently became accepted as a legitimate role for the state and has been an important feature in Japan's post Second World War development in a range of new industries. Little attention was given to ideologically-based concerns with limiting intervention to correcting deficiencies caused by market failure. Government support of "near market" applied development has been considered to be perfectly acceptable as long as it does not simply take the form of an unalloyed subsidy to a particular firm of industrial grouping. Rather, the philosophy has tended to reflect the idea that there should be sufficient competitive activity in the system to allow the recipient of the subsidy to digest its benefits without acquiring the economic equivalent of obesity. Competition should be constructive in stimulating rival firms to make progress without eliminating players from the game. In some instances, creating a healthy environment for innovation has represented the limit of policy intervention. For example, Japan's highly successful consumer electronics industry was established with support to create a favourable business environment using macroeconomic policies, generous tax provisions and compensation for deficiencies in the market mechanism (Okimoto: 1986 p549). The sector than prospered through Japanese firms' rapid assimilation and improvement of US technological advances, coupled with sustained capital investment, effective process engineering and aggressive marketing.

By contrast with consumer electronics, the computer and semiconductor industries were targeted for special attention. MITI's image of orchestrating collaborative projects which successfully enhanced the competitiveness of participating firms, was based on initiatives in applied rather than basic research. In this respect, pragmatism centred on a clear target: catching up with the West. Moreover, pragmatic catch-up projects tended to be near market ventures and were not really all that "collaborative" in terms of the joint production and sharing of knowledge. This modularisation enabled the benefits of so-called collaborative research projects to be "internalised" by participating firms without compromising the distinctive aspects of their technological knowledge bases. Firms did not have to share their proprietary knowledge and so retained elements of diversity in their approaches to innovation. This meant that rival firms were pursuing moving frontiers of best-practice technology from a range of different angles: thereby promoting the elements of technological diversity that drive the very process of competitive innovation. Nonaka and Yoneyama have argued that an imprecise understanding of the exact capabilities of rival firms operating in semiconductor component markets can lead to a redoubling of competitive efforts. A process which they refer to as "overshooting" leads to firms innovating to a greater extent than is necessary to capture market share at successive levels of technological development: thereby "bidding-up" the currency of best practice technology in a virtuous cycle of innovation (Nonaka and Yoneyama: 1992).

Genuine knowledge sharing has tended to be confined to Japan's more basic collaborative research projects which do not have immediate implications for competitive performance. Moreover, the direct importance of these collaborative projects to the competitive performance of participating firms declined sharply once Japan started to catch up with best-practice IT technology. This is somewhat paradoxical in that the period of declining relevance has coincided with a dramatic expansion in the West's use of collaboration as a policy support mechanism to promote competitiveness in the IT sector using "pre-competitive" (ie "far from market") knowledge-sharing projects. It was Japan's success in applied collaborative research that gave credibility to its Fifth Generation Computer Programme, even though the country had no track record in this type of basic-research-driven venture. Thus, it could be argued that many Western initiatives reacted in the wrong way to the wrong signal.

The subject of "lessons for the West" arising from Japan's experience with collaborative research draws heavily on the example of the UK government's £350 million "Alvey Programme for Advanced Information Technology" (1983-1988). Many features in the design of this programme can be traced to the recommendations of a committee established in 1982 under the chairmanship of John Alvey (who was then the Senior Director of Technology at British Telecom) to improve the competitiveness of the UK IT sector by supporting "pre-competitive" collaborative research. Much of the justification for this programme was based on arguments to mobilise national resources in the face of the challenge posed by Japan's Fifth Generation initiative. Alvey stands out as a notable example of intervention on the part of a Conservative Government, led by Margaret Thatcher, which was committed to minimising government intervention in industry. The sheer scale of the Alvey initiative was without precedent and the programme has been described as the largest single venture of its type ever attempted by the UK during peacetime. The case-study of the Alvey Programme is of particular interest because many of its features are reflected in approaches to collaboration have since become well established both in the UK and across Europe with programmes such as ESPRIT, Eureka and a host of similar initiatives.

A further important manifestation of collaborative research which can be related to the period following the launch of the Fifth Generation Programme can be seen in the case of the United States. This shift towards collaboration was all the more remarkable because any collusion of this type had previously been prohibited by the antitrust laws which have been an important distinguishing feature of the US "innovation system". By contrast with Japan and Europe, the commercialisation of semiconductors and computers has also featured significant efforts on the part of new firms (Mowery: 1992). In this respect, the entrepreneurial flexibility of new firms can also mean that they lack the "broad gauge" central core of research that enables them to restructure their technological knowledge bases to meet the challenges of dynamic shifts in the prevailing technological and commercial environments.

A common feature of many Western models of collaboration is the use "pre-competitive" research projects as policy support mechanisms to underpin the competitiveness of domestic IT industries. At some point, the research should become "competitive" and erstwhile collaborators are expected to stop collaborating and start competing. One justification advanced for this model of collaboration is that it creates a form of "temporary monopoly" whereby the differences between rival firms that normally drive the engine of competitiveness are suspended. The aim of the policy is to combine the ability of a large organisation to devote resources to research, with the active rivalry of independent firms seeking to use exploitation to gain a competitive advantage.

Part of the case for arguing in favour of horizontal collaborative groupings hinges on the idea that "the whole is greater than the sum of the parts". The hope is that there will be a multiplier effect on government funding as project participants spur each other on to achieve greater technological progress than would have been possible if they had acted individually. Nevertheless, while collaboration suddenly became "fashionable" in the 1980s, this form of joint research is by no means new (the case of Industrial Research Associations was noted in Section 1). Collaborating to share the costs and risks of research has a long history although, in the past, the value of such ventures was generally thought to be limited to very particular sets of circumstances, where the benefits of "low-cost access" to research results outweighed any potential commercial disadvantages associated with sharing that knowledge with other participating organisations. For this reason, firms tend to be most comfortable with projects that are at the basic end of the research spectrum. If horizontal collaborations do involve "near market" technologies, it is generally necessary to ensure that there good grounds for expecting that there will be an equitable distribution of benefits, as for example might occur in the development of an industry standard. Otherwise, so-called "natural" collaborations that involve "near market" technologies frequently centre on the type of non-horizontal links that exist between suppliers and customers or firms dealing with complementary technologies.

While the concept of "market failure" embraces a large number of potential deficiencies in the ability of competition to allocate resources in a desirable manner, the focus of the West's use of the term for justifying government-sponsored research lies with the unwillingness of firms to commit resources to longer-term projects where estimates of likely commercial returns are subject to high degree of uncertainty. This form of justification for intervention implies a primary concern with basic research areas which are outside the sphere of "natural" collaborations formed by firms for commercial reasons. Yet, support of far-from-market-collaborations as a means to pursue competitiveness relies on a high degree of optimism about matching research agendas to evolving market needs. Unless sufficient attention is given to potential exploitation routes at the outset, there is a very real risk that outputs will fail to feed into emerging trajectories of commercial development (Ray: 1992). The fact that research is collaborative does not insulate it from any of the traditional arguments about the uncertainties that are linked to "technology push" research projects. Markets, competing technologies, changes in standards, legislation and exogenous shifts in relative prices can all change dramatically in the time that it takes to bring a technology-push project to fruition: thereby reshaping the window of commercial opportunity that is available for exploiting the technology (Ray et al: 1989). At the same time, pursuing a research project collaboratively also introduces its own problems associated with costs of coordinating the work undertaken by different partners, fears related to the ownership of intellectual property and non-performance or withdrawal by partners during the life of the project.

Section 3: Government Policies to Support Information Technology

Reference has already been made to the "traditional" differences between Japanese and Western approaches to intervention. This section further explores more general aspects of the nature of intervention in the West and Japan. It concludes by proposing a "triangular representation" of different policy options. The triangle is defined by three basic axis of variation in the dimensions of government policies: (1) the extent to which the policies are either sector-specific or general (ie are they focused on a single industrial sector or do they affect a range of industries?); (2) the degree to which governments shape the direction and outcome of activities supported under interventionist initiatives, and; (3) the position of the policies on the spectrum between "supply side" and "demand side". In some respects, this could be thought of as a "four sided triangle", with time forming a fourth dimension to the image. The triangular model is introduced as a point of reference for subsequent sections relating to Japanese policy and Western responses. The thrust of the argument is that, overtime, Japan has pursued a relatively balanced mix of policy options within the "space" defined by the triangle of possibilities. While this mix includes collaboration, for various reasons the degree of commercial relevance associated with that option has declined since the mid-1980s. By contrast, the West has given a greater priority to collaboration during that period. As Section 5 will argue, one consequence of this move has been to draw attention to the disappointing level of exploitation that can be associated with public support for pre-competitive, collaborative research. One response to the problem of improving exploitation has been to consider a further area of the policy triangle concerned with assisting the diffusion of IT products.

Western economic policies are usually coloured by the relevant government's approach to "free markets" and "market failure" to induce industrial investment in longer term research projects. It has long been recognised that a competitive market system is likely to under-invest in technologies that are based on the production of new knowledge. Technological uncertainty means that firms operating in a competitive market might not be either willing or able to devote a level of resources to long-term research that is commensurate with ensuring a long-term ability to maintain a share of evolving markets. This sub-optimal allocation of resources tends to be most pronounced in technologies at the basic end of the R&D spectrum. A prevailing view in free market economies is that public support for basic research tends to be less controversial than "near market" research because it is distanced from the commercial world. In the early-1960s, Arrow (Arrow: 1962) and others argued that government funding of this type can offset this type of market failure without compromising competition. Basic research, by definition, is not directed towards commercial objectives and represents what could be described as "soft intervention". It increases technological variety without exerting any direct effect on the economic selection environment.

By contrast, what might be called "hard intervention", started to achieve prominence in the West during the 1980s. This emerging area of interventionist activity is concerned with policies that aim to create new technological infrastructures, directed towards specific economic growth paths which go beyond the goals of individual firms (Justman and Teubal: 1991). If these policies are to be effective, they require a deep understanding of the processes which shape trajectories of innovation and the parallel evolution of the needs of users at different points in the "supply chain" between basic components and finished products (PREST: 1992). The identification of strategic technologies in advance of market indicators almost inevitably reduces technological variety, since there are strong pressures to exclude options that appear to be less favourable. This reduction in variety impinges on the breadth of technological competition, although the speed with which firms pursue targeted trajectories of innovation is likely to be enhanced. In this respect, support for specific technologies focuses the competitive process on particular fields of enquiry at the opportunity cost of restricting the attention paid to technological options that embody a greater potential if they were explored further.

Japan's interventions to target its infant computer and semiconductor component sectors for support during the 1960s and 1970s avoided the difficulties that follow from a reduction in variety because they were mainly oriented towards transferring technology developed in the US, to the Japanese environment. The direction of technological development had already been defined by US firms. As the burgeoning literature on evolutionary economics has made clear, established technological trajectories that are supported by a similarly established base of users generally have a powerful "exclusion effect" on alternative forms of technology -- even if those alternatives embody a greater theoretical potential for exploitation (Georghiou, Ray et al: 1986). Japan's strategy of pursuing technology options that could be exploited in the economic niche excavated by IBM and other leading US firms, involved little commercial uncertainty. The challenge played to one of Japan's acknowledged strengths. It involved the pursuit of relatively predictable trajectories of technological development which centred on known technological parameters. This is seen particularly clearly in the case of semiconductor components. Once successive generations of technology had been "captured", attention could be given to process engineering. As the level of technology progressed, Japanese firms demonstrated a increasing ability to develop production process technologies which allowed them to meet price and quality targets. The realisation of economies of scale at each successive level of technology was assisted by a large domestic market and an orientation towards volume production which was unaffected by the "quality pull" effects of defence procurement policies of the type that had been a factor in shaping semiconductor certain aspects of developments in the US and other Western countries. From Japan's point of view, the problem has come in cases where trajectories of development are less clear as is frequently the case in the software engineering and AI (this is discussed further in Section 4.2).

By contrast to the history of government intervention in Japan prior to the late 1970s, the challenge to Western governments, that started to address the problem of developing appropriate IT support policies during the 1980s, was generally focused on the problems of assisting established industries that were being exposed to increasingly stronger competitive challenges. The justification for such initiatives was typically expressed in terms of the critical role that can be played by a strong indigenous capability in IT. Such an argument is frequently associated with bids to secure access to state-of-the-art IT for use in defence applications, and to justify support to civilian IT users that would be disadvantaged by a dependence on buying in technology from foreign suppliers. It is based on the premise that the ability to use IT effectively is linked to a national capability to supply IT.

Promoting a technology in the absence of clear market signals can be analogous to "pushing a piece of string" in the sense that research inputs might not be translated into commercial outputs: mechanisms are required to secure investment and give entrepreneurial direction. Clearly, advanced IT research will only acquire economic significance if it is exploited commercially and successful exploitation typically hinges on effective diffusion. This issue of diffusion raises two further categories of "market failure" that are of critical importance, namely: "capability failure" and "information failure". Capability failure encompasses such things as: deficiencies in the technical skills required to assimilate new technology that embodies a potential advantage over existing ways of doing things; inflexible organisational structures and an inability to form strategies which are appropriate to capitalising on new technological opportunities. Information failures relate to either a shortfall in the level of knowledge to make a "rational" decision or, alternatively, difficulties in processing available information effectively. While capability and information failures affect the IT industry in general, small firms are especially vulnerable to these problems. Overcoming these barriers to diffusion represents a formidable challenge to IT policy formation.

In comparison to the West, the structure and organisation of the Japanese IT industry tends to mean that the problems of capability and information failures are less significant. The Japanese industry centres on large firms with vertically integrated and diversified business activities. As Nonaka has noted, different phases in product development processes in Japanese firms are overlapping and when necessary staff can "move along with the project" as research is translated into competitive advantage. Knowledge is passed between team members "rugby style" as projects progress towards commercial fruition. The "integrated" organisational structures frequently found in Japanese firms appear to offer greater "capability" than Western models which feature greater separation between research, production and marketing functions (Nonaka: 1991).

3.2 Towards a classification of IT policies

Once the case for supporting IT has been accepted, there is a wide range and diversity of policy measures that can be adopted as mechanisms for assisting IT. These might focus directly on IT or, alternatively, include IT as a component part of more broadly-based policy packages, designed to promote economic growth and national competitiveness. In both cases, there is also scope for implementing policies at different points on the spectrum between hard and soft intervention. One further source of variation, that occurs in the case of policies directed specifically at the IT sector, is associated with the extent to which the policies address demand or supply-side factors. A convenient way of classifying different types of support mechanisms has been proposed by Guy and Arnold (Guy: 1991).

Policies that affect the production and use of IT can be characterised, in very general terms, as being either "sector-specific" or "environmental" in nature. The former category comprises policies that are targeted specifically on the IT sector and might include such things as government-sponsored R&D programmes, procurement contracts and schemes to promote awareness. At a more general level, environmental support schemes represent broad-brush measures that can be exploited by the IT sector as well as by other sectors of the economy (for example, tax incentives and regional development aid).

Both types of policy provide scope for emphasis which is either "developmental" or "regulatory", with the difference being determined, to a large extent, by the degree of government direction implicit in the action. Developmental policies have a directed, "hands-on" character. Firms are encouraged, via policies such as procurement, to follow paths which are intended to fulfil priorities identified by the state, with the result that technological variety is reduced. By contrast, regulatory policies such as the liberalization of telecommunications, are more "hands-off" and do not involve specifying how economic or technical development is to take place. R&D tax incentives constitute a "hands-off" policy-measure because government is not involved in decisions concerning the type of R&D undertaken by firms, whereas government is involved in such decisions in the allocation of loans or subsidies for specific R&D projects. These latter examples illustrate "hands-on" or developmental policy measures.

Within the spectrum of sector-specific policies, it is possible to distinguish three broad policy types: "demand-side" actions, "supply-side" actions and "bridging" actions, each of which can be further sub-divided into a range of policy options. Supply-side initiatives are oriented primarily towards bolstering indigenous IT supply capability, whereas demand-side policies are intended both to stimulate demand from indigenous producers and to improve the efficiency of user sectors via the diffusion of

IT products and services, be they supplied from indigenous sources or from elsewhere. Bridging actions aim to link supply-side and demand-side actions rather than relying on independently conceived "technology-push" and "demand-pull" measures.

In the broader sphere of "environmental" measures, it is more difficult to describe actions simply as supply-side or bridging policies. This is partly a consequence of one person's supply being another person's demand. For example, non-sector-specific capital equipment investments can be considered as supply-side measures by IT producers when used to purchase new production equipment for their own use, but these incentives can be regarded equally as demand-side measures when users take advantage of them to purchase IT products. Similarly, control of interest rates can be used simultaneously to regulate investment in new plant and to influence the overall level of demand in the economy.

The IT Policy Triangle defines three main policy clusters.

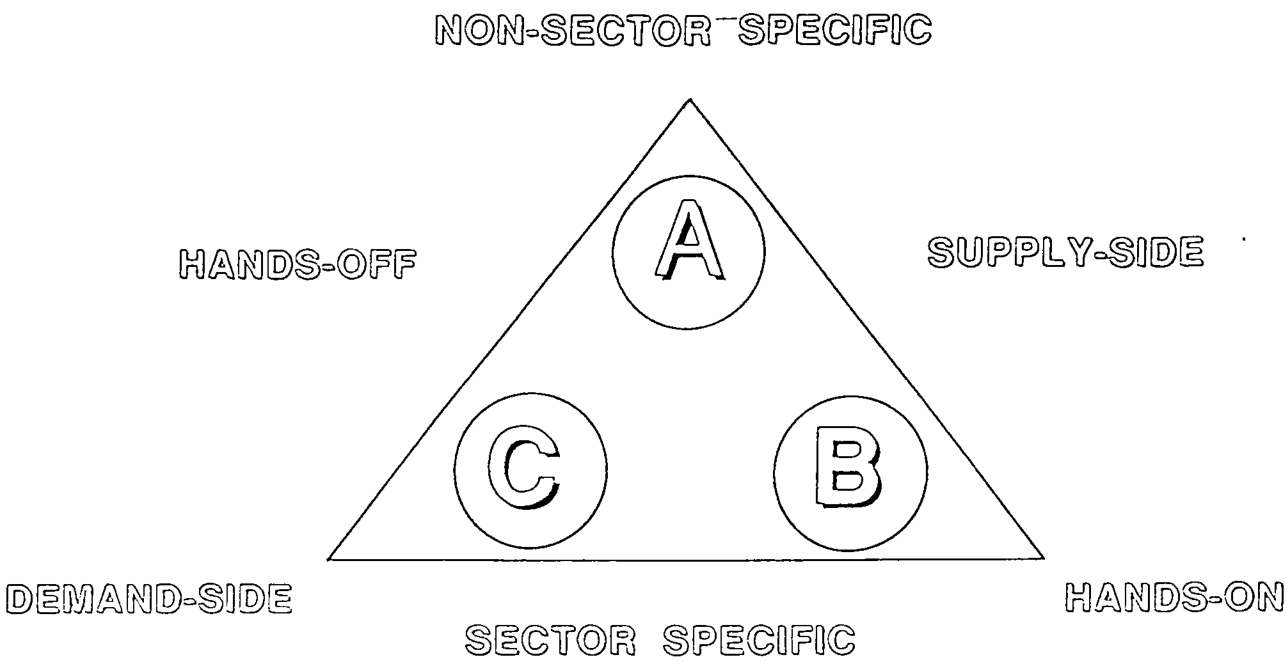
Cluster A Hands-off, Non-sector specific, Supply-side policies

> General R&D tax incentives. Available to all firms from a variety of sectors, with government having little or no say in the type of R&D conducted.

Cluster B Supply side, Hands-on, Sector Specific Policies

> These policies range from the direct subsidy of national champions to IT R&D programmes in areas that are deemed to be strategically important. Government usually has a strong say in the choice of priority areas and in sanctioning participation.

THE IT POLICY TRIANGLE



EXAMPLES

A - GENERAL R&D TAX INCENTIVES

B - IT R&D PROGRAMMES

C - IT EQUIPMENT DIFFUSION INCENTIVES

Cluster C Sector-specific, Demand-side, Hands-off policies

> A good example of this is an IT equipment diffusion incentive. By stimulating general demand for IT goods it is possible to benefit the IT sector.

Although there are a wide diversity of policy instruments which can be used to stimulate IT R&D, the main instruments in use tend to fall into one or more of the three main clusters. Cluster B policies (supply-side, hands-on and sector specific) are almost universally applied and constitute the main policy instruments in many countries. Government-sponsored collaborative research fits into this category, although its practical implementation varies significantly between countries. As the next section will make clear, a main feature of the Japanese case is not so much its use of collaboration but its deployment of a mix of policies, which collectively cover more than one policy cluster. It could be argued that problems with the exploitation of technology push collaborative projects has led to a growing realisation in the West that Cluster C policies (sector-specific, demand-side and hands-on) can be important instruments for stimulating the diffusion of IT. By contrast, it could be argued that close linkages between technological development and the evolution of different points on the "user chain" have been an enduring feature in the development of Japan's IT industry.

4 Japanese IT Policy and the use of Engineering Research Associations

The pragmatic dimension to Japanese government policy for industrial development has sometimes prompted the diagnosis that there is more concern with "winning the game" than creating a "level playing field". Supporters of the "Japan Incorporated" view often promote an image of MITI as the central headquarters of an industrial policy formation mechanism that is distrustful of government laissez-faire capitalism and a keen advocate of "hands-on" intervention. However, the extent to which subscribers to the metaphor actually consider Japan to be "incorporated" varies considerably.

Some of the more extreme interpretations of the "incorporated" view can give the misleading impression that Japan is an integrated, monolithic entity when, it reality, there is generally strong competition between firms and frequent disparities in the relative positions adopted by industry and different government ministries. Indeed, many of the supporters of the "Japan Incorporated" view would probably agree that competition has played an important role in Japanese industrial policy and acknowledge that in certain circumstances, "Schumpeterian" competitive rivalry, involving the use of technological innovation to capture an increased share of the market, is at the very heart of Japan's economic development. Their point is that Japanese government policy has operated in terms of a "desirable" level of competition, which is related to the relative ability of Japanese firms to compete in a national or global arena. From an external viewpoint, this can give an impression of an "incorporated" system. New industries might, for example, be afforded protection and subsidies until they are sufficiently well established to stand on their own feet. In practice, this involves the use of intervention to over-ride free market mechanisms and thereby "short-circuit" the market selection process.

There is, of course, no guarantee that this short-circuiting procedure will be effective. Competitive rivalry frequently leads to the production of alternative technical solutions to a particular problem. A reduction in rivalry can mean that technological options which do not appear to embody much potential for commercial exploitation are discounted more quickly than would otherwise have been the case. This can cause major problems if the market selection mechanism fails to evolve in the way that was predicted and, as Okimoto has pointed out, MITI has made some costly errors (Okimoto: 1989 p4-7). However, the case of the computer industry is acclaimed widely as an example of MITI "getting it right".

With regard to assessing the extent of the government's role in Japan's rapid industrial development, Hart has noted that the small group of Western scholars who write seriously about Japan is divided between those who see the role of the state as being central to the country's economic development and those who believe it to be more peripheral (Hart 1992: p37). While the importance of the state-industry partnership is generally acknowledged, there is often considerable debate about who actually has the upper hand. In some respects, the debate is redolent of features associated with past concerns about whether innovation was a product of "technology push" or "need pull". A widely-accepted way of dealing with this difficulty occurred with growing interest in a "combination view" whereby it was possible to subscribe to both models simultaneously, but with a degree of emphasis that varied according to contingent factors such as the type of technology in question, its relative maturity and so on. By the same token, it could be argued that there is a "middle ground" which can be used for interpreting Japanese support initiatives. The nature of this middle ground varies over time and according to the technology in question: it is contingent upon prevailing circumstances.

Japan pioneered the interventionist policies to support the computer industry in the late-1950s. At that time, the country recognised the importance of building a computer industry and was quick to see the strategic advantage that would arise from technological spillover into related areas such as telecommunications. Although the technology was new and in many ways of unproven value, companies already engaged in manufacturing telecommunications equipment and electronic devices were keen to take advantage of government support to try and exploit its potential as a high-value-added extension to their business activities. Legislation was passed in 1957 to exempt computer technology from anti-monopoly law put in place under the US Occupation. MITI helped to prioritise the acquisition of relevant technology by Japanese firms and thereby established a pattern for government support to promote the development of the computer and related industries. A critical ingredient in this pattern of support has been its consistency. For most of the post-war period, Japan has been ruled by the Liberal Democratic Party creating a record of political stability that is unprecedented amongst the world's large democracies. Against this background of stable government, the Ministry of International Trade and Industry (MITI) has achieved extraordinary scope for autonomous action (Okimoto: 1989 p181).

Japan's political stability has been matched by stable population of leading IT firms. By contrast with the IT industries in many Western countries, the Japanese IT industry has not experienced the effects of significant restructuring caused by mergers and takeovers. Such activities are comparatively rare in Japan. Interlocking patterns of company ownership associated with Japan's keiretsu -- business groupings centred on either a bank or a supplier chain dominated by a leading manufacturer -- provide a solid financial base for supporting longer term investments. On occasions, keiretsu are able to create barriers to foreign participation in Japanese business, for example, by preventing the acquisition of a Japanese company that could provide a gateway to the domestic market. At the same time, internal competition between companies in a particular sector belonging to different keiretsu tends to intensified.

Japan's tradition of lifetime employment mitigates against technology transfer being brought about by the movement of individuals between organisations and the formation of "spin-off" companies to develop specific technologies. Japan's leading IT companies have "broad gauge" technological knowledge bases which tend to include more across-the-board coverage of relevant technologies than is the case in many of their more specialised Western counterparts. Boundaries between companies tend to be much stronger than in the West and, while there is close interaction at the interface with suppliers and customers, the "true core" is well guarded from competitors (thereby providing scope for the "overshooting" phenomenon mentioned earlier).

The development of Japanese IT policy has followed from a long-term dialogue between MITI and the major firms operating in the IT sector. In the course of this dialogue, MITI and the firms have reached a high level of "understanding" about the basis on which policy support measures are given. Failure of firms to abide by the accepted "rules" could result in them being disadvantaged in future MITI initiatives. While the relative importance of MITI and the private firms is matter for debate, the growth of Japan's IT industry has been impressive. Anchordoguy's scholarly analysis of how Japan built a computer industry has identified four dimensions to Japanese government policies: protectionist regulation; heavy subsidies; the establishment a national company to rent domestically-produced computers to Japanese users at very favourable rates and; cooperative R&D projects (Anchordoguy: 1989 p15).

MITI's first step towards building a computer industry was to impose controls on computer-related foreign investment in Japan and restrict imports. IBM Japan, which was established as a 100 per cent subsidiary of its American parent in 1950, was put under pressure by MITI to share technology with the Japanese industry. In 1960, IBM was persuaded to give Japanese computer firms access to its patents, although the strategy was not entirely successful as no arrangement was made for the practical transfer of IBM technology to the Japanese industry (Fransman, 1990: p27).

An effective "bridging policy" to support Japanese computer manufacturers and users was established by the formation of the Japan Electronic Computer Company (JECC) in 1961. At a time when users tended to rent rather than buy computers, JECC bought systems from Japanese suppliers and rented them to domestic customers at subsidised rates. Vendors received a prompt return on their investment, while interest-free loans from the JECC provided capital to support improvement innovations. Over a 20 year period, $2 billion in low interest government loans was channelled into JECC (Anchordoguy: 1990). Although this sum might appear relatively small by today's standards the key point to note is that, at the time, it represented a significant amount of money in relation to what the firms themselves were able to spend. Moreover, the scheme preserved some aspects of market selection mechanisms in that it helped firms who were prepared to help themselves. Although computers produced by IBM during this period were frequently cheaper, more reliable and more powerful, Japanese public policy was oriented towards a long-term view of efficiency based on the ultimate acquisition of an indigenous state-of-the-art capability.

The fourth dimension to Japan's policy for IT has centred on government-sponsored collaborative R&D projects. During the period since the 1960s, collaborative research schemes orchestrated by government agencies have become firmly established as a major vehicle for public policy in the development of the Japanese industry. These schemes typically involve horizontal groupings of rival firms, together with the participation of government agencies or research laboratories. The aim is to use collaboration as a vehicle for sharing the costs and uncertainties of technological development in order to enhance long-term competitiveness.

Although Western commentators often speak as if collaborative research was intrinsically Japanese, MITI's system of research associations actually has foreign origins. In the late-1950s, the Director of MITI's Mechanical Engineering Research Laboratory, Dr Masao Sugimoto, was impressed by the British system of Research Associations (Levy and Samuels: 1989 p31). These associations had been introduced in 1921 to counter concern that Britain was loosing its technological leadership. Similar associations was subsequently created in a number of European countries and, although there was considerable diversity in the ways in which the British prototype was implemented in different national environments, a major survey published in 1965 reflected a generally low level of respect for the achievements of these bodies (Woodward: 1965). Nevertheless, Sugimoto was particularly interested in the assistance given by the British government to small and medium-sized firms and sought to transfer this feature of support to Japan. The first research associations in Japan were ad hoc ventures to support the manufacture of parts for motor vehicles. In 1961, the ERA system was put on a formal basis by the Research Association for the Promotion of Mining and Industrial Technology Act. This law gave research associations the status of a legal corporation which had the effect of making it possible for them to receive significant tax benefits. In the period up until 1965, 12 ERAs were established in a range of sectors.

Between 1965 and 1970, there was a moratorium on ERAs. This period coincided with the launch of MITI's National R&D Programme (often referred to as the large-scale project) which represented the Japanese government's first attempt to finance 100 per cent of the costs of certain R&D projects carried out by private firms. At the time it was believed that this form of support precluded the possibility of organising cooperative research schemes. However, it was subsequently decided that the two forms of support could complement each other and it became standard practice for MITI to implement national projects through the use of cooperative research projects (Kodama 1991 p86). A rapid expansion in the number of ERAs followed and an increased number of larger firms became involved as MITI started to use ERAs for broadly-based national projects in areas such as microelectronics, materials science and biotechnology.

Prior to 1980, computer-related ERAs had been concerned with transferring existing technology to Japanese firms. Japanese hardware and component manufacturers caught up with US best-practice technology, which have been seen as a sign that ERAs had served their purpose. In the event, a new type of ERA was pioneered which was designed to push back the frontiers of basic research. While the Fifth Generation Computer Project perhaps provides the most publicised example of this phenomenon, similar initiatives were launched in optoelectronics and component technologies for a supercomputer. Unlike previous IT ERAs, which were "distributed" in that participants worked from their own premises, these three new-style projects have been run from central research institutes. With less proprietary knowledge at stake, collaborators evidently feel more happy with closer cooperation (Levy and Samuels: 1991 p140).

4.1 A Review of MITI's Computer-related ERAs

The computer industry has seen more Engineering Research Associations (ERAs) than any other industrial sector, reflecting the potentially high returns from increased market shares that can be gained as a consequence of coordinated technological innovation. These ERAs may be traced from the Computer Basic Technology Research Association which was launched in 1962 to help Japanese manufacturers build a machine that would be able to compete with IBM's second generation 1401 series. It lasted until 1966 and funded on 50:50 basis by MITI and the participating firms. The association was also known as the FONTAC project, which drew the first three letters of its name from the initials of the participating companies: Fujitsu, Oki Electric and NEC. Fujitsu worked on the main processor and punch card equipment, while Oki and NEC addressed issues related to sub-processors and input/output equipment. Research was done in-house and there was minimal communication between the participating companies (Fransman: 1990 p29). In many respects, the FONTAC project could be regarded as being unsuccessful. Integration of the modules produced by the participating companies was problematic. Moreover, in the meantime, IBM had introduced its 360 series machines which effectively rendered the project's outputs obsolete.

MITI's response to IBM's 360 series machines took the form of the Very High Speed Computer System (VHSCS) which was launched in 1966. It lasted for six years under the overall technical leadership of MITI's Electro-Technical Laboratory (ETL). By contrast with the FONTAC project, the VHSCS involved all six major computer manufacturers: thereby defining the basic format for participation that existed through most of the subsequent ERAs. There was a clear division of labour in the project with Hitachi, Fujitsu and NEC working on mainframes and integrated circuits, while Oki Electric, Mitsubishi Electric and Toshiba worked on peripheral equipment. Hitachi took the lead and ETL provided some of the more basic research input. Although the project achieved most of its objectives there was still a wide gap with IBM. Many of the more significant benefits were indirect. According to Fransman (Fransman: 1990 p32), much of the background to NEC's current domination of the world market for memory devices can be traced to its specialisation in this technology during the VHSCS project. There was very little sharing of knowledge created in the project and none of the 39 patents produced involved two or more companies (Fransman: 1990 p34).

The gap with the US was made all the more apparent in 1971 when the launch of IBM's 370 series once again outflanked Japan's efforts (and also forced RCA and GE out of the US industry). MITI felt that there were too many computer manufactures to compete effectively and sought to strengthen the Japan's position by promoting the formation of national champions. Substantial financial assistance was promised if the six major firms agreed to some for of rationalisation into two or three groups. However, a combination of strong resistance by the firms and a significant cut in MITI's budget by the Ministry of Finance meant that the proposed mergers never took place. MITI's policy instead centred on the formation of a further ERA.

The New Series Project ran from 1972 to 1976 and was something of a turning point in that it allowed Japanese manufacturers to divide up the market so that they could collectively provide a full range of products that were capable of presenting an "across-the-board" challenge to IBM. It was the first Japanese project to aim at IBM compatibility. Government subsidies of 70.3 billion yen were made available to participating firms who were then required to contribute a similar level of funding from their own resources.

MITI forced the six firms in the project to form three teams although, in practice, the firms remained independent and there was conflict both between and within the partnerships. Fujitsu and Hitachi worked on the largest machines which represented a direct challenge to IBM's domination of the world market for mainframe computers. NEC and Toshiba worked on middle-sized machines, while Mitsubishi and Oki focused on smaller computers. Extensive use was made of private links that the Japanese companies had been able to establish build with US firms. By exploiting these links, the Japanese companies were more easily able to assimilate the technologies that were necessary to ensure compatibility with IBM machines. The project's strategy appeared to be highly effective and was instrumental in enabling Japanese hardware producers to match the performance of IBM 370 Series machines at prices which, by 1970, were between 15 and 20 per cent lower. For the first time, Japanese and US producers competed head-on.

Japan's progress in hardware during the late-1970s, focused attention on the US lead in very large scale integrated circuits (VLSI) and gave rise to the famous VLSI project which ran from

1976 to 1980. It cost 72 billion yen, 30 billion of which was provided by the government. Much of the justification for the project had its origins in the realisation that the US had a head-start in the development of VLSI circuits associated with "fourth generation" computing. In 1975, IBM was rumoured to be contemplating a "future system" line of computers using VLSI and MITI's view appeared to reflect the idea that their were too many computer makers in Japan to cope with a giant like IBM. The project might also be seen as a competitive response to a similar VLSI project launched in 1975 by NTT which gave substantial financial support to NEC, Hitachi and Fujitsu. MITI evidently felt that NTT had intruded into its territory (Anchordoguy: 1989 p140) and sought to establish a larger project which included five of the six domestic manufacturers: NEC, Toshiba, Hitachi, Fujitsu and Mitsubishi. Oki was excluded as a consequence of its failure to exploit the results of the New Series Computer Project and also because the company was experiencing severe financial problems which cast doubt over the probability that it would be able to make a useful contribution to the venture.

Research was carried out at three sites: a cooperative laboratory; the Computer Development Laboratories, (CDL) established jointly by Hitachi, Fujitsu and Mitsubishi; and NEC Toshiba Information Systems (NTIS) Laboratories owned jointly by NEC and Toshiba. The cooperative laboratory was distinguished by the fact that it existed on a single site and was staffed by research engineers from all five participating companies, as well as members of the Electrotechnical Laboratory which is part of MITI's Agency for Industrial Science and Technology. According to Okimoto et al, the work at this laboratory concentrated on common basic technologies which only accounted for a minor proportion of the project's overall research activities. The main part of the project was concerned with applied development leading to more immediate commercial exploitation and was undertaken by the companies (Okimoto et al: 1984 p19).

The VLSI project is generally acclaimed to have been an outstanding success. Considerable advances were made in process technology and by 1980, Japanese firms became world leaders in VLSI by producing products that exhibited 1.5 micron feature sizes. These achievements helped Fujitsu, NEC to introduce highly competitive fourth generation computers. The project also produced over 1,000 patents, although less than 20 per cent of these were jointly held by more than one company.

In commenting on the role of MITI in the success of the project, a Director of one of the joint research laboratories has been quoted as saying: "... The role of MITI was important. Also, much more money went to NTIS than to the joint research laboratories. That money was helpful for the individual five companies, I think, to develop practical technologies." (Fransman: 1990 p97). The implication appears to be that the project emphasised the practical development of technology rather than joint research. In this respect, the project falls into the "catch-up category" as Okimoto has observed:

> Even the heralded VLSI project (1976-1980), hailed as an unprecedented model of collaborative research failed to push semiconductor technology beyond the frontiers of knowledge (except perhaps in liquid crystal displays). While the VLSI project did advance the state of Japanese semiconductor knowledge, especially in the area of production technology (eg silicon crystal growth and processing), Japanese companies probably would have made such advances anyway. If so, the project's main accomplishment may have been to hasten the timetable of development, a nontrivial but hardly revolutionary accomplishment.
>
> (Okimoto: 1986 p541)

With hindsight, the VLSI project may be seen as representing the conclusion of the catch-up era. The "additionality" of the project achieved by government funding (ie outputs that would not have been produced in the absence of government funding) was evident in an increase in speed with which firms were able to pursue a trajectory that had been more-or-less defined by the US industry leaders. Given the problems that existed with several of the earlier computer ERAs and the initial reluctance of firms to participate in the VLSI venture, it is instructive to consider why the eventual outcome was widely acclaimed to be a success. One of the key factors in this success seems to have been clear technological objectives that were directly relevant to the business strategies of all the participating firms. Exploitation routes were apparent at the during the life of the project and gave direction to the research. While the firms' competitive instincts were to avoid collaboration, the level of government funding was sufficient to persuade them that failure to take part would place them at a serious disadvantage relative to participating firms. (The project enabled participating firms to double or even treble their potential research expenditures on relevant aspects of semiconductor technology.) It was a market-oriented venture which introduced the possibility of delivering tangible commercial benefits within a relatively short time.

Participation in the VLSI project gave Japanese firms what the US Semiconductor Industrial Association regarded as government subsidies which would be in breach of the American Anti-Trust Laws. It was a source of trade friction; along with unfair tariffs (Japan 12% verses USA 6%), preferential treatment of Japanese suppliers by NTT, allegations of "dumping" and a high trade surplus (Imai: 1983 p3). By contrast with this "in the market" orientation of the VLSI project, the next chapter in MITI's history of computer related ERAs took a very different turn toward basic research.

MITI's high-profile Fifth Generation Project involved ambitious plans to develop a new dimension of computing. While earlier generations of computers were associated with component technologies in the form of thermionic valves, discrete transistors and VLSI, the fifth generation centres on computer performance characteristics. Fifth generation computers were intended to understand spoken instructions, emulate human reasoning and explain how conclusions are reached -- in short, a machine that embodied artificial intelligence (AI). Advances in VLSI had introduced the possibility that traditional Von Neumann computer architectures, in which processing functions were performed sequentially, could be replaced with parallel processing. The practical realisation of parallel processing could create scope for the enormous increases in computing power that would be required for AI. Planners of Japan's fifth generation project envisaged that "thinking" computers would provide solutions to long-standing problems such as poor performance in software development and low white collar productivity (Unger: 1987 p9). They would be "machines for the 1990s". From the West's point of view, this was a formidable challenge from a country that had hitherto been an imitator. Moreover, Japan was threatening to take up the baton of leadership in a technological area that had been much discredited by extravagant claims on the part of AI enthusiasts.

Although foreign organisations were invited to participate in the FGCS project, the eventual outcome was an all-Japanese initiative. Work began in April 1982 at ICOT, which is a specially created central research facility, located in Tokyo. This use of a central research facility was a notable change in direction from the policy adopted by MITI's preceding closer-to-market cooperative projects where, with the exception of the VLSI project, firms conducted their work on their own premises (the so-called "distributed" model of collaboration). The basic nature of ICOT's research was probably a major factor in convincing firms that commercial confidentiality would not be a problem with this more open form of collaboration. However, Cusumano has noted that, of the participating firms, only the company that agreed to produce the hardware showed any enthusiasm for the project. He suggests that part of the reason for this might have been apprehension about the role of the central research facility, although a more important factor was perhaps the risky and difficult nature of a project that seemed to have no immediate commercial applications (Cusumano: 1991 p411).

ICOT was staffed by researchers seconded from the eight industrial participants in the project: Fujitsu, Hitachi, NEC, Toshiba, Mitsubishi, Oki, Matsushita and Sharp. In addition to supporting the central research facility, the FGCS project also spent a substantial amount of its budget on research contracts placed with the participating firms. Funding for the project came entirely from the government and, at the end of the project's original 10-year life-span, some 54 billion yen had been spent. Although MITI had planned that the participating firms would donate matching funding to the overall project budget, in the event, the industrial contribution was limited to sending researchers to the central research facility at the government's expense. In 1985, there were 50 researchers and, by the end of 1990, there were about 100 researchers.

Phase one, from 1982 to 1984, aimed to develop basic technologies. The next phase was to generate the building blocks of computers capable of "reasoning" and the final phase between 1989 and 1992 was designated as the period within which the prototype fifth generation machine would be constructed. This was envisaged as "user friendly" machine with 1000 parallel processors. While the project was able to meet its targets for phase one, subsequent goals proved to be more difficult and there was also a growing divergence between ICOT research and the more immediate commercial interests of participating firms. As the project approached its conclusion, a critical article in Nature (26th March 1992) proposed that the Fifth Generation project illustrated the problems of Japan's rigid bureaucracy, noting that:

> By the mid-1980s, it was clear that other approaches to parallel computing not based on traditional artificial intelligence techniques, such as neural networks or the

massively parallel machines created by Thinking Machines Inc. of the United States looked more promising. But having told the Ministry of Finance that it would build a 1090-processor machine, MITI had no choice but to continue towards that goal.

When ICOT held an international conference to report on its 10 year work programme, the three largest "parallel inference machines" exhibited only had 256 parallel processors each (New Scientist: 13th June 1992). The project was extended for a year to pursue further the goal of the 1000 processor machine. It was subsequently announced that there would also be an additional one year extension, during which time researchers would rewrite programmes to run on conventional machines.

The Director of ICOT, Kazuhiro Fuchi, defended the project in his keynote conference speech claiming that parallel will be a core for future technologies that will be able to beyond the framework of what is possible in conventional computing. Critics argued that ICOT's venture into basic (as opposed to applied) collaborative research suffered because it was difficult both to set goals and adjust objectives in the light of changed circumstances. Other technologies subsequently proved to be of much greater-than-expected importance but they were not in the original ICOT plan and ICOT could not adapt. (For example, the entrepreneurial flexibility that had for example enabled Sun Microsystems in the US to exploit Reduced Instruction Set Chips (RISC) was not a feature of the ICOT model.) Similarly, promising approaches to AI such as neural networks, which attempt to mimic the functioning of the human brain, fell outside ICOT's research agenda. Nikkei Business reported on tensions arising between the government and the firms, although the firms did not criticise the government openly, the article claimed that there was mounting dissatisfaction the nature of government initiatives. The case of NEC was cited a firm that was formally a keen member of ICOT but subsequently tried to distance itself from the work. NEC equipment on show at the 1992 exhibition did not bear the company logo to avoid public association with the project. While one earlier benefit to NEC from participation in ICOT was an air crew management system which has been sold commercially, this was based on "traditional technology" developed in the first phase of the project (Nikkei Business: June 29, 1992).

An objective assessment of ICOT's achievements is difficult because the publicity at the beginning of the project led to unrealistic expectations. At a technical level, the project was acknowledged to have produced some notable achievements. However, there was some divergence between the project's research agenda and the parallel evolution of participating companies technological priorities (Washington Post: June 2, 1992). During the project's first 10 years, a total of 184 researchers, all under the age of 35 worked at ICOT's central research facility (New Scientist June 13, 1992). Yet, while the experience that these individuals gained might be one of the more significant benefits of ICOT, it is difficult to be clear about the time-scale within which these benefits will be realised.

By contrast with the Fifth Generation project, MITI's follow on 10 year "Real World Computing Programme" appears to represent an attempt to circumvent this problem by using a diversity of research strategies prior to mid-term appraisal of which technologies to select for mainstream development (Science, October 23 1992). The Real World Computer will be oriented towards a flexible information system with an intuitive information processing capacity similar to that of human beings. Hajime Irisawa, who is a former MITI official and Executive Director of the Real World Computing Programme, has described the project as "very basic": there is no intention of even building a prototype computer (Tokyo Business: March 1993 p3). MITI is expected to provide something in the order of 90 per cent of the funding which is estimated to be in the order of 60 million yen over the 10 years. The project aims to create a new infrastructure for basic research which is expected to include a number of non-Japanese organisations.

In summary, while the achievements of IT ERAs are cited as examples of effective cooperation they have also embraced a potent mixture of competitive rivalry between participating firms. Anchordoguy points out that:

> "Cooperative" R&D conjures up images of members of different firms working together on the same problem. While this did occur, it was rare. For the most part, tasks were assigned to different companies. In some cases, the firms divided up the work and gave one another access to the resulting patents; in other cases, the firms split into groups to take different approaches to the same problem while agreeing to share results.
>
> (Anchordoguy: 1989 p43)

Further support for the idea that inter-firm knowledge sharing is of comparatively minor importance to firms participating in Japan's national cooperative projects is provided by Fransman's detailed analysis of cooperation and competition in information technology in the Japanese system. Quantitative survey data obtained from companies participating in five major national programmes led him to conclude that: "Access to knowledge contributed by other participating organisations was not generally felt to be a very important benefit..." (Fransman: 1990 p252). While greater knowledge sharing has been a feature of the more basic research consortia launched during the 1980s, this type of sharing does not involve significant amounts of proprietary knowledge.

MITI's collaborative ERAs show that if certain circumstances collaboration between competitors can be of considerable importance to the development of Japan's IT industry: for example, the New Series and VLSI projects stand out as successful projects. Yet, it should be stressed that "collaborating to compete" is rarely easy. Effective collaboration requires a sufficient inducement to collaborate. Typically this involves a sufficient incentive to participate (usually if the form of government funding), a belief that the potential outcomes that will be commercially relevant and an expectation that it would be possible to "internalise" these outputs without leaking proprietary knowledge to competitors in the grouping. The commitment of industrial funding to the project can also be a major factor in encouraging firms to link the research agenda to commercial requirements.

4.2 A Note on Collaborative Software Projects

In comparison to its promotion of computer hardware and components, the history of MITI's ventures into collaborative research into software have been of limited success. Prior to the 1980s, MITI did not channel significant funds into collaborative software R&D projects. While specific projects have experienced different problems, Cusumano notes that there have been some common themes: "poor planning, disagreements on objectives and poor results" (Cusumano: 1991 p389).

Of the more recent software projects, SIGMA (Software Industrial Generation Maintenance Aids) is perhaps worthy of special mention in that it represented a high profile attempt to address Japan's emerging "software crisis" by automating the production of software and facilitating its re-use by improving the quality of software components. SIGMA was organised by MITI and run through its Information Processing Agency (IPA). Work began in 1985 and lasted 4.5 years. The overall budget was 25 billion yen, which came from government and industry sources (with the size of industrial contributions being determined in accordance with the company's turnover). A total of 194 industrial organisations participated including 15 hardware manufacturers, 109 software companies and 11 foreign firms with Japan-based operations. Sigma aimed to produce a UNIX based workstation which could be used for developing applications software more efficiently. Following the project's completion in 1990, the SIGMA Systems Company was formed to assist in the commercialisation of the projects outputs. However, the company was not able to cover its costs and sales from SIGMA tools were negligible.

A major problem with the SIGMA project was that the tools developed did not have any significant advantages over the products of major software houses, while the range of tools was limited. Switching to SIGMA tools would involve companies in a change of software and hardware to adopt a system that lacked some of the facilities provided by current technology. Another difficulty was that the workstation and software makers who supported other operating systems were also expected to act a SIGMA sales agents and were thereby confronted with a direct conflict of interests. Some critics of SIGMA have suggested that problems arose because MITI was trying to push firms towards technologies that lagged behind best practice alternatives.

5 The UK Alvey Programme: A Case-study of a European response to Japan's Fifth Generation Programme

One of the first initiatives that can be directly related to the Fifth Generation announcement was the UK government's Alvey Programme to promote pre-competitive research in advanced IT. It is used here to provide a case-study of "European-style" collaboration. In Europe, government policies to support electronics related industries began to emerge as a subject for debate in the late 1970s. A traditional predilection for "soft" interventionist policies to support a more healthy investment environment began to give way to more blatantly interventionist sector-specific "strategic" policies.

Prior to the fifth generation announcement, the UK had been actively seeking industrial links with Japan in order to offset declining competitiveness in the domestic IT sector. ICL, which was Britain's only significant indigenous computer manufacturer, had already forged links with Fujitsu and the official view was that Britain might be able to benefit from further links with the Japanese IT industry. However, approaches made to Japan during the period leading up to the October 1981 "Fifth Generation" conference revealed that the country considered itself to be self-sufficient in hardware terms and was interested in gaining access to British academic expertise, particularly in artificial intelligence. One academic, Professor Donald Michie, is Reported to have commented that collaborating with Japan in this area would be rather like: "cooperating with a vacuum cleaner" (Oakley and Owen: 1989 p17). This concern about a one-way flow of information was reflected widely in academic, government and industrial circles. One consequence was to focus attention on how best to emulate the Japanese research effort.

Alvey was set-up as the first stage in a 10 year plan to improve the competitiveness of the UK IT sector although, in the event, it was only funded for five years. The programme began in 1983 and broke new ground in that it was sponsored by three different sections of government: the Department of Trade and Industry (DTI), the Ministry of Defence (MoD) and the Science and Engineering Research Council (SERC). Its main thrust was to support pre-competitive, collaborative research projects in the enabling areas of IT. Some 200 collaborative projects involving partners from industry and academia were undertaken and the overall budget was 350 million pounds sterling, 200 million pounds of which came from government sources with industrial participants providing the balance. For the most part, a "distributed" model of collaboration was used with projects typically lasting in the order of three years. By contrast with the Japanese model of collaboration, there was a very real expectation that there would be substantial knowledge transfer between partners. Government funding was not provided until all the partners had signed a collaboration agreement which covered the ownership of intellectual property produced. Firms tended to be cautious in their approaches to these agreements and many projects suffered long delays as a consequence of the time that it took to draft an agreement that was acceptable to all the partners in the project.

Alvey was successful in promoting collaboration between UK industry and the national science base. It also provided valuable learning experience for the majority of participants, paved the way for further collaboration at the UK and European levels and offered lessons for the running of a rather more modest follow on programme to support IT through the use of collaborative R&D. Revitalising the UK IT sector was rather more problematic and, in many respects, the level of exploitation of Alvey outputs has been disappointing. In some cases, barriers to exploitation arose because of poor linkages between R&D and production facilities, while in other instances technical difficulties proved to be insurmountable. However, there were also difficulties which arose from the fact the research had been undertaken as part of a collaborative project. The involvement of other partners mean that projects are relatively inflexible in the face of changing commercial circumstances. Major changes in a project's direction involved gaining the agreement of other partners and the government. Project progress might also be affected by a divergence between the interests of the academic participants and the commercially-related concerns of industrial collaborators. Withdrawal by partners, following a reappraisal of business and technical priorities, tended to create problems for other collaborators (Guy, Georghiou, Ray et al: 1991 p V).

An independent evaluation of the Alvey Programme concluded that pre-competitive research and development programmes are well suited to a range of tasks but are not in themselves sufficient mechanisms to bolster the competitive performance of the IT sector. Complementary private sector and government initiatives are needed to: relate IT development to users; promote effort within firms to formulate technological strategies to facilitate the exploitation of research, and; a serious re-evaluation of the need for patient capital (Guy, Georghiou, Ray et al 1991). To varying extends, each of these three "deficiencies" are less of a problem in Japan.

While interventionist policies enabled Japan to build an IT industry in the shadow of IBM, they have not solved the shortcomings associated with the exploitation of outputs arising from programmes of basic collaborative research. Rather support policies in Japan interacted with the Japanese environment to create a "climate for innovation" through tax incentives for research and infant industry protection. This has been helped by structural features in the Japanese economy. Japan's success in consumer electronics was an example of close matching of innovation trajectories to prevailing patterns of user requirements, while commercial returns on this effective coupling process was helped by a domestic market which is more than twice the size of that in the UK. The absence of high-specification military procurement policies, combined with competition between a number of domestic producers is also instrumental in stimulating both competitive innovation and aggressive pricing policies. Japanese industrial structure and, in particular, the broad technological and foundations of the leading players in the IT sector has been a source of relatively patient capital.

Even though collaborative research does not in itself appear to be an entirely satisfactory solution to the problem of revitalising the UK IT industry, it has been retained a leading position in the portfolio of British support mechanisms. A scaled-down national programme of collaborative research has followed from Alvey (The Information Engineering Advanced Technology Programme), while an expended commitment has been made to pan-European collaborative research.

The launch of Alvey was followed by a dramatic expansion in pan-European collaborative R&D under the European Community's first Framework Programme (1984-87), which covered a broad range of research areas and has been followed by subsequent programmes. These programmes are intended to support pre-competitive research projects. A fourth Framework Programme was agreed in 1992. The most prominent IT initiative in the framework scheme is probably the European Programme for Research in Information Technology (ESPRIT). This began in 1984 and covers microelectronics, software engineering, computer integrated manufacturing and advanced IT systems for business and the home. ESPRIT is a "technology push" initiative without any formal mechanism for linking projects to the evolving needs of IT users. The most important benefits derived by industrial participants in ESPRIT have been mainly associated with improvements in basic know-how the adoption of more ambitious research objectives (OECD: 1992 p76). ESPRIT is complemented by the Eureka Programme, which aims to be market-driven. It was launched in 1985 by President Mitterand of France as a response to President Reagan's Star Wars initiative. Eureka provides funding for a variety of technologies and involves all 12 member states of the European Community, as well as seven other nations in Europe and the European Commission. One particularly significant piece of work funded under Eureka in the IT sphere is the Joint European Submicron Silicon Investigation (JESSI) project which could be seen as a European response to the USA's Sematech project, which is introduced in the next section.

At the pan-European level, the "overheads" associated with collaborative research tend to be amplified by the geographical separation between partners and language barriers. Concern has been expressed that the "pre-competitive" emphasis of ESPRIT is producing research that is a still some considerable distance from the market and vulnerable to the type of barriers to exploitation that beset the Alvey project. Successful collaboration between industrial firms is generally associated with clear research targets which embody a clear potential for exploitation and are shared by all the participants. In this respect it is instructive to consider the case of a "spontaneous" European collaborative response to the Fifth Generation programme which was initiated without government funding. The (ECRC) European Industry Research Centre located in Munich was the established in 1984 as an Anglo-French-German collaboration by ICL, Bull and Siemens. By contrast with ICOT, the ECRC has been able to shift its emphasis in the light of changing circumstances. It is only about half the size of ICOT, with some 50 researchers, and has concentrated on more modest projects which are coupled to the commercial requirements of partners (Guardian: Aug 13 1992).

Collaboration has become well established in Europe as a way for spreading the costs and uncertainties of research. Yet these collaborative ventures frequently centre on research that is some considerable distance from the market and involve academic as well as industrial collaborators. Routes to exploitation are less clear than was the case of the more successful commercially-oriented Japanese schemes. The European IT industry also differs from Japan in that it is fragmented and subject to constraints imposed by a large number of relatively small national markets. Differing national priorities, coupled with cultural and language barriers, add to the difficulties of implementing a concerted programme of action. At the same time there are restructuring and adjustment issues associated with successive waves of mergers and takeovers. This means that the planned "temporary monopoly" that would be associated with a collaborative project is sometimes overtaken by an actual monopoly that occurs in the wake of moves toward increased industrial concentration.

6 The Rise of Collaboration in the United States

In the USA there are a few overtly "hands-on" actions in the civilian sphere and a plethora of "hands-off" actions, both non-sector-specific and sector specific. The other major characteristic of the US support is a range of sector-specific actions determined by the Department of Defense; many of which have a determinedly hands-on nature.

During the 1970s, the United States led the world in component technology, computer manufacture and many aspects of what has since become known as "software engineering". At the federal level, the official US industrial policy has been avowedly non-interventionist: the policy was not to have a policy. By contrast, many individual state governments have a long tradition of interventionist policies. In practice, federal defence spending has performed a key role in establishing America's post Second World War lead in electronics and computer-related technologies. National security was used as a justification for "hands on", sector-specific interventionist industrial policies.

Although a relative decline in US's industrial competitiveness over the 1980s led to calls for a more coordinated approach to industry , these were met with fierce opposition in official circles. In 1981, the Reagan Administration entered the White House with a strong commitment to minimal intervention in the commercialisation of technology. It was deemed that the appropriate role for federally-funded research in the civilian sector should be restricted to supporting basic research. At that time, the exploitation of research was a matter for market forces. Nevertheless, during the course of the 1980s, collaboration in support of the pursuit of competitive advantage gained ground and established a trend which looks set to continue into the 1990s. This is worthy of special note because it runs contrary to the tradition of Anti-Trust which has been a very deeply engrained feature of American economic policy. Moreover, in sharp contrast to MITI's collaborative ERAs and government-sponsored European responses to the Fifth Generation Programme, collaboration in the US had private sector origins.

Japan's announcement of its Fifth Generation Computer Programme caused concern amongst members of the US IT industry and policy-makers. While the perceived threat was not sufficient to break the "anti-centralist" tradition of US politics, it did provide an opportunity to mobilise Congressional support for an increase in funding to established agencies. For example, the Department of Defense's Defence Advanced Research Project Agency (DARPA) launched a ten year Strategic Computing Programme in 1983 which set ambitious targets for the practical demonstration of advanced AI and parallel computing. The National Science Foundation (NSF) also expanded the scale of funding for computing and AI. In addition, NSF played a pivotal role in consolidating the US's leading position in packet-switched networking and computing. A further policy action with implications for the IT industry was the Strategic Defence Initiative (more popularly known as Star Wars). It was first announced in 1983, as a space-based system to defend the US from inter-continental ballistic missiles. By 1993, the project had consumed some $32 billion -- mainly on ambitious military-oriented projects which are distanced from commercial markets.

Outside of government, one of the early responses to the Fifth Generation announcement was the Semiconductor Research Corporation (SRC). This was created in 1982 as a permanent non-profit-making institution linked to the highly influential Semiconductor Industry Association. SRC is supported by industrial corporations who pay a subscription in proportion to their turnover and, in return, gain access to a broad spectrum of semiconductor research projects, conducted at US universities under SRC sponsorship. (By contrast with Japan which is frequently characterised as having a relatively weak university sector, US industry has a solid history of using of universities to support research activities.)

The major non-governmental collaborative response to Japan's plans for fifth generation computing was the setting-up of Microelectronic and Computer Technology Corporation (MCC). This is an independent research institute funded by a consortium of US companies. It was set-up in 1982 to undertake pre-competitive research in semiconductor and computer technology on a permanent basis. For the US, MCC was nothing short of revolutionary. It involved unprecedented cooperation in a fiercely competitive industry and was only made possible by changes in the anti-trust legislation. A central research facility was constructed at Austin in Texas and work began in 1984. From the outset, MCC was seen as a bold initiative that would only produce results in the long-term. During the late-1980s, MCC embarked on a era of restructuring which led to an increased emphasis on interim deliverables while, at the same time, pursuing longer-term goals. In this respect, MCC's continued survival reflects a degree of flexibility which is way beyond what proved to be possible at ICOT.

MCC was at the forefront of a new approach to collaborative research in the US. During the 1980s, several Bills were passed by Congress which were designed to aid certain collaborative R&D activities that could be regarded as crucial to the national interest. In particular, these Bills served to clarify the position of collaborative R&D with regard to existing anti-trust legislation. This paved the way for a wide variety of research consortia and, by the late-1980s, collaboration had been established as a legitimate vehicle for sharing the costs and uncertainties of pre-competitive R&D (see: Evan and Olk, 1990).

While MCC paved the way for collaboration in the US, the launch of the Sematech Consortium in 1987 represented a sea change in the US administration's prevailing attitude to collaborative R&D. Sematech was founded with the largely commercial objective of enabling the US to compete more successfully with Japan in the manufacture of semiconductor devices. It is a non-profit making organisation funded by a total of $500 million over 5 years from the US Department of Defence, via DARPA, and a similar sum made up from subscriptions paid by 14 leading semiconductor manufacturers.

Competitiveness in chip manufacturing processes had been driven by the quest for increased density in the production of memory chips. The problem for the US was that, by the mid-1980s, leadership in this technology was tending to shift to Japanese firms. Moreover, US firms were also being displaced from the key component technology of dynamic random access memory (D-RAM) chips by Japanese competition. Fears that US firms would fall behind in semiconductor production technology without an indigenous D-RAM capability were countered by the idea that SEMATECH would act as a "technology driver" or "forcing ground" for promoting state-of-the-art processes, although the extent to (LSI Logic, which was founder member of Sematech, withdrew in January 1992 arguing that the subscription could be used better internally.)

A further innovation in federal support for R&D has followed from the 1988 Omnibus Trade and Competitiveness Act. One of the consequences of this act is the creation of what some commentators have referred to as a 'Civilian DARPA' in the form of the National Institute of Standards and Technology's Advanced Technology Programme (ATP). This small but innovative scheme was launched in 1990 as a mechanism for providing federal support to US business carrying out pre-competitive R&D in generic technologies (defined as concepts, components, processes or scientific knowledge that could be applied to a broad range of products and processes). The emphasis is on supporting technologies such as IT that will play a significant role in enhancing US competitiveness.

During the period since Japan's Fifth Generation announcement, US policies that impinge on IT have been changing. Collaboration has become established as a legitimate mechanism for conducting pre-competitive R&D both for private industry and, more recently, for federally-funded research. An industrial policy is slowly beginning to emerge as part and parcel of the evolution of policies for national security, on the one hand, and a competitive trading position, on the other. Defence research funding is now being used to support advances in civilian technologies in the expectation that it would preserve a national capability that could be exploited in future military programmes which, as Mowery and Rosenberg have argued, is a reversal of earlier patterns of funding and technological spillover (Mowery and Rosenberg: 1989). However, there is a sense in which the national focus of these policies has been overtaken by the globalisation of the computer industry. Following the signing of the Japan-US Semiconductor Trade Agreement in September 1991, there has been a steady increase in the "natural alliances" between Japanese and American firms and many would argue that international rather than national ventures will become more relevant as the 1990s unfold.

While it is difficult to equate initial post-fifth-generation developments in the US to the UK's Alvey Programme and similar European government-sponsored responses to the "Japanese challenge", the rise of private-sector-initiated collaboration during the 1980s reflected a growing belief that "new tactics" were required to compete with Japan. Moreover, the principle of sharing research costs and uncertainties gradually permeated official policy making, leading to the rise of ventures such as Sematech which are US becoming established as legitimate industry support mechanisms for "keeping up" with leading Japanese firms. The principle of federal support for collaborative research in pursuit of competitiveness is also illustrated by the National Bureau of Standard's advanced Technology Programme. Although this only exists on a modest scale, it is nevertheless indicative of a new approach to policy formation.

6 Concluding Comments

Markets are very complex structures. Moreover, the nature and dimensions of complexity vary considerably between different national environments. While it could be argued that "national innovation systems" perform broadly similar basic functions in the sense that they translate technological knowledge into commercial products and production processes, there are considerable differences in the way in which different innovation systems perform these functions. In particular, substantial variations exist in the relationship between private firms, governments and bodies contributing to aspects of "public domain knowledge" that are relevant to technological development (eg universities and similar institutions).

The development of an effective IT capability by Japan's "national innovation system" was conditioned by a number of circumstances that were particular to Japan. Policies were initially directed towards creating economic "space" for the basis of a computer industry to be established in the face of an overbearing competitive treat posed by IBM. The use of US-style military procurement to assist in this objective was precluded by a post Second World War ban on defence-related exports. Since direct foreign investment ran against Japan's tradition of self-sufficiency, the relative status of collaboration was higher on the agenda of policy options than might otherwise have been the case. Even then, collaboration was only one of four basic policies. Moreover, the building of a "collaborative culture" did not occur in an instant but rather as the consequence of a gradual learning process, which took place over a series of projects. Strong competition between the firms was accompanied by a sometimes less than harmonious relationship between the industrial sector as a whole and the government. Attempts by MITI in the early-1970s to restructure the industry into a few "national champions" were strongly resisted by the firms and in the end did not take place. Thus, a drift towards monopoly which is generally restrained by legislation in the West (eg through

US Anti-Trust Laws etc) was constrained by the "natural" competitive instincts of Japanese firms.

Given the extent of competition between Japan's IT firms, it is perhaps appropriate to ask why initiatives such as the VLSI project were apparently so successful. In prospect, the firms were reluctant to participate in a venture that could compromise their independence. Yet the degree of government funding was high enough to mean that non-participation would place firms at a commercial disadvantage relative to participating firms. This commercial incentive was accentuated by the project's "near market" orientation. Although there was a central facility which provided for an environment for shared knowledge creation, this was mainly concerned with more basic research. The bulk of the project's commercially-oriented development work was organised on a more "modular" basis, enabling firms to internalise the benefits of government-sponsored research without compromising their competitive positions. Commercialisation of project outputs was helped by effective internal communication channels that exist between different sections within Japanese firms. Against the background of Japan's stable industrial structure, the project could be thought of as an example of the government providing a "balanced subsidy" to rival firms, rather than creating a mechanism for sharing the risks and uncertainties of research. These uncertainties were in any case already limited by the fact that the "window of commercial opportunity" for the technology had already been opened by leading US firms and the direction of technological development was well signposted.

Once Japan started to catch-up with the West, the position began to change. The clear target disappeared and it became more difficult to see how MITI could impose strategic direction on an industry that was subject to such a rapid pace of technological development, combined with turbulent changes in the structure of its associated markets. One dimension of MITI's response was a move towards collaborative basic research projects. The Fifth Generation Computer Systems Project was a major departure from the preceding applications-oriented ERAs. In some respects, it could be seen as an attempt to build a basic research component into an innovation system which did not have a strong tradition of links with university research. Its achievements have not been closely correlated to the evolving agenda of participating firms' commercial requirements and the translation of outputs into competitive advantage is likely to be an indirect process. Many aspects of the project's work have entered the public domain and have a status which is not altogether unlike that of academic work conducted in Western universities. The Real World Computing Programme is a further extension of the use of collaboration to promote inter-firm, "close to the public domain" basic research. In this respect, collaboration is being used to foster the development of a new research network.

Given the very particular nature of the circumstances under which collaborative research promoted the competitiveness of Japanese IT firms, it is perhaps hardly surprising that the West's attempts to use the concept as a means for matching the dynamism of the Japanese economy have not been without their problems. The expectation that the Alvey Programme could use pre-competitive collaborative research to match Japanese-style competitiveness asked more from collaborative research than had been achieved in Japan. It was the application-oriented ERAs organised on modular basis that were most closely associated with promoting industrial competitiveness. The Fifth Generation Project's use of shared knowledge creation was a radical departure from previous practice.

While problems with exploitation are likely to remain a problem for pre-competitive collaborative research programmes in any national environment, it does not necessarily follow that such initiatives are without value. New networks of the sort being pioneered in Japan's Real World Computing Programme were established with some considerable success under Alvey. These networking benefits are also a feature of pan-European initiatives and have also been exhibited by collaborative schemes in the US. Such networks are of special importance in national environments where there is scope to extend the role of public sector research in the national innovation system. Countries, like Britain and the US, which have a strong academic research in IT-related sectors have used cooperative research to consolidate their national knowledge bases. During the 1980s, Anti-Trust restrictions (which were eliminated from the Japanese environment in 1957) were relaxed in the US, thereby articulating a fundamentally new attitude to competition. Federally supported initiatives such as Sematech are also being commended to the Clinton Administration as policy as models for improving the national innovation systems. Trans-national links across Europe have also helped to unite disparate resources. However, the construction of these new communication infrastructures does not solve the problem of how best to proceed into the unknown territory of research-driven innovation. While they can provide an effective tool for supporting national and international knowledge creation, claims that they will automatically strengthen competitive performance should be treated with caution.

During the period when Japan's computer industry was catching-up with best practice Western technologies, the government's policies were often effective in minimising the effects of competitive disadvantages which confronted Japanese firms. Since the early-1980s, the Japanese government has faced the problem of producing policies that foster national competitive advantages. Governments in such a position are not usually well placed to "pick winners" and Japan's approach to supporting the IT industry now features a substantial element of basic research: thereby reflecting a long-established theme of policies practised in the West. Understanding future patterns of innovation will require a deep appreciation of how IT firms' organisational knowledge creation processes interact with evolving technological and market systems at national and international levels.

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