JAPAN'S USE OF COLLABORATIVE RESEARCH TO BUILD A COMPUTER INDUSTRY: LESSONS FOR THE UK?

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The announcement by Japan's Ministry of Trade and Industry in 1981 of its intention to use government-sponsored collaborative research to lead the world towards 'Fifth Generation' computing prompted a sudden enthusiasm for collaboration in Europe and the US. The UK was at the vanguard of this movement to 'learn from Japan' and used pre-competitive collaborative research as the central organizing theme of its Alvey Programme to strengthen the country's ability to compete in advanced information technology (IT). While Alvey produced a number of benefits, commercialization of research outputs fell short of popular Western perceptions of Japan's achievements. However, a review of MITI schemes prior to the Fifth Generation announcement reveals that, for the most part, they were neither pre-competitive nor collaborative. Moreover, problems with abstracting the operation of MITI's schemes from other aspects of Japan's national innovation system undermine their value as a model for UK policy.

Keywords: collaborative research, competitiveness, government policy, computer industry, information technology

INTRODUCTION

The processes that drive Japan's industrial development remain unclear to many Western observers. Japanese firms do not seem to be, in any obvious way, especially efficient or entrepreneurial, yet their growing impact on the global arena of competition has been staggering. One popular explanation for this increased competitiveness centers on the close relationship between government and industry. The widely used 'Japan Inc.' metaphor portrays the Ministry of International Trade and Industry (MITI) as the central headquarters of industrial policy in an integrated, monolithic system. While the extent to which this metaphor is appropriate has been the subject of debate,[1] there is a widely held view that MITI's use of collaborative research in Engineering Research Associations (ERAs) during the 1960s and 1970s was a key element in helping Japanese firms catch up with US and European computer technology.

The culmination of MITI's catch-up ERAs in the computer sector came with the apparent success of its 1976-80 government-sponsored collaborative program to

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allow five firms to develop Very Large Scale Integration (VLSI) technology. In the West, it seemed that MITI had somehow colluded with industry to enable rival firms to cooperate in horizontal collaborations that provided economies of scale in research and development. MITI's announcement, in 1981, that it was going to establish a ten-year collaborative program to pioneer so-called 'Fifth Generation Computing Systems' (FGCS) fueled Western concerns that collaboration was akin to a secret weapon that would enable Japan to lead the world into a new era of information technology (IT). There was a wave of Western counter measures amidst arguments that the time had to come to fight fire with fire by imitating Japanese-style collaboration in order to match Japan's improved competitiveness.[2] Yet, a closer consideration of Japan's innovation system and the historical evolution of MITI's computing ERAs suggests that the logic behind the West's sudden belief in the power of collaborative research reflects a misunderstanding of Japan's use of collaboration.

This paper reviews the development of MITI's computer ERAs within the context of Japan's national innovation system and uses the UK's Alvey Programme to develop advanced information technology through pre-competitive, collaborative research as a case-study of a high-profile policy to counter the threat of Japan's FGCS initiative.[3] Part of the argument draws on some 34 interviews, conducted in Japan during 1992-93, with policy makers, senior industrialists and researchers associated with MITI's collaborative research schemes.[4]

Alvey was a bold move to bolster competitiveness through the use of collaboration among industry, academia and government research establishments. It stimulated research that helped to bind together different sectors of the UK IT community through the development of informal communication networks. At the same time, it provided valuable education and training opportunities for researchers and helped to promote common IT standards. While these achievements alone might be taken as more than sufficient justification for the program, the fact remains that the original objective was to create a more competitive IT industry. The extent to which participating firms were able to translate Alvey research outputs into improved competitive advantage fell short of early expectations, perhaps revealing a natural consequence of pre-competitive research. The Alvey philosophy was to support unified collaborations, involving the joint creation of basic knowledge by different organizations (produced with a significant involvement by academics) that was not immediately relevant to a firm's ability to compete and was therefore pre-competitive.[5]

Whereas a long running dialogue between MITI and a small clientele of firms shaped the gradual evolution in the format of near market ERAs that led up to VLSI program, Alvey was an intrepid step towards a new kind of UK support policy. It had no less than three sponsoring government departments and involved 127 firms, together with 74 universities and polytechnics, working in a total of 192 collaborative projects (as well as 117 projects in which academics worked under the supervision of an industrial 'uncle'). On average, projects lasted for 3 years and included a total of three or four industrial and academic organizations. Pre-competitive collaboration involves huge amounts of time and effort to realize an objective that, by its very definition, is still too far from market to make a direct contribution to competitiveness. Although the subsequent Information Engineering Advanced Technology Programme (IEATP) placed less stress on pre-competitive research, it retained Alvey's philosophy of attempting to interweave strands of academic and industrial research.

This paper has three key themes. First, Alvey pioneered a form of collaboration that is much more complicated than the mechanisms used in MITI's more successful computer ERAs. In common with earlier computer ERAs, the VLSI program was a largely modular collaboration between a small number of industrial companies. A long-term dialogue among industry, the bureaucracy and government helped to shape the gradual development of these schemes as part of broader policies to help Japan catch-up with best practice Western technology. Japan's national innovation system was a crucial element in both the design and practical operation of the ERAs. Imitating Japanese style collaboration without appropriate regard to the characteristics of Japan's national innovation system is likely to be problematic.

The paper's second theme is that there has been an important shift in emphasis in the Japanese system's approach to basic research following the end of the catch-up era. When MITI was orchestrating schemes to follow the US and European lead in computer technology, it was feasible to minimize diversity within the Japanese system in order to make more rapid progress down the trail blazed by leading Western firms. After catch-up, it was more difficult for MITI to produce support policies that would be of direct benefit to Japanese firms. In many areas, Japanese firms stood on the frontier of international best practice technology and were better placed than MITI to make judgments about potentially rewarding avenues of technological development. Consequently, FGCS marked the birth of a new type of ERA directed towards basic research and unified collaboration. But since Japan did not have a track record in either area, it seems unrealistic to emulate the effects of the VLSI program by imitating objectives associated with the FGCS project.

The third theme of the paper is that Japanese and UK expectations about the nature and benefit of collaborative schemes moved in opposite directions after the early-1980s. For example, MITI's launch in 1992 of its Real World Computing initiative aimed to realize basic research objectives. Emphasis is on a style of knowledge sharing that appears to be redolent of Alvey, but without expectations of paving a direct route to improved competitiveness. In contrast, the UK's IEATP tried to place more weight on exploitation. Moreover, subsequent UK government policy has stressed wealth creation as a means of learning from Japan by channeling scarce resources towards areas that will generate the best economic and social benefits.

The paper approaches the above themes by considering ways in which Japan's national innovation system has been relevant to MITI's practical development and execution of computer ERAs. Next, it presents a historical review of MITI's computer ERAs and then contrasts this with the UK's response to the challenge of Japan's FGCS program. On the basis of these cases, the paper assesses some of the limitations of collaboration and identifies problems associated with 'learning from Japan.'

JAPAN'S NATIONAL INNOVATION SYSTEM

This section deals with four aspects of Japan's innovation system that relate to MITI's design and implementation of its computer ERAs. The first point concerns precedents that have helped to justify government intervention as a legitimate component in the innovation system. The next two subsections look at the application environment for government policies, which simultaneously features a stable framework of actors and a coordination mechanism that is capable of 'electrifying' this framework with powerful dialogue among different sectional interests. Switching to a slightly different tack, the fourth point considers the Japanese education system's bias towards engineering and applied technology rather than science. While the UK might have largely failed to develop effective bridging mechanisms between its prowess in basic research and economic development,[6] the need to integrate basic and applied research efforts has not been a significant issue in Japan's application-oriented innovation environment.

1 Government Involvement in Economic Development

Many aspects of Japan's industrialization embody an approach different from that of the UK's national innovation system. During the Industrial Revolution, the UK led the world into a new era of manufacturing. Firms sought to gain a competitive advantage over their rivals, stimulating technological innovation in a search for ever more advantageous production processes and products that better met evolving consumer requirements. Schumpeter's famous metaphor, in which he talks of gales of 'creative destruction,' describes the phenomenon whereby new industries surge forth at the expense of activities that are less relevant to prevailing patterns of demand.[7] During the nineteenth century, the UK state took on regulatory functions in the interest of maintaining competition but, it had little to do with the selection of new forms of economic activity.

On the other hand, Japan's industrialization features a long history of pragmatic government intervention to acquire and develop foreign technologies. This process was not so much creative destruction since the creativity and the selection of winning technologies took place largely in the battleground of Western economies, but rather the steady improvement of promising avenues of development, with an emphasis on assimilation rather than revolution. Following Japan's long period of seclusion from the outside world (1639-1854), the fear of colonization helped to establish the principle of the state acting to manage the market economy, especially in industries concerned with military technologies.

The 1868 Meiji Restoration and the creation of a non-feudal central government in Tokyo marked the inauguration of a number of policies to import foreign organizational systems and technologies. Wolferen has noted: "As Meiji industrialization took off, government control over the economy became automatic, since the government either put up the capital itself or encouraged private investors to do so by according them protection."[8] Catch-up development involved building a window on Western technology and devising methods for establishing that expertise inside Japan.

The Japanese state assumed what Johnson has described as 'developmental functions' in which it took an active role in steering the drive towards industrialization and, in the process, forged a rather different type of relationship with industry than that in regulatory states like Britain.[9] Helped by a large internal market, the government has been able to act in concert with industry to seed a number of key technologies and nurture their development: for example, through subsidies and protection from foreign competition.

2 A Stable Industrial Structure

Japan's interlocking system of company ownership affords firms a degree of stability when it comes to taking a long-term view of technological development. Compared with the UK, a larger proportion of Japanese company directors tend to come from production and technology departments. Many of the large shareholders in established Japanese companies are banks and other organisations that are friendly to the firm, and reciprocal share holdings help this relationship.[10] Mergers tend to be much less common than in the UK, while expectations of lifelong employment mitigate against the formation of spin-off companies.

Individuals typically build careers within the confines of an organization, providing a considerable incentive for management to invest time in training. This often includes rotation between job functions, providing an opportunity to build a tacit understanding of different activities that stretch across the organization. Long hours coupled with out of hours socialization, such as spending the evening relaxing with colleagues, going on company outings at weekends, and so on, all help to build social bonds and lubricate information flows within the organization.

The social networks that overlay Japanese company culture provide considerable scope for the type of shared experiences that encourage high levels of trust. When a project moves from the R&D department to production and sales departments, it is quite common for members of the project team to move with it, thereby taking the project to market rugby style, with members of the team moving forward together. By contrast, the segmented approach to innovation that can often found in UK companies is perhaps more like a relay race, with the baton being passed from department to department. While this might avoid the dangers of non-creative group think, there is always the danger of dropping the baton in transit![11]

In a number of revealing insights into the Japanese knowledge creating system, Nonaka has suggested that, by Western standards, much of the glue (the form of shared tacit knowledge) that holds the Japanese innovation system together might be redundant information.[12] Western organizations often use manuals to codify information and official procedures that specify responsibilities and obligations, thereby saving the enormous time commitment required to intrude into the activities of colleagues to share their aspirations and problems. Nevertheless, on occasions, apparently redundant information can be invaluable in providing scope to re-configure problems, thereby overcoming difficulties and moving towards solutions. All this helps to keep the baton of innovation from falling to the ground.

The relative stability of Japan's leading industrial firms provides anchor points for informal communication networks that cut across industry, policy making and government, thereby helping to avoid what Walker has called 'problems of coordination' in the UK system.[13] Typically these occur in producer-user relations, managerial links between engineering design and marketing, and in relationships between banks and industry. Against the background of stability on the government side (with the Liberal Democratic Party holding power from 1955 to 1992), MITI achieved considerable scope for cultivating its spheres of influence. In the case of the computer industry, MITI has dealt with the same small clientele of firms, frequently playing the role of an honest broker that seeks to advance competition within Japan, while trying to keep all the major players in the international game.

3 A Coordinated System

Macdonald has pointed out that: "In the rush to emulate Japanese cooperation, it is often forgotten that this is supported by less formal links among Japanese firms and by informal information networks."[14] Many dimensions of Japan's 'system' depend to some considerable extent on informal networks that create a framework for communication that is both extensive and robust. This network is energized by active rivalry between firms and between different government ministries, providing a forum for vigorous debate, but also constraining radical shifts in policy — in much the same way as drag chains restrain the launching of a big ship. A spread of power across the network provides a system of checks and balances that make it difficult for any one party to gain the upper hand. The system involves many interacting spheres of influence that create scope to change unacceptable policies by applying pressure from many different angles.

Japan's industrial policy tends to evolve in an incremental manner with gradual shifts in emphasis. Within this structure MITI has been able to develop some considerable ability to exert influence over industry. For its part, industry can also bring pressure to bear on MITI; for example, through links with politicians that are in a position to influence the bureaucracy.[15] These respective spheres of influence have helped to create consistent policy that has emerged from continuing cycles of (frequently vigorous) debate and compromise, gradually building on the experiences of past successes and failures.

4 Engineering Before Science

A feature that would-be imitators of Japanese collaboration sometimes overlook is that Japan's economic miracle has generally owed very little to basic science and creative research. Industry is responsible for the majority of Japan's high overall expenditure on R&D. Even though industry is increasingly stressing the need for more basic research, in reality it directs the bulk of its spending towards applied development projects.

The education system's ability to generate large numbers of extremely well informed engineers and technicians, but relatively few science graduates, distinguishes Japan from the US and leading European nations. This has helped to nurture Japan's established strengths in manufacturing process technologies, product reliability and flexible design, thereby supporting high-speed economic development.

Japan's combined total of bachelor and master level degrees in engineering in 1990 was 86,115 compared with only 14,217 in science – a ratio of 6:1 in favor of engineering! The picture in the UK is very different. Despite having less than half the population of Japan, it still produces significantly more science graduates (21,900 in 1988). The number of UK engineering graduates in 1988 was only 15,200.[16]

Compared with leading European and US university systems, Japanese higher education places limited emphasis on research and the quality of teaching. Rather, the ranking of Japanese universities depends on the difficulty of their entrance examinations, and the extent to which top companies hire their graduates. Top companies prefer to hire bachelor or masters level graduates from the most prestigious institutions and put them through in-house training programs. In this respect, firms believe that an early appreciation of the company culture is far more important than the development of the individual's pursuit of creative research. Bright students are reluctant to jeopardize their chances of a good permanent position by pursuing doctoral research. (Japanese society generally emphasizes group norms over individual creativity, as illustrated in the often-quoted Japanese proverb: "The nail that sticks out gets hammered down.") In 1989, Japan produced only 1,774 engineering PhDs, while the number of science doctorates was a mere 876. During 1988, the UK, produced 4,500 PhDs in engineering and 7,200 in science.

A Consensus-based system?

Western impressions of Japan's propensity for consensus can provide fertile soil for over-generalization. Commentators often link Japan's image as an integrated island nation — dominated by a single race, secluded for a long period from the outside world, using a unique language, and bound together by a social system that emphasizes conformity — to the idea that cooperation is somehow inherent to Japanese culture. But though notions of a national spirit might provide a rallying cry for organizing concerted action at the national level (especially in response to pressure from abroad), Japanese society embraces fierce rivalries among different interest groups, companies and government industries. Such rivalries provide a consistent theme in the historical evolution of MITI's computer ERAs.

THE CHANGING ROLE OF MITI'S COMPUTER ERAS

Western preoccupation with collaborative research often obscures the fact that it has been only one of several policies to support Japan's development of a computer industry. Anchordoguy has identified four types of support initiatives[17]:

- protectionist regulation;
- heavy subsidies;
- the establishment of a national company to rent domestically produced computers to Japanese users at very favorable rates, and;
- cooperative R&D projects.

MITI's first step towards building a computer industry was to impose controls on computer-related foreign investment in Japan and to restrict imports.[18] Its foundation of the Japan Electronic Computer Company (JECC) in 1961 provided an effective policy that linked support for supply-side innovation with evolving market requirements. At a time when users tended to rent rather than buy computers, JECC bought systems from Japanese suppliers and rented them to domestic firms at subsidized rates. This gave vendors a prompt return on their investment and channeled the bulk of support towards the more efficient firms. In addition, the JECC also provided interest free loans to encourage improvements.

Yet, cooperative R&D schemes are what has captured the West's attention. (Paradoxically, Japan developed the idea of ERAs from Britain's system of Industrial Research Associations.[19]) MITI launched its first computer ERA — the Computer Basic Technology Research Association — in 1962 as a four-year venture to help Japanese manufacturers build a machine that could compete with IBM's 1401 series. Fujitsu, NEC and Oki cooperated on a modular basis with 50 per cent funding from MITI. However, IBM's launch of its 360 series overshadowed the project's outputs.

MITI responded with an ERA to develop a Very High Speed Computer System (VHSCS), which stretched over a six-year period, starting in 1966, and included all six major manufacturers (Fujitsu, NEC, Hitachi, Oki Electric, Mitsubishi Electric and Toshiba). Like its predecessor, the project's organization was modular, with little inter-firm knowledge creation. None of the 39 patents produced involved more than one company.[20] The project achieved most of its technical objectives, but failed to close the gap with IBM, which had widened following the 1971 introduction of its 370 series.

MITI sought to strengthen the Japanese industry by promising substantial financial assistance if the six major firms agreed to some form of rationalization into two or three groups. The firms opposed the idea and MITI eventually opted for another ERA. As it happened, the 1972-76 New Series Project proved to be a turning point, enabling the Japanese producers to divide the market and, collectively, provide a challenge to IBM. It was the first project to aim at IBM-compatible products and half of the 140 billion yen budget came from the government. The project was instrumental in enabling Japanese firms to match the performance characteristics of the IBM 370 series at competitive prices.

The famous 1976-80 VLSI project helped to consolidate Japan's position. It cost 72 billion yen, 30 billion of which came from the government. The project included five of the big six firms. It excluded Oki, which had failed to exploit outputs from the New Series Project and was struggling with severe financial problems. Although MITI insisted on having a cooperative laboratory (located on a single site with researchers from all five companies), its work concentrated on common basic technologies that accounted for only a minor proportion of the project's overall research activities.[21] The main part of the project concentrated on applied development, undertaken on a largely modular basis by the individual companies, and led to more immediate commercial exploitation. Okimoto has commented on a tendency to exaggerate the value of Japan's national research:

> 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 (e.g., silicon crystal growth and processing), Japanese companies probably would have made such advances anyway. If so, the project's main achievement may have been to hasten the timetable of development, a non-trivial but hardly revolutionary accomplishment. [22]

Although the firms were initially reluctant to participate in any venture that might compromise their competitive advantages, the opportunity to speed-up their VLSI research efforts subsequently persuaded them to participate. As Odagiri has pointed out, much of the success of the project was due to the presence of an enormous competitive threat from IBM.[23] The VLSI project provided a mechanism for firms to increase the speed with which they could pursue market-oriented agendas of technological development and catch-up with their Western competitors.

In the words of Irving Berlin, "the toughest thing about success is that you have to keep on being a success." The conclusion of the catch-up phase undermined the extent to which MITI could pursue its established pattern of support policies. Thus the FGCS stands out as an unblushing move to capitalize on the momentum of catch-up policies and thereby project an image of Japan leading the world towards a new generation of computing. The announcement of this plan, at an international conference held in Tokyo in 1981, caused shock waves of concern to reverberate around the international IT community. Although Japan invited foreign organizations to participate in the FGCS project, the eventual outcome was an all Japanese effort. One British academic commented that collaborating with Japan in this area would be rather like "collaborating with a vacuum cleaner,"[24] thereby expressing a concern that Japan considered itself to be self-sufficient in hardware and was now seeking to acquire expertise in artificial intelligence. Western attention instead focused on how best to outflank Japanese efforts. For example, UK delegates to the 1981 Tokyo conference concluded that one of the most significant benefits to arise from their visit lay in the lessons learned about the way in which Japan was organizing IT developments for the 1990s. "In many important respects the Japanese approach to organizing IT developments for the 1990s could be taken as a model for what any country would need to do if it was to be credible and competitive in IT over the next ten years or so."[25]

The organization of the FGCS project was very different from MITI's previous ERAs. A substantial component of the project centered on a single laboratory, where members of participating firms would work together to realize the project's objectives. This was in sharp conflict with the competitive instincts of the Japanese firms, who generally did not share a Western faith in the the project. Cusumano has suggested that, of the participating firms, only the company that agreed to produce the hardware showed any enthusiasm for the project.[26] While this might have been apprehension about the role of the central research facility, a more important factor was perhaps the risky nature of the project and the fact that it seemed to have no immediate commercial applications.

The budget for the ten-year project was 54 billion yen. According to MITI's original plan, it expected participating firms to provide 50 per cent of the project budget. In the event, all the funding came from government and the industrial contribution involved sending researchers to the central laboratory. A total of eight firms participated, with consumer electronics giants Matsushita and Sharp joining the six participants of previous computer ERAs.

The selection of appropriate criteria for assessing the FGCS project's achievements is difficult because the publicity at the beginning of the project led to unrealistic expectations. A divergence between the project's rigid agenda and the emerging research interests of participating firms overshadowed research achievements.[27] As the project drew to a close, a report in *Nature* commented that "By the mid-1980s, it was clear that other approaches to parallel computing not based on artificial intelligence techniques, such as neural networks or the massively parallel machines created by Thinking Machines Inc. of the United States looked more promising."[28] But the project could not adjust. Nikkei Business reported that there had been growing tensions between the government and firms as technologies not covered by the project proved to be of greater significance than expected.[29]. It suggested that, from the firms' point of view, the value of national projects ended with the catch-up phase of Japan's technological development. Other observers argue that, ultimately, the greatest benefit of the project might lie in the personal experience gained by the individual researchers. During its first 10 years, a total of 184 young researchers — all under 35 — had experience of working on the FGCS project.[30]

MITI launched the successor Real World Computing Program (1992-2002) as an effort in fundamental research. Its objective is to develop a flexible information system with an intuitive information processing capacity that is similar to that of human beings. Research spans five themes: theoretical foundations relating to the representation of information; novel functions involving the integration of pattern processing and signal processing methods; self-learning neural systems; massively parallel systems; and optical systems. By 1994, the project had initiated research at MITI's Electrotechnical Laboratory with a partnership including 16 Japanese firms[31] as well as four foreign research institutions.[32] Hajime Irisawa, who is a former MITI official and executive director of the program, has described it as "very basic" commenting that there was no intention of building even a prototype computer.[33] Furthermore, the project features a mid-term review to appraise progress and select the more promising technologies for future development. MITI plans to provide 90 per cent of the total budget, estimated at 60 million yen over 10 years.

The history of MITI's computing ERAs reveals the dividing line between modular near market initiatives, which culminated in the VLSI program, and a subsequent switch to basic research. For example, in comments that relate to near market initiatives, Anchordoguy has observed that:

> Cooperative R&D conjures up images of members of different firms working together on the same problem. While this did happen 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 the results.[34]

The modular nature of MITI's application-oriented ERAs, and the contrasting image of the FGCS project, were interpreted rather differently in the UK's Alvey Programme.

BRITAIN'S RESPONSE: THE ALVEY PROGRAMME

While Western governments have long recognized that a competitive market economy is likely to under invest in technologies that depend on the creation of new knowledge, past policies to correct this failure of the market often exhibited distinctly hands off qualities. For example, government might support basic research without making any effort to influence subsequent economic or technological developments. However, the Alvey Programme marked a more hands-on approach to policy-making. Launched in 1983 as the first stage in a ten year plan (but, in the event, funded for only five years), it aimed to generate the image of improved competitiveness that had followed in the wake of MITI's VLSI program.

Government funds for the project came from the Department of Trade and Industry, the Ministry of Defence, and the Science and Engineering Research Council (SERC). A special Alvey Directorate, staffed by representatives of the sponsoring departments as well as by industry and academia, was formed to run the program. The total budget was £350 million, £200 million of which came from the three government agencies, with industry providing the balance. Industrial participants received 50 per cent of their costs, while academics were funded in full by the SERC.

For the most part, there was an expectation that knowledge would be transferred across organizational boundaries, thereby forming a basis for unified (as opposed to modular) research. Alvey projects covered a wide spectrum of IT technologies, which included VLSI, software engineering, intelligent knowledge-based systems and man-machine interfaces. In total, more than 5,000 people were involved with the implementation of Alvey research projects, frequently covering areas where Japanese collaborative research had been less than successful. For example, despite a number of MITI ERAs in software engineering, Japan continued to lag behind international best practice in this area. While specific projects suffered from different problems, Cusumano notes that there were some common problems which occurred in projects completed in the period before 1990. These included "poor planning, disagreements on objectives and poor results."[35]

In contrast to the relatively stable, long-term, government-industry dialogue that characterized MITI's more successful modular computer ERAs, Alvey projects aimed to build instant knowledge-sharing collaborations that spanned industry, academia and, in some cases, government research establishments. Moreover, this pre-competitive approach to supporting competitiveness was often set in the context of a turbulent industrial environment. Mergers and takeovers that occurred during the life of the program could easily disrupt collaborative groupings. The potential relevance of a project often diminished during the time taken to assemble a project consortium, agree on a research agenda, receive official approval for support, and complete the actual work program. In a number of cases, exploitation failed to take place because key partners withdrew from the project. Problems with flexibility were frequently compounded by the need to gain official approval for any significant project restructuring. On other occasions, shifting business strategies interrupted the relay race style transfer of projects from the laboratory to the market. While project team members working in industrial research laboratories might remain thoroughly committed to the project and were keen to pass on the baton of project achievements for development, there were instances where senior management had independent thoughts about the wisdom of competing in a particular race.

An independent evaluation of the Alvey Programme concluded that pre-competitive R&D programs are well-suited to a range of tasks, but are not in themselves sufficient to bolster competitive performance. Complementary private sector and government sector initiatives are needed to relate IT development to users, and to promote effort within firms to formulate strategies to facilitate the exploitation of research. Furthermore, there was a need for a serious re-evaluation of the need for patient capital.[36]

POST-ALVEY COLLABORATION IN THE UK

Even though Alvey did not appear to be an entirely satisfactory solution to the problem of revitalizing the UK IT industry, collaboration formed the backbone of the successor Information Engineering Advanced Technology Program (IEATP). This retained a broadly similar structure to Alvey, but funding was much more modest. The budget was about £100 million, half of which came from the DTI and SERC, with industry providing the balance.

To a large extent, IEATP suffered from many of Alvey's difficulties with collaboration and exploitation, although it differed from its predecessor. In recognition of the role that entrepreneurial small firms can play in providing a source of innovation, IEATP targeted small and medium sized enterprises (SMEs) and attracted 85 such organizations to the program. To compensate for one of the limitations of Alvey, IEATP placed more emphasis on work that was likely to lead directly to commercial fruition. It also tried to increase the level of user involvement in the program. Priority was given to collaborative groupings that included a user firm, a product-focused small firm to drive R&D towards exploitation, and an academic institution to provide a creative input. Nevertheless, the program failed to solicit significant participation from the wide range of IT user companies in the UK.

A new direction for IT support policies came with the publication of the UK government's 1993 White Paper on Science and Technology.[37] Support for national collaborative research was largely withdrawn in favor of policies to revitalize "wealth creation" through "fostering the climate for innovation," developing access to technical help and facilitating technology transfer. Some support for technology development was retained, but this was to be focused on near market R&D and restricted to SMEs. Firms seeking support for collaborative research were directed towards pan-European schemes.

The White Paper also advocated the use of Technological Foresight as a central plank of the UK's future science and technology policy. This foresight exercise aims to identify generic technologies that are likely to yield the greatest economic and social benefits to the UK in the long term. The argument is that Foresight can inform decisions by government, industry, research councils and academia on R&D priorities and underlying skill needs.[38] The UK's problem is perceived to be not the quality of its science and technology, but a relative weakness in exploiting them to economic advantage.[39] In this context, the decision to pursue Foresight has followed an examination of overseas experiences, with Japan being one of three countries selected for special attention.[40] Even though various Japanese institutions conduct exercises to generate scenarios about future developments in science and technology, these are but one of many influences in a complex dialogue between government, the bureaucracy and industry. Moreover, basic research has not traditionally been a major factor in the technological success of Japan's innovation system. Consequently, it hardly seems appropriate to use the Japanese experience as a model for directing the UK's strengths in basic science towards the generation of improved industrial competitiveness.

WHY COLLABORATE?

Following MITI's announcement of its FGCS program, collaboration suddenly became fashionable in Europe and the US. One prominent illustration of this trend was the 1984 launch of the first European Strategic Programme for Research in Information Technology (ESPRIT), which included pan-European collaborative research in microelectronics, computer integrated manufacturing, and advanced IT systems for business and the home. Subsequently, cooperative research emerged as an important element of the European policies of support for industry. In the US, the formation of the Microelectronics and Computer Technology Corporation in 1982, a research centre that was jointly funded by a number of private firms, spearheaded a relaxation of the country's strict Anti-Trust Laws.[41] This paved the way for further collaborative ventures, such as the formation of Sematech in 1987, a venture funded by the Department of Defence to enable US firms to conduct joint research in the manufacture of semiconductor devices.

The West's new-found enthusiasm for collaboration in the 1980s was remarkable because it flew in the face of prevailing attitudes to inter-organizational knowledge creation. Although existing forms of collaboration, such as industrial research associations, have often been thought to be worthy, their activities have been described as "hardly more exciting than the work of the local Post Office".[42] In a limited range of circumstances, collaboration might be expedient; for example, to divide the cost of expensive research facilities or to share knowledge about new technologies of unclear commercial potential. However, it was always an unlikely basis for mounting a counter challenge to increased Japanese competitiveness. While collaboration might avoid commercial sensitivities at the basic end of the research spectrum, it tends to be more problematic in near-market ventures and the sheer effort required to implement effective collaborative ventures tends to make them a choice of last resort.

Collaboration to create knowledge across organizational boundaries has to overcome concerns about partners taking a free ride. Mutual distrust can prevent the disclosure of potentially useful information and thereby compromise efficiency. By their very nature, collaborations are built in a kind of no man's land between organizations. While the individuals involved have obligations to the collaboration, they also have loyalties to their parent organization. Building stable collaborations between committed participants consumes considerable resources and, on occasions, maintaining stability can become more prominent than progress towards intended objectives.

At an informal level, knowledge creating networks, based on personal trust between individuals, frequently span organizational boundaries and work effectively to the mutual benefit of those involved. However, establishing this form of mutual understanding on a formal basis, between individuals who might not otherwise have worked together, can be challenging. In consequence, a sustained commitment to collaboration by top management is generally an important factor in making it legitimate in the eyes of the individuals involved. The more effective formal collaborations tend to be between organizations in which top management can articulate clear motivation for making the collaboration work and thereby transmit a sense of purpose to the individuals responsible for its implementation. While this might exist in 'natural' collaborations (for example, between a supplier and a customer, or firms dealing in complementary technologies), it can be much more difficult to manufacture this type of commitment to fit with the rules and conditions for receiving government funding. This is especially true when government initiatives strive to support the counter-competitive notion of horizontal collaborations between rival firms.

While MITI's computer ERAs of the 1960s and 1970s might be seen as offending against the logic of a 'natural' collaboration, they overcame this problem by operating on a largely non-collaborative basis. Catching up with the West gave individual firms a very clear sense of purpose, helping them to exploit traditional strengths in applied development and using rugby style approaches to technological development. Closing the gap with the West was a powerful focus for top management and researchers alike, while privileged access to users in the protected Japanese domestic market gave a valuable breathing space during the struggle to catch up. All of this is in sharp contrast to European Community collaborative programs, where, according to Georghiou and Metcalfe, there can be problems with the diffusion of knowledge from those performing R&D to those in a position to apply it to new or improved products or processes. These include lack of "commitment of senior management, lack of a skilled user base able to take up the results, lack of interchange of personnel and lack of an initial exploitation strategy for the project. This area is not well understood but is clearly of great importance."[43]

In building an understanding of these issues, it might be that the time has come to re-assess the limitations of collaboration as a policy support mechanism for promoting competitiveness.

CONCLUSION

In many ways, Western perceptions of the processes that drive the Japanese innovation system suffer from the problems of trying to look through a two-way mirror from the wrong side. Japan has built an effective window on the outside world with many Japanese spending extended periods studying abroad, but Westerners frequently see little when they try to look into the Japanese system. Even when certain aspects of the Japanese system appear to be clearly visible, these views are sometimes little more than slightly imperfect reflections of the observer's previous assumptions. While it might have been tempting to conclude that the apparent success of MITI's VLSI program held lessons for the UK, it is difficult to abstract the idea of Japanese-style collaboration from factors associated with the evolution of the country's industrial innovation system.

Japan has a long history of government intervention in the structural development of the economy, a relatively stable industrial structure, and a complex network of coordination systems. MITI's use of collaborative research in its computer ERAs during the 1960s and 1970s was only one of several industry support measures designed to help the infant Japanese industry. Protected markets, heavy subsidies and bridging schemes between suppliers and users, were also important elements in the equation. In contrast, Alvey supported only collaborative research: combining novelty with complexity. It was a sudden switch towards to a more hands on policy by the UK government, aiming to pursue unified research collaborations spanning industry and academia. The Alvey Programme sought a type of knowledge creation that was far more complex than that sought by MITI's modular ERAs.

Alvey's use of academic research highlights a further difference between the Japanese and UK innovation systems. Japan's university system emphasizes teaching over research and produces large numbers of technologists and engineers rather than scientists, and very few PhDs. In this respect, the UK, which produces about eight times more science doctorates than Japan every year, has an important national asset that has not been a main feature in Japan's management of its national innovation system

Japan's position at the forefront of a number of areas of technological development has presented it with new challenges, which include addressing the role of creative research in supporting future patterns of technological development. Some critics argue that the very cultural homogeneity and lack of appreciation of the benefits of variety that helped to fuel Japan's economic miracle are in danger of becoming a singular disadvantage that will detract from the ability of Japanese firms to use research driven innovation to compete on a global basis. The FGCS project revealed some of the problems of over-ambitious expectations. Nevertheless, MITI appears to have learned from the experience and its Real World Computing Program highlights modest objectives that, in some ways, have more in common with what might be seen as the incidental benefits of Alvey (such as the development of research networks, training opportunities for researchers, and so on).

At a time when Japan is showing signs of trying to emulate Western strengths in basic research and creativity by moving towards the generation of increased scientific and technological variety, UK policy appears to be going in a rather different direction in the sense that wealth creation involves greater selectivity. Although the Japanese example has been cited in support of both Alvey-style collaboration and, more recently, technology foresight, it can be argued that important differences in national innovation systems make Japan an unsuitable model for UK policy in these areas.

NOTES AND REFERENCES

1 Wolferen argues that the metaphor is misleading because "Japan has nothing comparable to a chairman of the board, a president or even a board of directors as a means of providing a unified view on which to base decisions." K. van Wolferen , *The Enigma of Japanese Power: People and Politics in a Stateless Nation*, Macmillan, London, 1990, p.58. Also, Hart has noted that there is some dispute within the small group of scholars who write seriously about Japan as to whether the state is central or peripheral to Japan's economic development. J. A. Hart, *Rival Capitalists: International Competitiveness in the United States, Japan and Western Europe*, Cornell University Press, New York, 1992, p.37.

2 According to Ferné, some 20 other national programs followed the announcement of Japan's FGCS program. G. Ferné, 'R&D programmes for information technology', *OECD Observer*, August/ September, 1989, pp.10-13.

3 The authors were members of a team which evaluated the structure and organisation of both the Alvey Programme and the subsequent Information Engineering Advanced Technology Programme. The views expressed here are entirely their own.

4 These interviews were conducted by Ray as part of a Science and Technology Agency Fellowship spent at the National Institute of Science and Technology Policy (NISTEP), Tokyo, Japan.

5 Macdonald has questioned the meaning of 'pre-competitive' research, suggesting that there are no parts of a firm's activities — and certainly not R&D — that are totally removed from the need to compete. S. Macdonald, 'Formal collaboration and informal information flow', *International Journal of Technology Management*, 7, 1/3, pp.49-60.

6 W. Walker, 'National innovation systems' in R. Nelson (ed.), *National Innovation Systems*, Oxford University Press, Oxford, 1993, p.180. Walker quotes medical research, pharmaceuticals and the National Health Service as examples of successful integration.

7 J. Schumpeter, *Capitalism, Socialism and Democracy*, Unwin, London, 1943, chapter 7.

8 van Wolferen, *op cit.*, pp.492-3.

9 C. Johnson, *MITI and the Japanese Miracle: The Growth of Industrial Policy 1925-1975*, Stanford University Press, Stanford, 1982, chapter 1.

10 H. Odagiri and A. Goto, 'The Japanese System of Innovation: Past, Present and Future' in R. Nelson (ed.), *op. cit.*, 1993, p.106.

11 I. Nonaka and T. Ray, *Knowledge Creation in Japanese Firms*, Research Report 34, National Institute of Science and Technology Policy Science and Technology Agency, Japan, 1993.

12 I. Nonaka, 'Redundant, overlapping organization: a Japanese approach to managing the innovation process', *California Management Review*, 32, 3, 1990, pp.27-38. See also I. Nonaka, 'Creating organizational order out of chaos: self-renewal in Japanese firms', *California Management Review*, 30, 3, 1988, pp.57-73; and *idem*, 'Toward middle-up-down management: accelerating information creation', *Sloan Management Review*, 29, 3, 1988, pp.9-18.

13 Walker, op cit., pp.180-2.

14 Macdonald, *op cit.*, p.52.

15 van Wolferen, *op cit.*, p.165.

16 Original data were supplied by the Japanese Ministry of Education, Science and Culture (Monbusho), and made available to the authors by A. Arima, President, RIKEN, Wako-shi, Saitama, 351-01, Japan. Arima the data are also used A. Arima, 'Daigaku kaikaku no igi' ['The significance of university reforms'], *Hiroshima Daigaku Foramu* [*Hiroshima University Forum*], 26, 10, 1994, pp.10-13.

17 M. Anchordoguy, *Computers Inc.: Japan's Challenge to IBM*, Harvard University Press, Cambridge, Mass., 1989, p.15.

18 M. Fransman, *The Market and Beyond: Cooperation and Competition in Information Technology in the Japanese System*, Cambridge University Press, Cambridge, 1990, p. 27.

19 J. D. Levy and R. J. Samuels, *Institutions and Innovations: Research Collaboration as Technological Strategy in Japan*, Department of Political Science, Massachusetts Institute of Technology, Cambridge, Mass., 1989, p.31.

20 Fransman, *op cit.*, p.34.

21 D. Okimoto, T. Sugano, and F. Weinstein, *Competitive Edge: the Semiconductor industry in the USA and Japan*, Stanford University Press, Stanford, 1984, p.19.

22 D. Okimoto, 'The Japanese challenge in high technology' in National Academy of Sciences, *The Positive Sum Strategy: Harnessing Technology for Economic Growth*, National Academy Press, Washington DC, 1986, p.561.

23 H. Odagiri, 'Government policy toward industrial R&D: theory, empirical findings, and Japan's experience', *Policies on Industrial R&D*, 1989, pp.211-26.

24 B. Oakley and K. Owen, *Alvey: Britain's Strategic Computing Initiative*, MIT Press, Cambridge, Mass., 1989, p.17.

25 *ibid*, p.25.

26 M. Cusumano, *Japan's Software Factories: A Challenge to US Management*, Oxford University Press, Oxford, 1992, p.411.

27 'Japan's 'fifth generation' computer development project comes to an end', *Washington Post*, 2 June 1992.

28 D. Swinbanks and C. Anderson, 'Japan stubs its toes on fifth-generation computer', *Nature*, 26 March 1992, p.273.

29 'Koo-ryoku ushinau kanmin kyodoo kai-hatsu' ['Government-public development (projects) are losing their effectiveness'], *Nikkei Business*, 19 June 1992, pp.20-1.

30 M. Cross, 'Farewell to computing's fifth generation', *New Scientist*, 13 June 1992, pp.12-13.

31 Fujikura, Fujitsu, Furukawa, Hitachi, Japan Iron and Steel Federation, Matsushita, Mitsubishi Electric, Mitsubishi Research, NEC, NTT, Oki, Sanyo, Sharp, Sumitomo Electric, and Toshiba.

32 Gesellschaft fur Mathematik und Datenevarbeitung mbH(GMD), Institute of Systems and Science, National University of Singapore, Stiching Neurale Netwerke, and the Swedish Institute of Computer Science.

33 'Real world computing: a brave new world', *Tokyo Business*, March 1993, p.3.

34 Anchordoguy, *op cit.*, p.43.

35 Cusumano, *op cit.*, p.389.

36 K. Guy, L. Georghiou, P. Quintus, M. Hobday, H. Cameron, T. Ray, *Evaluation of the Alvey Programme for Advanced Information Technology*, HMSO, London, 1991, p.vii.

37 *Realising Our Potential: A Strategy for Science, Engineering and Technology*, HMSO, London, 1993.

38 *UK Technology Foresight*, Parliamentary Office of Science and Technology, London, January 1994, p.1.

39 W. Waldegrave, 'Launch of government's technology foresight programme,' *Foresight: Newsletter of the Technology Foresight Programme*, 1, Spring 1994, p.1.

40 *UK Technology Foresight*, *op cit.*, p.1.

41 M. Evan and P. Oak, 'R&D consortia: a new US organizational form', *Sloan Management Review*, 31, 3, 1990, pp.37-46.

42 F. Woodward, *Structure of Industrial Research Associations*, OECD, Paris, 1965, p.39.

43 L. Georghiou and J.S. Metcalfe, 'Evaluation of the impact of European community research programmes upon industrial competitiveness', *R&D Management*, 23,2, 1993, p.168.