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Strategic Research Partnerships: Empirical Evidence from Asia

MARIKO SAKAKIBARA & MARK DODGSON

ABSTRACT *This paper evaluates the role Strategic Research Partnerships (SRPs) play in Asia. Specific Asian institutional settings influence the roles of SRPs. Japan is regarded as a forerunner in the practice of SRPs. In Japan, lack of spillover channels, limited opportunities for mergers and acquisitions, weak university research and pressure for internal diversification motivate firms to form SRPs. In Korea, SRPs are regarded as a means to promote large-scale research projects. In Taiwan, SRPs are formed to facilitate technological diffusion. Empirical findings on SRPs, focusing on government-sponsored R&D consortia in Japan, are summarized. Issues regarding SRP formation, their effect on R&D spending of participating firms, and productivity, are examined. Reference is made to alternative forms of measurement of SRPs and their potential application to Asian countries is assessed. Enhancing the capacity of policy-makers to assess the extent and contribution of SRPs is considered to be a priority.*

1. Introduction

Strategic Research Partnerships (SRPs), in the form of technology-based joint ventures, strategic alliances and multi-partner R&D projects, are an important feature in the generation and diffusion of technology and, by extension, industrial development. They are an important feature of the research environment and industry in most industrialized and industrializing nations. This paper examines the roles SRPs have played, and are playing, in Asia, and some issues related to the measurement of the extent and the outcomes of SRPs.

Japan is regarded as a forerunner in the practice of SRPs. The most celebrated example is the VLSI (Very Large Scale Integrated circuit) project, designed to help Japan catch up in semiconductor technology. The project, conducted between 1975 and 1985 with a budget of 130 billion yen (US $591 million) of which 22% was financed by the government, developed state-of-the-art semiconductor manufacturing technology. All of the major Japanese semiconductor producers participated in this project, and Japanese semiconductor companies gained world leadership after the project. It is widely believed that this success story is only one of many.

The perceived success of the VLSI project has motivated other countries to emulate 'Japanese style' collaboration. For example, the 1984 US National Cooperative Research Act was enacted to relax antitrust regulations in order to allow the formation of research

Mariko Sakakibara is at the Anderson Graduate School of Management, University of California, Los Angeles, 110 Westwood Plaza, Los Angeles, CA 90095–1481, USA (Tel: +1-310-8257831; Fax: +1-310-2063337; E-mail: mariko.sakakibara@anderson.ucla.edu). Mark Dodgson is at the Technology and Innovation Management Centre, University of Queensland, Brisbane, QLD 4072, Australia (Tel: +61-7-33651615; Fax: +61-7-33654222; E-mail: mark.dodgson@uq.edu.au).

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joint ventures. Major cooperative R&D projects followed. SEMATECH was established in 1987 to develop semiconductor production technology with a US $1.7 billion budget as of 1996, half of which was financed by the government. The Department of Defense sponsored cooperative ventures on the development of flat-panel displays, which was estimated to spend US $1 billion over five years beginning in 1994. A successor bill of the 1984 law, The National Cooperative Research and Production Act, was passed in 1993 to extend the 1984 law to not just research and development, but to production of new technologies as well.

The 'lessons from Japan' were also applied in Europe, where the block exemption from Article 85 of the Treaty of Rome, which determines EEC competition rules for certain categories of R&D agreements, was introduced in 1985. Even earlier, many cooperative R&D projects were organized, including the US $5.6 billion European Strategic Program for Research and Development of Information Technology (ESPRIT) project in 1984, and the UK Alvey project in 1984, both for the development of computers and information technology. These projects were in response to another famous Japanese cooperative R&D project, the Fifth Generation Computer Project. Other European efforts include programs under the European Research Coordination Agency, started in 1985.

There are similar efforts in emerging economies in Asia, although the scale and ambition of SRP activity are significantly smaller. The Korean government has launched a series of cooperative R&D projects whose scheme is very close to the Japanese one, and in Taiwan there is its own version of R&D consortia.

The paper focuses on Asian experiences with SRPs. We find that, while there are some common motivations underlying the formation of SRPs internationally, there are broad national differences in the role they play. There is also varying capacity in government and research organizations to quantify and measure the contribution of SRPs.

2. What are SRPs?

SRPs are understood here to essentially involve shared commitment of resources and risk by a number of partners to agreed complementary research aims. SRPs can occur 'vertically' throughout a value chain, from the provision of raw materials, through the design, production and assembly of parts, components and systems, to their distribution and servicing. 'Horizontal' SRPs, on the other hand, occur between partners at the same level in the value chain.

SRPs between firms can take a variety of forms. They may be a joint venture, formed by two or more partners as a separate company with shared equity investments. They can be a partnership or 'strategic alliance' linking firms on the basis of continuing commitment to shared business or technological objectives without equity sharing. They may take the form of R&D contracts or technology exchange agreements whereby firms' shared objectives involve the interchange of research findings or technological know-how. Universities and public research laboratories are often partners in such R&D contracts. SRPs may take the form of 'innovation networks', combinations of firms and research organizations that share research agendas.

3. Motivations for SRP Formation

There is a wide range of explanations for why firms (and research institutes) collaborate in their research activities. From an economic perspective, SRPs are used as a means to set cost-sharing and/or output-sharing rules for the participants in an R&D project in order to correct market failures which would otherwise prevent firms from conducting the socially optimum level of R&D. From an organizational perspective, SRPs are a vehicle by which firms overcome their resource constraints through the learning of skills and capabilities from other participants.[1] There are many other motives, such as to share and/or reduce risks or uncertainties[2] and to affect competitive positions through standard setting, competitor exclusion or locking-in key players.

Government often uses SRPs as a policy tool to promote innovation. The form of government involvement can vary. It can fund research projects conducted by SRPs, affect their membership and organizational decisions and set rules of antitrust enforcements. The degree and the type of government involvement depends on industry structures, business systems and research infrastructure within national innovation systems.

For example, business systems—the ways in which firms relate to one another, to their employees, government and to financial systems—vary so significantly that different kinds of capitalism can be described.[3] These systems affect the general propensity towards cooperation, and will influence the extent and role of SRPs. Differences between 'Anglo-Saxon', 'Rhine' or Japanese capitalism will be seen in the breadth and depth of SRP activity. This can be a reflection of the differing strategies of firms as they relate to others along a continuum of spot-trading to 'obligational contractual relations'.[4] These differences are particularly important when consideration is made of Chinese capitalism.[5] In addition to its ubiquity in China, Taiwan and Singapore, Chinese business practices, which are strongly family-based, are dominant in Malaysia, Indonesia and the Philippines. Chinese family businesses have a strong preference for doing business with people that are associated through kinship or geographical origins. This can have the effect of limiting options for SRPs.

The propensity to conduct SRPs is obviously affected by differing research infrastructures and the way these are integrated within national innovation systems. National science and technology capabilities, as determined by levels of R&D expenditure and employees, investment in universities, etc., vary very significantly within Asia.

Many Asian nations remain impoverished in this regard. Within East Asia there are massive differences in science and technology capabilities, seen particularly clearly in disparities in R&D expenditure and employment.[6] Whilst Singapore, Taiwan, Korea and Japan have developing research infrastructures, particularly in some industries and relatively coherent national innovation systems, other East Asian countries do not possess the capacity to undertake SRPs. With countries, like Indonesia and Thailand, spending around US $2 per capita annually on R&D, SRPs are only likely to be a marginal concern for the limited number of science and technology-based organizations and firms.

In the following subsections, we review the role SRPs play in some Asian countries. Given the predominance of the Japanese experience in the formation and assessment of SRPs, this country receives most attention in our analysis.

3.1. SRPs in Japan

SRPs play a very important role in Japan because of its distinctive institutional settings. First, the importance of SRPs as a vehicle to share knowledge with other firms becomes more important where imperfections of factor markets are severe.[7] The lifetime employment system prevalent among large corporations is a cause of low mobility of researchers among companies. Companies are oriented to maintain a stable number of researchers, and so even if they recognize new technological opportunities, it is hard for them to suddenly increase hiring. Also, though the situation has been changing recently, we seldom observe researchers move from one company to another, especially to a competitor. Some years ago, Saxonhouse[8] pointed out that the Japanese government's cooperative R&D projects are viewed as a substitute for the unusually high degree of informal interfirm communication which takes place among the more professionally oriented, potentially mobile R&D personnel in the USA. This is a view that has continued currency, despite recent changes in the labor market in Japan. American researchers might be implicitly disclosing potentially proprietary information in order to enhance their employment prospects and also in order to receive in exchange proprietary information of commensurable value. Without having spillover channels through recruiting in the external labor market, Japanese companies are motivated to use SRPs as a means of information exchange.

Second, Mergers and Acquisitions (M&As) as an alternative instrument to access research inputs tend to be cumbersome. Compared with the USA, M&As are still uncommon in Japan because the dominant owners of corporations are institutional shareholders—often motivated to solidify relationships not to seek immediate returns. Rules which facilitate M&As are less developed than in the USA. Moreover, R&D knowledge and capability belong to individuals,[9] not to firms, and so acquisitions intending to capture R&D capability can turn out to be purchases of 'empty shells' due to the departure of all key personnel with the 'crown jewels'. Under these circumstances, cooperation with other companies becomes a practical alternative.[10]

Third, relatively weak research capability in universities and national research laboratories, and the weak linkage between these public research organizations and corporations in Japan, make knowledge transfer among firms through SRPs important. In the USA, strong university-based efforts and university-firm linkages work as a substitute for knowledge sharing through SRPs.[11]

Fourth, firms are often motivated to form SRPs as a means of internal diversification. SRPs are directly connected with diversification in Japan because, as Porter[12] points out, entry into new businesses is typically conducted by established firms through internal diversification. Japanese companies tend to face weaker pressure from shareholders than US firms to realize short-term returns, and so a goal for them is their own perpetuation.[13] Due to the construction of the market for corporate control, resource reallocation from mature and/or declining businesses to emerging businesses is conducted internally. Through the participation in SRPs, firms can test the possibility to diversify into new businesses. Sakakibara[14] empirically finds that the motives for cooperative R&D are analogous to the motives for diversification.

Because of these critical roles SRPs play, we expect to observe many SRPs in Japan. The exact number of SRPs is difficult to obtain because 'pure-private' SRPs are not often announced, and so journal-article databases can be biased. Corporate executives have noted that the existence of private SRPs itself could be a signal to rival companies regarding which research direction companies try to seek.[15] Because of its higher incidence, longer history and better data source, the rest of the paper is based on analysis of government-sponsored R&D consortia in Japan. It should be noted that many of the institutional settings in Japan are common throughout industrialized Asia, particularly regarding weak university research, a preference for organic rather than acquired diversification and, in countries like Korea, and where Chinese family businesses predominate, limited labor market mobility.

The promotion of cooperative R&D by the Japanese government started in 1959, when the Ministry of International Trade and Industry (MITI) and aircraft makers launched the YS-11 turboprop aircraft development project.[16] In 1961, a formal scheme to promote cooperative R&D efforts was established as the Act of the Mining and Manufacturing Industry Technological Research Association. Under the Act, which was modeled after the British Research Associations—initiated in 1917 and later adopted by Germany, France and Sweden—firms can pool researchers and funds into nonprofit Mining and Manufacturing Technological Research Associations (TRAs hereinafter). The formation of TRAs was intended to promote R&D consortia as a means of coping with trade liberalization and to enhance the productivity of Japanese industries. At that time, Japan faced the task of abolishing protective policies for domestic industries following these industries' recovery from the devastation of the Second World War.

Under this scheme, participating companies enjoyed several tax benefits on their research expenses. Typical tax benefits included accelerated depreciation for expenses on machinery and equipment, instant depreciation of fixed assets for R&D and discounts of property taxes on fixed assets used for R&D.[17] The TRA system was introduced as a substitute for direct R&D subsidies to individual companies, which the Japanese government had to phase out as Japan prepared to join the league of developed countries and to abolish protective policies. After the scheme of TRAs was introduced, the amount of R&D subsidies to individual companies considerably declined and in order for firms to receive significant amounts of R&D subsidies, they needed to form R&D consortia.

TRAs are not the only form of cooperative R&D in Japan. Other organizational forms for cooperative R&D include foundations and corporations. These forms are chosen by participants on the basis of each form's financial and organizational benefits (for details of different types of cooperative R&D, see Sakakibara[18]). It is not only MITI, but also many other ministries that are involved in the formation and operation of these consortia.

The most comprehensive data on SRPs have been collected and documented in Sakakibara,[19] which include 237 government-sponsored R&D consortia that occurred between 1959 and 1992. Some 1171 companies participated in these consortia during this period and many were involved in multiple projects. Inclusion of these multiple projects yields a data set with 3021 company-project pairs. They cover all the identifiable government-sponsored R&D consortia during that period including all the TRAs as well as other forms of cooperation.

Figure 1 illustrates the overall trend of Japanese government-sponsored R&D consortia

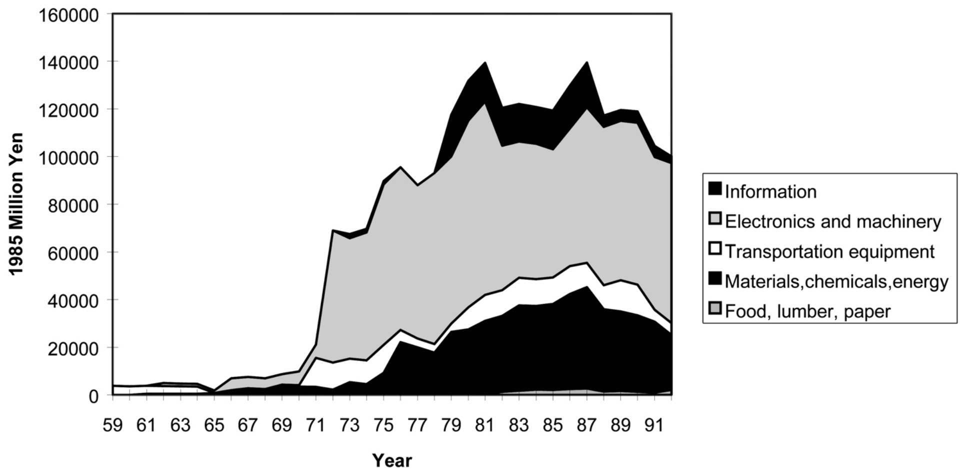

Figure 1. Japanese R&D consortia total budget by sector (Source: Sakakibara, 1994).

in terms of the budget allocated in each project, aggregated by sector. This figure illustrates that the efforts peaked in the late 1970s and 1980s. This figure also shows that while the electronics and machinery sector caught much attention, consortia are observed in many other sectors as well.

3.2. SRPs in Other Asian Countries

There is very little data available on SRP activity, or assessment of their contribution, in other Asian countries.[20] Historically, there has been little collaborative research activity, as the focus of industry and technology policy in these nations has been on 'catching-up', primarily through importing and developing production capabilities based on low labor costs, i.e. involving the diffusion and adaptation of existing technologies, rather than the creation of new technologies through research. Leading-edge university-based research has been minimal, as has been the capacities within firms in these countries to absorb advanced research findings from elsewhere. More recently, however, the technology diffusion capabilities of firms in countries like Korea and Taiwan have extended into technology creating capabilities.[21] As Linsu Kim[22] puts it: Korea is moving from 'imitation to innovation'. This is illustrated in the data on gross expenditure on R&D, where in 1999 Korea spent US $18.5 billion (ahead of Canada and Italy); Taiwan spent US $4.5 billion (ahead of Sweden and the Netherlands); and the next highest spender in the region is Singapore, with US $1.7 billion.[23]

The promotion of Korean cooperative R&D started in 1982. The government introduced the Industrial Research Association (IRA) system, which was modeled after the Japanese TRA system. Under each industry-based IRA, many specific consortia were formed. The Korean government provided the participants of IRA with various incentives such as exemptions of military obligations for male researchers, accelerated depreciation of R&D investment, etc. A notable development occurred in 1986, when the Ministry of Science and Technology introduced large-scale cooperative R&D projects mainly in the electronics and information areas. The Electronics and Telecommunications Research Institute, a government R&D institute, served as a coordinator, and only large members in electronics-related IRAs participated in these consortia.[24]

In policy terms, Korea began its move towards more research-orientated, rather than mission-orientated, science and technology policy in the 1990s. The Highly Advanced National (HAN) project between 1992 and 2001, for example, included private-sector participation and funding in collaborative research projects on industrial technologies. This scheme promoted large-scale research projects. To formalize and to further promote collaborative research, the government introduced the Cooperative R&D Promotion Law in 1993 to provide the legal basis for priority funding of cooperative research.[25]

Within Korea, the role of government R&D institutes (GRIs) has been important for the nation's technological development, particularly in improving the capacities of large firms to transfer technology from overseas. Despite this, past attempts by the government to encourage joint research projects between GRIs and Korean firms have not been very successful.[26] However, the recent privatization of numbers of GRIs is expected to increase the extent of collaborative activity with industry.

Sakakibara and Cho[27] found that, though basic systems of government-sponsored R&D consortia in Japan and Korea are similar, the implementation has been very different between two countries. Korean R&D consortia in the 1990s are concentrated in the electronics and machinery industries, and tend to be much smaller, with fewer participants and shorter duration than Japanese equivalents. They did not fully promote R&D cooperation, knowledge sharing, or scale economies equivalent to the Japanese level, even the level reached by Japan in the 1960s. In addition, Korean R&D consortia focused on applied, industry-specific technologies with a clear goal that other countries have already proved. Personal rivalry among *chaebol* leaders, limited learning opportunities, limited resources, the short history of R&D and R&D cooperation, inadequate goal setting, and the antagonistic business-government relationship contributed to the relative ineffectiveness of Korea's R&D consortia.

The structure of Taiwanese industry, with its predominance of smaller firms, has encouraged a particular form of SRP, with its primary aim being the diffusion and application of research findings. Studies, for example, have shown the importance of institutions, such as the Industrial Technology Research Institute (ITRI), in encouraging technological development and diffusion in Taiwan through collaborative projects.[28] Detailed, in-depth case studies on the electronics industry in Taiwan, such as Mathews and Cho,[29] have shown the importance of collaborative research relationships for the development of the industry. Such collaborative research activity has been instrumental in explaining the successful development of the IT industry in Taiwan. The networks created amongst small Taiwanese firms through their research links with research organizations and international firms have played such an important role in the success of the industry, that Mathews and Cho have described the model as a new form of economic learning.

4. Policy Needs for Indicators

The previous section establishes a critical role SRPs play in various institutional settings. This is a necessary but not sufficient condition to call for the government's support for this particular policy instrument. If the government supports SRPs that would have been formed without government sponsorship, there is, of course, no need for government intervention. Also, if government-sponsored SRPs do not achieve intended goals to stimulate additional private innovative activities, the validity of their existence becomes doubtful.

In order to determine whether the government should promote SRPs, empirical examination of existing SRPs are informative. A natural question for policy makers is whether the SRPs they promote attract the right kind of firms from a public-policy perspective, and whether the SRPs they support are an effective means to stimulate additional private R&D efforts rather than crowding out private spending. The research productivity of SRPs is also an important consideration.

Supporting SRPs is only one of many policy tools government can choose to stimulate innovative efforts. For example, public procurement, funding of research in national laboratories and universities, tax incentives, subsidies to individual firms can be chosen as a policy means.[30] The evaluation of the effectiveness of SRPs by measuring their productivity thus gives the government useful guidance regarding whether they should choose SRPs over other policy means.

This section focuses on three issues regarding SRPs: their formation, their effect on R&D spending of participating firms, and their productivity. As Japan has the longest history of using SRPs in the region and because the only available systematically-collected data is Japanese, our focus is inevitably on Japan. Even so, empirical studies on SRPs for these issues are still limited within Japan. The paucity of empirical research is largely due to the difficulty of obtaining data on government-sponsored SRPs. Even in Japan, there is no central clearing house for such data, and even within MITI, the largest sponsor of SRPs, no single place from which one can obtain the whole data of MITI-sponsored SRPs. Nonetheless, compared with other Asian countries, where the incidence of SRPs is smaller, and the capacity in government and academia to evaluate their contributions is minimal,[31] the Japanese data is significantly better. It should be emphasized that the following analysis applies to SRPs formed within the specific context of Japan as outlined in Section 3.1, although, where possible, evidence from elsewhere is used to assist generalization.

4.1. Formation of SRPs

In the analysis of the formation of SRPs, an important issue for policy makers is the firm- and industry-level determinants of the formation of R&D consortia.[32] At the industry level, there are two important considerations. The first is the degree of competition of the industry in which member firms of a SRP belong. The degree of industry competition will affect a firm's propensity to participate in SRPs in two opposite ways. As Katz[33] discussed, firms in competitive industries might be more motivated to form R&D consortia to ease the subsequent product market competition. Also, SRPs allow firms to access complementary technology that enables firms to develop their R&D capabilities and improve their strategic position. These needs might be greater in competitive industries.[34] On the other hand, organizational economics and organizational theory document the difficulties involved in organizing cooperative ventures in general,[35] and SRPs in particular.[36] These studies emphasize the organization costs associated with complex ventures, including costs to monitor opportunistic behavior of participants, and to align interests among participants. If firms are in highly concentrated industries, they might find the cooperation (or collusion) easier to achieve because these difficulties can be resolved in an oligopolistic understanding among rivals.

The second is the degree of R&D spillovers. SRPs consortia can be used as vehicles to internalize the externality created through spillovers of research outcomes.[37] Firms can agree to share the costs and outputs of an R&D project before its execution, so they can restore the incentive to conduct R&D. Cohen *et al.*[38] found that, on average, intra-industry R&D spillovers are more extensive in Japan than in the USA. One major channel that facilitates spillovers is the patent system. In Japan, patent applications are automatically published 18 months after their initial filing. In the USA, in contrast, the content of the patent applications will be published only if they are granted, which is typically more than two years after the application. Under these conditions, spillovers can be major issues determining the participation in SRPs in Japan.

Firm-level factors can also influence the rate of participation in SRPs. The first factor that plays an important role is R&D capabilities of participants. Firms can use SRPs to gain access to technological capabilities of other firms to create next-generation technological competencies.[39] This might imply that a firm that currently has disadvantageous R&D capabilities is motivated to form R&D consortia more than R&D-capable firms. However, Cohen and Levinthal[40] demonstrated the possibility that a company's own R&D increases its learning capability from others. Firms that already invested in R&D, therefore, can benefit more from R&D consortia than less R&D-capable firms, and so they might be more motivated to learn from others.

The second factor of consideration is the experience of past participation in SRPs. The network of prior alliances provides information of new alliance opportunities, potential partners and their quality.[41] With the formation of new alliances this network updates, it is the new network that becomes influential for subsequent firm behavior.[42] In the case of SRPs, the experience of participation in past consortia can create a technological network through which a firm can gain access to technological resources of other firms. Furthermore, Baumol[43] argued that cheating in the cooperative R&D game can be easily detected in a repeated game situation, and punishment to exclude a cheater from the following projects is very costly for a cheater. Therefore, firms that have repeatedly participated in R&D consortia can benefit from the sustained cooperation, which further motivate them to participate.

The third factor is the encounter with other firms in product markets. The literature on networks stresses a firm's access to external networks as an important source of capabilities that the firm can draw upon.[44] When a firm is diversified, it is likely that the firm has a better knowledge on potential partners in SRPs through contact with a large number of firms in many product markets. In other words, contact with other firms in product markets constitutes a network through which the firm can obtain superior information on future consortia. Also, when a firm is diversified into many product markets, the firm might wish to draw on outside knowledge to a greater extent by combining in-house technological competencies and external technological acquisitions to serve these markets.[45] This desire further motivates the firm to form SRPs.

Sakakibara[46] finds from an event-history analysis that both industry and company factors affect the formation of R&D consortia. It is found that a firm in an industry with weak competition and appropriability conditions has a higher rate of consortia participation. A firm's R&D capabilities, network formation through past consortia, encounter with other firms in product markets, age and past participation in large-scale consortia also positively affect its tendency of consortia formation. This indicates that firms that frequently participate in SRPs are the ones that will gain most from participation and have potential for effective cooperation. The implication of this for policy makers is the requirement to recognize that they need to take both industry and company factors into account when deciding the target firms. Even if they want to attract a specific type of firms to government-sponsored SRPs, it might be difficult to do so if these conditions are not met.

4.2. Effect on R&D Spending of Participating Firms

The second issue of the interest is the effect of participation in SRPs on R&D spending of participating firms. Do SRP member firms increase or decrease their R&D spending? An answer to this question depends on the motives of participants and the organization of SRPs.

Sakakibara[47] makes a distinction between cost-sharing SRPs and skill-sharing SRPs. Cost-sharing SRPs refer to consortia formed to share fixed costs of R&D among participants, to realize economies of scale in R&D, and to divide tasks among members and avoid 'wasteful' duplication. In contrast, objectives of skill-sharing SRPs include learning from other participating firms. This type of SRP can be viewed as opportunities for one partner to internalize the skills or competencies of the others to create next-generation competencies. This learning function of SRPs becomes especially important when firms try to enter a new business, to redefine their core industries, or when they respond to shifting industry boundaries.

The diversity of capabilities SRP participants possess can distinguish the different motives to participate in SRPs. In the case of skill-sharing or learning-based R&D cooperation, what is important is not only the outcome of the project, but also the process of resource accumulation, or learning in a SRP. Participants with a skill-sharing motive might find it easier to reach an agreement to cooperate without a clear end result in mind than firms whose primary motive for cooperation is cost-sharing. In addition, skill-sharing is an important means for a firm to enter a new business, implying that this motive is more likely in pre-competitive R&D where conflicts of interests are less apparent. Firms from different industries, therefore, might find it easy to cooperate when their motivation is skill-sharing. Also, the capabilities of participants in skill-sharing ventures are likely to be heterogeneous so as to best combine complementary resources and knowledge. This implies that participants are likely to come from a wide range of industries.

In contrast, cost-sharing, or scale-based R&D cooperation requires a relatively clearer understanding of the objective and configuration of a cooperative R&D project, because the benefits of cost-sharing and the realization of economies of scale has to be understood by member firms before the execution of the project. Participants in R&D consortia motivated by cost-sharing are likely to belong to a single industrial sector, because they are more likely to have similar prior knowledge, which makes the agreement easier to achieve. Their capabilities are, therefore, likely to be homogeneous.

The cost-sharing and skill-sharing motives are not necessarily mutually exclusive. An R&D consortium can pursue both motives simultaneously. The point here is that the relative importance of these motives can be distinguished by the diversity of capabilities among the consortium's participants. Sakakibara[48] finds that the relative importance of the cost-sharing motive in R&D consortia increases when participants' capabilities are homogeneous or projects are large, while the relative importance of the skill-sharing motive in R&D cooperation increases with heterogeneous capabilities, based on the survey data on Japanese government-sponsored SRPs.

The effects of SRPs on a participating firm's R&D spending will differ according to their motives for participation and thus the diversity of member firms in SRPs. There are three ways that the diversity of R&D consortia participants affects the R&D expenditures of participating firms.[49] The first is the spillover effect of a firm's own R&D on others' R&D productivity. When the outcomes of SRPs are pooled and shared, firms find it best to increase their R&D efforts. The spillover effect is larger if a degree of knowledge complementarity among participants is higher, because firms can achieve better outcomes by combining their knowledge. Assuming that the diversity of participants increases the degree of knowledge complementarity, this diversity implies higher R&D expenditure.

The second effect of cooperative R&D on a firm's R&D spending is from learning, which is defined here as efforts by firms to assimilate and exploit knowledge or information generated by other firms.[50] Suppose that higher R&D expenditure facilitates better learning capability. Levin *et al.*,[51] for example, point out that independent in-house R&D is the most effective means to learn about rivals' technology. It is also documented that Japanese companies participating in consortia customarily set up in-house research groups to absorb and utilize the results of R&D consortia.[52] If there are better learning opportunities created by SRPs, the participants spend more in their R&D. Assuming that diversity of participants increases a degree of knowledge complementarity and thus learning opportunities, diversity implies higher R&D expenditure.

The third effect relates to the impact of R&D cooperation on product market competition. The more direct the product market competition among the participants, the less willing they will be to cooperate even if they own complementary knowledge. Katz[53] argues that if higher levels of R&D make market competition more intense by lowering firms' production costs, then the resulting decline in profits will reduce their incentive to conduct R&D. Katz showed that R&D consortia could depress R&D as firms seek to lessen the severity of competition in the product market. In the case that participants are from more diverse industries (as opposed to coming from a single industry) in the product market, however, this argument implies higher R&D expenditure by consortia participants, since the market-competition effect is expected to be smaller in this case.

All three effects suggest the possibility that R&D consortia whose members have diverse backgrounds may increase participants' R&D spending, relative to consortia of single-industry participants. Note, these three effects are not necessarily mutually exclusive. The spillover effect and the learning effect are the results of technological diversity of consortia participants, while the product-market-competition effect is related with the degree of direct competition among participants in product markets. Sakakibara[54] finds from firm-level financial data and consortia data that when SRPs consist of firms with diverse technological knowledge, these firms offer learning opportunities and increase spillover productivity, which result in more intensified R&D efforts of participants. When R&D consortia participants have diverse business backgrounds, the expected product market competition is less intense, leading to higher R&D expenditures by participants. Sakakibara[55] also finds from the survey data that when the skill-sharing motive for participating in cooperative R&D becomes relatively more important than the cost-sharing motive, a firm's R&D spending is likely to increase, consistent with results based on quantitative data.

4.3. Performance Evaluation of SRPs

The third, and perhaps most important issue, is the determinant of the performance of SRPs. There are multiple levels one can approach on this issue. The first level is the overall impact of the participation in SRPs on research productivity of participating firms. As explained earlier, there are many reasons for which we expect a positive relationship between the participation and the increase in research productivity of participants, including the cost- and skill-sharing effects. Branstetter and Sakakibara[56] examined the data on Japanese government-sponsored R&D consortia. They found that if a firm participates in an additional project per year, it would raise its patenting per R&D dollar (i.e. its research productivity) by between 4 and 8%.

A more disaggregated approach is to identify the characteristics of consortia that are associated with the increase of research productivity of participating firms. Branstetter and Sakakibara[57] examined the same data. They focused on two major characteristics of SRPs: spillover potential and *ex-post* product market competition among participating firms. Theoretical literature, Katz[58] and others, predicts that the greater the potential level of R&D spillovers within consortium, the greater the level of R&D by member firms. This is because when a firm can benefit more from R&D outcomes by other member firms through higher spillovers, the firm is motivated to conduct more R&D, leading to better research outcomes as SRP members. On the other hand, some of the private benefits of cooperative R&D, in terms of raising firm profits, could be dissipated through product market competition. When the level of product market competition among participating firms is not intense, a participant can appropriate all the return's R&D outcomes, motivating member firms to conduct more R&D and achieve greater outcomes. Branstetter and Sakakibara[59] measure spillover potential as technological proximity among member firms in the technological space, calculated from member firms' patent portfolio and the level of *ex-post* product market competition as the product market proximity of member firms. Their outcome measure is the number of patents taken by consortia participants in technological areas targeted by consortia. They find positive association between technological proximity and consortium outcomes, and a negative relationship between product-market proximity and consortium outcomes. In addition, they employ qualitative characteristics of consortia taken from survey results by

Sakakibara,[60] and find that these consortia are most effective when they focus on basic research.

Sakakibara and Branstetter[61] apply the same methodology to the data of US consortia, sponsored by the Advanced Technology Program of the Department of Commerce. They find similar results in the US case: There is a positive association between the intensity of participation in research consortia and the overall research productivity of participants. There is also a positive impact of consortia on the research productivity of participants in the technological areas targeted by the consortia. This positive impact of consortia is higher when the average technological proximity of participants is high. In both Japanese and US SRPs, there is evidence that R&D intensive firms tend to benefit more from the participation in consortia.

Sakakibara[62] conducted an analysis of the performance of R&D consortia from a managerial perspective. The results show that there is no clear link between the existence of R&D consortia and industry competitiveness. This study also investigates the perceived benefits and costs of Japanese R&D consortia based on 398 responses to questionnaires distributed to high-level corporate R&D managers who have participated in R&D consortia. The perceived benefits of projects are rather intangible, such as researcher training and increased awareness of R&D in general, not the commercialization of project outcomes. The overall subjective evaluation of the typical project's success is modest, and participants do not perceive R&D consortia to be critical to the establishment of their competitive position. This finding of the positive but modest benefits of SRPs is consistent with the finding from econometric studies.

5. Data Issues of Evaluation Studies

5.1. Selection Problem

There is a fundamental issue that researchers have to cope with when they conduct evaluation studies of government-sponsored R&D. Participation in SRPs, or the selection of member firms by the government, is not a random event. To the extent that they could, governments seek to encourage firms with strong R&D programs to participate in their sponsored SRPs because they want to maximize the returns from government subsidies. As a result, if we observe good outcomes from certain types of SRPs, we cannot distinguish whether these types of SRPs are designed to yield good outcomes, or if only good firms participate in these particular SRPs. This selection problem is the single greatest limitation of past research to measure the impact of public-technology programs.[63]

The data obtained by Sakakibara[64] make it possible to employ several techniques to deal with the selection problem. The data contain multiple dimensions of information (SRP, firm and time). At the SRP level, they include a description of each project, its period of operation, the total budget, the amount of government subsidy, and the names of participating firms. At the firm level, the data include all the financial information. They also contain not only input data (R&D expenditure) but also output data, measured as the number of patents taken by participating firms, both the overall patenting and patenting in the targeted area. These data are available over a long period of time; the most detailed data are available from the early 1980s to the mid 1990s. In addition to these quantitative data, qualitative evaluations of managers from participating firms are obtained through questionnaire survey.

The analyses of Branstetter and Sakakibara,[65] for example, demonstrate a way to address the selection problem by utilizing these data. By employing the data of patenting in the targeted technologies before, during and after participation in a consortium by individual firms, they can control for pre-existing technological strength of a firm in the targeted technologies, which enable them to isolate an additional effect due to the participation.

Also, the data set includes observations on firms that did not participate in consortia. This dimension helps to highlight the effect of participation. Even if we observe any increase in R&D outputs by a participating firm during the period a SRP operated, we cannot conclude that increase is due to the SRP. It might be the case that technological opportunity in that field increased, or the overall economic condition was favorable. By having firms that did not participate as a control, we can 'extract' the pure-participation effect.

Finally, because we observe the same firms participating in multiple consortia, we are able to measure the marginal impact of different consortium characteristics and firm characteristics on research outcomes, controlling for consortium and firm fixed effects. A conceptual experiment this data set allows is, for example, to examine how the same firm would perform if we moved it from a consortium with a set of characteristics to one with a different set of characteristics. In a similar manner, we can estimate the impact of different firm characteristics; in other words, we can determine what kinds of firms benefit most from SRPs.

Qualitative and quantitative data offer different advantages. R&D output in this data set is measured by the number of patents generated by firms. There are limitations inherent in the patent data. For example, some innovations are not patentable. The impacts of learning by researchers in SRPs are not even codifiable. Survey data provide us with qualitative aspects of the outcomes of SRPs and it is best, as discussed earlier, to utilize both types of data to evaluate SRPs.

5.2. Different Forms of Measurement

There are a variety of different forms of measurement of SRPs, and these are briefly described below. Their application to the measurement of SRPs in Asia, outside of Japan, has been distinctly limited. Observations are offered on the efficacy of their use in Asia.

Scientific Indicators and Bibliometrics.[66] Mapping techniques based on patent and bibliometric data are being used to analyze the structure and dynamic development of scientific and technological developments, including the growing inter-relationship or fusion of areas of science and technology. These indicators not only measure the 'context' or environment in which SRPs occur, but also directly record the SRPs of individual companies and research institutes. They are only of value in those countries whose research systems produce world standard science and technology, and their use in Asia is limited to those very few countries with significant basic research activities, or to distinctive areas of scientific excellence, such as rubber in Malaysia, or rice in the Philippines.

International and National Surveys. A range of international and national surveys is conducted that contains data on SRPs, or SRP-like activities (although the paucity of research activity, and the incapacity to record that that there is, in many Asian nations must be recalled). The Annual World Competitiveness Yearbook, for example, surveys its respondents about whether technology transfer between companies and universities is sufficient, and whether technological cooperation between firms is common or lacking. This survey shows that countries such as Singapore and Taiwan are assessed to do comparatively well in the effort to which firms collaborate with other firms and universities. In common with a number of other such surveys, given the limited respondent numbers in many of these countries, it is unwise to place too great reliance on these data.

China records the increasing number and value of domestic technology development contracts between buyers and sellers of technology in its *Science and Technology Indicators*, published by its Ministry of Science and Technology, but while these may include SRPs according to our definition, they are also likely to include one-way transfers of technology. There is an obvious need to improve the extent and quality of such surveys in Asia and this will require substantially enhanced local policy evaluation capabilities.

Specific Databases on Alliances. Several databases measure the number of new international technology alliances announced in the technical press. These tend to cover high-profile technology creating projects and under-represent more technology diffusion-oriented partnerships and those based outside non English-speaking countries. The best of these databases, the MERIT-CATI database, which includes inter-firm collaborations, shows the increase in the number of new collaborations being formed throughout the 1980s and 1990s. The majority of these new collaborations occur in new technologies, particularly in IT, and are based in the USA, Japan and Europe. Although there has been an increase in partnerships outside of the Triad, primarily in technologically advanced Asian nations, these still only account for around 20% of the total recorded number.[67] The major drawback of these databases is that they rely on information that has to be reported by more or less publicly available sources and thus the proportion of unreported or confidential agreements is unknown. They may also underestimate the extent of alliance activity amongst technologically advanced Asian nations.

We can find no examples of specific databases on SRPs in Asia outside of Japan. Given the increasing science and technology capacities in some countries, this is considered to be an activity worthy of encouragement.

Network Analysis. Networks of one sort or another are powerful mechanisms for communication and the transfer of complicated information and technology flows. Networks can enable the sharing of resources, for example, specialist equipment or R&D projects where the costs and risks of investment to any individual firms would be prohibitive. Definitions of network vary, but here they are considered to be an open system of interconnected firms and institutions with related interests.[68] Networks offer a rich web of channels, many of them informal, and have the advantage of high source credibility—experiences and ideas arising from within the network are much more likely to be believed and acted upon than those emerging from outside. They are therefore an effective mechanism for encouraging learning, an objective of SRPs. Their formation has been a major innovation policy objective around the world.[69]

The measurement of the extent and outcomes of networking activity as it applies to research is very difficult. For example, while there are data on the number of suppliers a particular firm may have, and firms know how much of their R&D is undertaken externally, there is rarely detailed information on the importance and nature of particular links with suppliers or collaborators. Within the management and business literature in Asia there is substantial attention placed on 'internal' networking activities, particularly within the *keiretsu* in Japan and *chaebol* in Korea. In future, the technological aspects of this networking activity would provide fertile grounds for additional research, especially regarding how technology is accessed and developed outside of the 'internal' formal network in the absence of significant M&A activity.

Case Studies:
(1) *Firms*—Case studies of individual firms show both the extent of SRPs and, more than any other indicator, their (often changing) focus, and outcomes. For example, Dodgson and Kim[70] show the reliance of Samsung Electronics on various forms of technological link with US and Japanese firms, and the way in which the form of partnership undertaken changes as Samsung became more technologically self-sufficient. The focus of the partnerships progressed from licensing-in to joint R&D projects. Given the high potential of detailed learning from case study analysis, greater numbers of case studies with this perspective are to be welcomed.

(2) *Regions*—Analyses of particular regions can show the extent of localized SRPs and the importance of particular stimuli, such as strong research institutes or high levels of localized government expenditure specific to SRPs. Mention has already been made of ITRI in Taiwan, and its role in the regional economy. Although still in its development stage, Malaysia's Multimedia Super Corridor represents a very large-scale initiative to build regional research partnerships facilitated by substantial infrastructural investment. Other initiatives, such as Science Park developments in Singapore, Penang in Malaysia and Daeduk in Daejeon, Korea, warrant detailed explorations regarding the manner in which they facilitate effective SRPs.

(3) *Industries*—By conducting in-depth case studies on particular industries it is possible to delineate the most important collaborative research relationships. This is exemplified in Mathews and Cho's[71] analysis of the electronics industry in Taiwan, which merits replication in other industries in Asia. This form of analysis would benefit extension beyond high-tech industries into more traditional industries, such as food and textiles.

(4) *Technologies*—The study of particular technologies, such as semiconductors,[72] has proven very valuable in improving our understanding of economic development, and the related and evolving role of R&D in technologically advanced Asian nations. In the Asian context, the high-tech focus of these studies would again be valuably be supplemented by the examination of other 'lower' areas, such as environmental technologies. As many nations, such as Singapore, are substantially expanding their investments in biotechnology, there may be value in creating a biotech-specific database of collaborative activity.

(5) *Policies*—Large-scale evaluations of SRP-promoting policies—for example, of the VLSI project, SEMATECH, or ESPRIT—can measure the extent, motivation and outcomes of SRPs. We can find no examples of in-depth, program-specific evaluations of such policies undertaken outside Europe, USA and Japan.

6. Conclusions: Future Empirical and Policy Analysis

As SRPs are created for a variety of purposes and assume a range of different forms (differences that are accentuated when international comparisons, and different institutional settings, are factored in) there are immense methodological problems in measuring their extent and contribution.

Though we can learn a lot from existing data, certainly they are not perfect. First, we need multiple measures to evaluate the outcomes of SRPs. The ultimate goal of SRPs is the commercialization of research. It is very difficult to map from SRPs to the eventual commercialization of the targeted research project, however, because there is a time lag between a project and a commercialization: this time lag is project specific. Also, participating firms need to make their own efforts after the conclusion of SRPs. It is therefore difficult to quantify the exact contribution of SRPs on the eventual commercialization. Any data that help the mapping from SRPs to commercialization would be useful.

Also, it is very helpful for policy makers to obtain data of pure private SRPs. As already discussed, journal-article database might have a bias toward 'hot' fields such as information technology, because they are frequently covered by media. Having data of pure private SRPs, policy makers can compare them with government-sponsored SRPs, and evaluate the marginal effect of government support.

Another issue regarding evaluation of the role and importance of SRPs at a national policy level is that their contribution may be changing over time. For example, changing policies towards research institutions not only affect the extent of SRPs, but also their intent. Seen particularly in countries like Taiwan and Korea, the national research institutions have had to adapt and change in their research activities as some industries have moved from positions of technological following to technological leadership: from technology diffusion to technology creation.[73]

Given the increasing importance of SRPs throughout much of Asia, more data on them are helpful not only for policy makers but also for managers who consider participating in SRPs and are trying to maximize returns from participation. A number of forms of measurement have been described, with varying utility for examining different aspects of SRPs. A much more complete reflection of the extent and importance of SRPs can be gained by combining a number of these different indicators for specific analytical purposes. This is, perhaps, the largest challenge for policy-makers in the region: not only do new data sources need to be developed, but new methods of combining and analyzing different types of data need to established. Given the significance of SRPs, this warrants expanded policy analysis capabilities in the governments of the region.

Notes and References

1. M. Sakakibara, 'Heterogeneity of Firm Capabilities and Cooperative Research and Development: An Empirical Examination of Motives', *Strategic Management Journal*, *18*, 1997, pp. 143–164.
2. J. Hagedoorn, 'Understanding the Rationale of Strategic Technology Partnering: Interorganizational Modes of Cooperation and Sectoral Differences', *Strategic Management Journal*, *14*, 1993, pp. 371–385.
3. R. Dore, *Stock Market Capitalism: Welfare Capitalism: Japan and Germany versus the Anglo-Saxons* (Oxford, Oxford University Press, 2000); P. Hall & D. Soskice, *Varieties of Capitalism* (Oxford, Oxford University Press, 2001).
4. M. Sako, *Prices, Quality and Trust: How Japanese and British Companies Manage Buyer Supplier Relations* (Cambridge, Cambridge University Press, 1992).
5. S.G. Redding, *The Spirit of Chinese Capitalism* (Berlin, Walter de Gruyter, 1993).
6. M. Dodgson, 'Policies for Science, Technology and Innovation in Asian Newly Industrializing Economies', in: L. Kim & R.R. Nelson (Eds), *Technology, Learning and Innovation* (Cambridge, Cambridge University Press, 2000).
7. M. Sakakibara, 'Evaluating Government-sponsored R&D Consortia in Japan: Who Benefits and How?', *Research Policy*, *26*, 1997, pp. 447–473.
8. G.R. Saxonhouse, 'Japanese Cooperative R&D Ventures: A Market Evaluation', Research Seminar in International Economics, Seminar Discussion Paper No. 156, Department of Economics, the University of Michigan, 1985.
9. E. von Hippel, *The Source of Innovation* (Cambridge, MIT Press, 1988).
10. M. Sakakibara, 'Cooperative Research and Development: Who Participates and in Which Industries Do Projects Take Place?', *Research Policy*, *30*, 2001, pp. 993–1018.
11. Sakakibara, *op. cit.*, Ref. 7.
12. M.E. Porter, *Capital Choices: Changing the Way America Invests in Industry* (Boston, Council on Competitiveness and Harvard Business School, 1992).

13. Dore, *op. cit.*, Ref. 3.
14. Sakakibara, *op. cit.*, Ref. 10.
15. Based on author interview.
16. This section draws heavily on M. Sakakibara & D.-S. Cho, 'Cooperative R&D in Japan and Korea: A Comparison of Industrial Policy', *Research Policy*, *31*, 2002, pp. 673–692.
17. The Council of the Mining and Industry Technology Research Association, *The 30 Year History of the Mining and Industry Technology Research Associations* (Tokyo, The Council of the Mining and Industry Technology Research Association, 1991).
18. Sakakibara, *op. cit.*, Ref. 7.
19. M. Sakakibara, 'Cooperative Research and Development: Theory and Evidence on Japanese Practice', Ph.D. Thesis, Harvard University, 1994; Sakakibara, *op. cit.*, Ref. 1, 7.
20. This assertion is based on research visits to, and collection of available data from, Taiwan, Indonesia, China, Malaysia, Singapore, India, Vietnam, Philippines, Hong Kong, Brunei and Thailand. Confirmation of this view was provided by the two major government science and technology policy agencies in Korea and Taiwan as part of the preparation of this paper.
21. M. Dodgson, 'Science, Technology, and Innovation: Issues and Rationales', in: M. Asher, D. Newman & T. Shyder (Eds), *Public Policy in Asia* (Westport, Quorum Books, 2002).
22. L. Kim, *Imitation to Innovation: the Dynamics of Korea's Technological Learning* (Boston, Harvard Business School Press, 1997).
23. DEST, *Science and Technology at a Glance* (Canberra, Department of Education, Science and Training, 2002).
24. Sakakaibara & Cho, *op. cit.*, Ref. 16.
25. W.-Y. Lee, 'The Role of Science and Technology Policy in Korea's Industrial Development', in: L. Kim & R.R. Nelson (Eds), *Technology, Learning and Innovation* (Cambridge, Cambridge University Press, 2000).
26. Kim, *op. cit.*, Ref. 22.
27. Sakakaibara & Cho, *op. cit.*, Ref. 16.
28. Dodgson, *op. cit.*, Ref. 6; H. Rush, M. Hobday, J. Bessant, E. Arnold & R. Murray, *Technology Institutes: Strategies for Best Practice* (London, International Thomson Business Press, 1996).
29. J.A. Mathews & D.-S. Cho, *Tiger Technology: The Creation of a Semiconductor Industry in East Asia* (Cambridge, Cambridge University Press, 2000).
30. M. Dodgson & J. Bessant, *Effective Innovation Policy: A New Approach* (London, International Thomson Business Press, 1996).
31. Dodgson, *op. cit.*, Ref. 6.
32. The arguments in this part draws heavily on M. Sakakibara, 'Formation of R&D Consortia: Industry and Company Effects', *Strategic Management Journal*, *23*, 2002, pp.1033–1050.
33. M.L. Katz, 'An Analysis of Cooperative Research and Development', *RAND Journal of Economics*, *17*, 1986, pp. 527–543.
34. J. Baum & C. Oliver, 'Institutional Linkages and Organizational Mortality', *Administrative Science Quarterly*, *36*, 1991, pp. 187–218; K.M. Eisenhardt & C.B. Schoonhoven, 'Resource-based View of Strategic Alliance Formation: Strategic and Social Effects in Entrepreneurial Firms', *Organization Science*, *7*, 1996, pp. 136–150.
35. J.P. Killing, *Strategies for Joint Venture Success* (New York, Praeger, 1983); K.R. Harrigan, *Strategies for Joint Ventures* (Lexington, Lexington Books, 1985); K.R. Harrigan, *Managing for Joint Venture Success* (Lexington, Lexington Books, 1986); V. Pucik, 'Strategic Alliances, Organizational Learning, and Competitive Advantage: The HRM Agenda', *Human Resource Management*, *27*, 1988, pp. 77–93; B. Borys & D.B. Jemison, 'Hybrid Arrangements as Strategic Alliances: Theoretical Issues in Organizational Combinations', *Academy of Management Review*, *14*, 1989, pp. 234–249.
36. Y.L. Doz, 'Technology Partnerships Between Larger and Smaller Firms: Some Critical Issues', *International Studies of Management and Organization*, *17*, 1987, pp. 31–57; K.J. Hladik, 'R&D and International Joint Ventures', in: F.J. Contractor & P. Lorange (Eds), *Cooperative Strategies in International Business* (Lexington, Lexington Books, 1988), pp. 187–205; R.N. Osborn & C.C. Baughn, 'Forms of Interorganizational Governance for Multinational Alliances', *Academy of Management Journal*, *33*, 1990, pp. 503–519; T.M. Jorde & D.J. Teece, 'Innovation and Cooperation: Implications for Competition and Antitrust', *Journal of Economic Perspectives*, *4*, 1990, pp. 75–96.

37. A.M. Spence, 'Cost Reduction, Competition, and Industry Performance', *Econometrica*, *52*, 1984, pp. 101–121.
38. W.M. Cohen, A. Goto, A. Nagata, R.R. Nelson & J. Walsh, 'R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States', working paper, Carnegie Mellon University, 1998.
39. M. Dodgson, *Technological Collaboration in Industry: Strategy Policy and Internationalization in Innovation* (London, Routledge, 1993).
40. W.M. Cohen & D.A. Levinthal, 'Innovation and Learning: The Two Faces of R&D', *Economic Journal*, *99*, 1989, pp. 569–610.
41. B. Kogut, W. Shan & G. Walker, 'The Make-or-Cooperate Decision in the Context of an Industry Network', in: N. Nohria & R. Eccles (Eds), *Networks and Organizations: Structure, Form, and Action* (Boston, Harvard Business School Press, 1992), pp. 348–365.
42. R. Gulati, R., 'Network Location and Learning: The Influence of Network Resources and Firm Capabilities on Alliance Formation', *Strategic Management Journal*, *20*, 1999, pp. 397–420.
43. W.J. Baumol, 'The Mechanisms of Technology Transfer, II: Technology Consortia in Complementary Innovations', in: *Entrepreneurship, Management, and the Structure of Payoffs* (Cambridge, MIT Press, 1993), pp. 193–222.
44. Gulati, *op. cit.*, Ref. 42; B. McEvily & A. Zaheer, 'Bridging Ties: A Source of Firm Heterogeneity in Competitive Capabilities', *Strategic Management Journal*, *20*, 1999, pp. 1133–1156.
45. O. Grandstand, P. Patel & K. Pavitt, 'Multi-technology Corporations: Why They Have "Distributed" Rather Than "Distinctive Core" Competencies', *California Management Review*, *39*, 1997, pp. 8–25.
46. Sakakibara, *op. cit.*, Ref. 32.
47. Sakakibara, *op. cit.*, Ref. 1.
48. *Ibid.*
49. M. Sakakibara, 'The Diversity of R&D Consortia and Firm Behavior: Evidence from Japanese Data', *Journal of Industrial Economics*, *49*, 2001, pp. 181–196.
50. Cohen & Levinthal, *op. cit.*, Ref. 40.
51. R.C. Levin, A.K. Klevorick, R.R. Nelson & S.G. Winter, 'Appropriating the Returns from Industrial Research and Development', *Brookings Papers on Economic Activity*, *3*, 1987, pp. 783–820.
52. F. Kodama, *Emerging Patterns of Innovation* (Boston, Harvard Business School Press, 1995).
53. Katz, *op. cit.*, Ref. 33.
54. Sakakibara, *op. cit.*, Ref. 49.
55. Sakakibara, *op. cit.*, Ref. 1.
56. L. Branstetter & M. Sakakibara, 'Japanese Research Consortia: A Microeconometric Analysis of Industrial Policy', *Journal of Industrial Economics*, *46*, 1998, pp. 207–233.
57. L. Branstetter & M. Sakakibara, 'When Do Research Consortia Work Well and Why? Evidence from Japanese Panel Data', *American Economic Review*, *92*, 2002, pp. 143–159.
58. Katz, *op. cit.*, Ref. 33.
59. Branstetter & Sakakibara, *op. cit.*, Ref. 57.
60. Sakakibara, *op. cit.*, Refs. 1 and 7.
61. M. Sakakibara & L. Branstetter, 'Measuring the Impact of U.S. Research Consortia', *Managerial and Decision Economics*, *24*, 2003, pp. 51–69.
62. Sakakibara, *op. cit.*, Ref. 7.
63. T.J. Klette, J. Moen & Z. Griliches, 'Do Subsidies to Commercial R&D Reduce Market Failure? Microeconometic Evaluation Studies', *Research Policy*, *29*, 2000, pp. 471–495.
64. Sakakibara, *op. cit.*, Refs. 1, 7 and 19.
65. Branstetter & Sakakibara, *op. cit.*, Ref. 56 and 57.
66. This section is based on M. Dodgson & S. Hinze, 'Indicators used to measure the Innovation Process', *Research Evaluation*, *8*, 2000, pp. 101–114.
67. G. Duysters & J. Hagedoorn, 'International Technological Collaboration: Implications for newly industrializing economies', in: L. Kim & R.R. Nelson (Eds), *Technology, Learning and Innovation: Experiences of Newly Industrializing Economies* (Cambridge, Cambridge University Press, 2000), pp. 193–215; J. Hagedoorn, A.N. Link & N.S. Vonortas, 'Research Partnerships', *Research Policy, 29*, pp. 567–586.

68. See M. Castells, *The Rise of the Network Society* (Oxford, Blackwell, 1996).
69. Dodgson & Bessant, *op. cit.*, Ref. 30.
70. M. Dodgson & Y. Kim, 'Learning to Innovate: Korean Style—the case of Samsung', *International Journal of Innovation Management*, *1*, 1997, pp. 53–67.
71. Mathews & Cho, *op. cit.*, Ref. 29.
72. M. Hobday, 'Innovation in East Asia: Diversity and Development', in: M. Dodgson & R. Rothwell (Eds), *The Handbook of Industrial Innovation* (Cheltenham, Edward Elgar, 1994), pp. 94–105.
73. Kim, *op. cit.*, Ref. 22; Dodgson, *op.cit.*, Ref. 6.