Social Capital and International R&D Collaboration

Theoretical Thoughts and Evidences

Ning Li

ABSTRACT

The ongoing process of globalization is reinforced by international R&D collaboration through flow of knowledge across boundary of nations. Although studies of international R&D collaboration are numerous, few of them have related this phenomenon to cultural elements such as values, attitudes, and norms. This paper analyzes social capital in international R&D collaborations. The author proposes three arguments: (1) although traditional scientific culture fails to foster social capital because of lack of mutual trust, it has changed towards more group-oriented over time. (2) while both scientific culture and national culture contribute to creation of social capital in R&D collaborations, the extent to what each culture plays depends on the knowledge intensiveness of the R&D area. The more knowledge intensive an R&D area is, the stronger role scientific culture plays in this area; and (3) the increase in international R&D collaboration is partially resulted from the increase of social capital in scientific communities, and this in turn reflects the shift of traditional scientific culture.

INTRODUCTION

The process of globalization has been accelerated by tremendous innovations in science and technology, especially by innovations carried out through international R&D collaborations that encourage cross-national flows of knowledge. This phenomenon can be attributed to, among many reasons, increasing cost and risk in R&D and endogenous complexity of science and technology. Research and development (R&D) activities are changing from individual oriented to group oriented and the locus of a large proportion of R&D are moving from within an organization to more than one organization through network of institutions.

The increase of international R&D collaborations has got much emphasis. Several important aspects such as inter-firm linkage, strategic alliance, and network learning, have aroused research interests of scholars. However, most of the studies are based on a rather "traditional paradigm" of the management and control and have not put sufficient emphasis on interactions between individual scientists and the dynamic, flexible new organizations and institutional arrangements (for example, Belussi and Areangeli, 1998; Gassmann and Zedtwitz, 1999; Hicks and Katz, 1996, Niosi, 1999; and Raan, 1997). Particularly, few of these studies have related this phenomenon to cultural elements such as values, attitudes and norms within scientific community

This paper tries to discuss cultural impacts on international R&D collaboration using a theoretical framework of social capital and proposes some arguments. Social capital refers to stocks of cultural elements such as social trust, norms, and values that people can draw upon to solve common problems for mutual benefits. It is a research approach to deal with cooperation between individuals and between organizations. The main arguments of this paper are as follows. First, traditional scientific culture fails to foster social capital mutual because of the shortage of mutual trust. However, it has been changed towards more group-oriented over time due to increasing endogenous complexity of science and technology, combined with some political and economic factors and these changes have resulted in an increase of social capital. Second, both scientific culture and national culture contribute to the creation of social capital in R&D collaborations, and the extent to which each culture influences depends on the knowledge intensiveness of the R&D areas in which people cooperate. The higher the intensiveness of knowledge in an area, the more influential the scientific culture is. Finally, the increase in international R&D collaboration partially results from the increase of social capital in scientific communities. This in turn reflects the shifts of traditional scientific culture towards more group-oriented

This paper is organized in the following way. First, social capital in scientific community is studied in some details, including traditional norms, reasons of changing, and new patterns of social capital in scientific community. Second, national cultural differences and their role in R&D behaviors are investigated, and a comparison between the roles played by national culture and scientific culture is provided. Third, issues related to international R&D collaboration, such as the role social capital plays and the reasons for more cooperation, are discussed. Evidence is also provided. Finally, main findings of this paper are concluded.

SOCIAL CAPITAL IN SCIENTIFIC COMMUNITY

Social Capital: Main Features

Social capital deals with features of human behaviors (e, g, networks, norms, and trust) that facilitate coordination and cooperation for mutual benefit. Some features of social capital have been recognized through a series of studies. Scholars like Coleman (1988), Fukuyama (1995, 1999, 2000), and Putnam (1993, 2000) have applied the concept of social capital to a wide range of issues, from explaining economic performance to building social order, and in various level of magnitude, from individuals, to organizations, to regions, and to nations. Among many characteristics of social capital some are noteworthy. First, the constituent elements of social capital are trust, norms, and networks. Trust is developed over time as individuals gain confidence in the reliability of others in a series of interactions. Norms of appropriate behavior are formed as a social contract through interactions among actors. The norms of reciprocity are fundamental to productive relationships (Fukuyama, 1999). Usually actors within collaborative networks behave not only in the interest of the group but also in their own long-term self-interest. Here, a reputation for trustworthiness is essential.

Second, the size of cooperation network may expand over time. Social capital is located both in the sharable resources held by individuals and in the cooperation network. A network develops when a group of individuals or organizations develop reliable, productive communication and decision channels (Fountain, 1998). For example, a group of scientists who have collaborated on a relatively small scientific project may then use their collaborative ability to propose and to complete larger, more complex research projects. While trustful relations tend to be self-reinforcing in the positive direction, mistrust tends to cycle in the negative direction.

Third, social capital is created when coordination (cooperation) costs are less than its benefits. Coase (1937) compared the cost of coordination and its benefits in his study of the formation of firms. He argues that a firm will continue to expand until the former exceeds the later. This notion has gone far beyond firms since its first inducement. In a human society, transaction costs involved in the coordination process differ under different cultures. Although in most situations partners tend to be better off when they cooperate each other, under a condition in which people tend to rely on a hierarchy to enforce appropriate behavior, collaboration between people is usually not favored.

Fourth, social capital is inherently neither good nor bad. It is a tool that may be employed for legal or illegal purposes, for good or bad. Trust allows actors to engage in productive collaboration, but trust also provides a necessary condition for fraud and other illegal activities. For example, network of firms collaborating to produce new technologies or applications widely report the benefits of cooperation; cartels, unfortunately, also understand the benefits of network approaches to production and distribution. The use of the concept of social capital depends entirely upon the values and objectives of the actors involved.

Finally, social capital can be either more inward looking or more outward looking. Putnam (2000) refers the two directions as bonding social capital and bridging social capital. According to Putnam, bonding social capital tends to reinforce exclusive identities and homogeneous groups by choice or by necessity, while bridging social capital encompasses people across diverse social cleavages and is better for linkage to external assets and information diffusion. For example, ethnic fraternal organizations are bonding and civil rights movement is bridging.

Traditional Culture in Scientific Community

Before going any further into how social capital influences R&D activities, it is necessary to have a discussion on culture in scientific communities. Within scientific community, norms and values are essential to understanding how social capital is formed and how it changes (increases or decreases). With regard to R&D activities, two features stand out as the fundamental traditions in scientific community: hierarchy and competition.

First, cultures in scientific community can be characterized by a system of stratification with elitist in the extreme. This is typically a hierarchical structure. In such a system, only those people who get the most attention, that is, who are best known enjoy a so-called "multiplier effect" (Merton, 1968). Horizontal information flows are very rare.

The structural hierarchy has direct impact on information flows and resource allocation. In the communication system, a scientific contribution has greater visibility in the community of scientists when it is introduced by a scientist of high rank than when it is introduced by one who has not yet made his mark. In allocation of scientific resources, centers of demonstrated scientific excellence are allocated for larger resources for investigation than centers, which have yet to make their mark. The social processes of social selection that deepen the concentration of top scientific talent create extreme difficulties for any efforts to counteract the institutional consequences of the "Matthew effects" in order to produce new centers of scientific excellence.

Second, closely related to the hierarchical structure, scientific community is highly competitive. Merton (1969) states that in science communities, the race for priority, which has been frequent throughout the entire era of modem science, might provide clues to ways in which the institution of science shapes the motives, passions and social relations of scientists. As a result, this may lead to deviant behavior of scientists, because the priority is often morally judged, not systematically investigated. Scientific behavior is mainly an exchange of information for recognition. Information is a gift made in conformity with the norms of science, but needing to be legitimated by the scientific specialty within which it is produced (Glasner, 1996). Deviance occurs when either gifts are not made or the recipients do not give them the expected degree of recognition.

Beside the high competitiveness for scientists in race for priority of scientific discoveries, commercial technology fields see an even more fierce competitiveness in the pursuit of patents. Since being granted a patent means a right of monopoly for benefit from producing the products, it is a kind of competitiveness driven by economic interests.

Therefore, traditional cultures in scientific communities do not encourage the creation of social capital. Traditionally the level of trust in science community is pretty low. The nature of high competitiveness and hierarchy may lead scientists to be cautious in trying to find flaw in others' publications and to be defensive. As long as an individual can handle a research project by himself, others are not like to be involved.

Changes of Social Capital in Scientific Community: Causes and Effects

Although in the present times traditional scientific cultures are still effective and sometimes even dominate behavior of scientists, scientific culture has been experiencing a shift from individual oriented to more group-oriented. The driving forces for the changes are both endogenous and exogenous. They together make changes in scientific culture inevitable.

First, increasing complexity in science and technology provides endogenous incentive for R&D cooperation among scientists. One the one hand, the development of scientific enterprise has long been in an era labeled as "big science" by Price (1963). "Big science" reflects not only the institutionalization but also the complexity of intemal logic of sciences. Scientific knowledge is increasing sharply towards two directions: the emerging of news disciplines and synthesis and integration based on multidisciplinary research. The expanding volume of scientific information makes it increasingly difficult for scientists to locate information they need for research. Scientists who have no relationship with the large groups of collaborators in their research areas have the greatest difficulties to do so. On the other hand, network is crucial to modern R&D. Leveque, Bonazzi, and Quental (1996) argues, for exploratory R&D[1], the main source of performance is its leaming capacity and cooperation facilitates learning through involvement of partners that permits easy access to the partners' competences and skills. This notion is consistent with the beliefs by Rycroft and Kash (1999) in talking about the technological innovation for complex technologies.

Second, external factors like economic and political forces may drive the norms in scientific community towards group-oriented as well. With regard to political forces, on the one hand, government-industry relationships have contributed to the increase of cooperation in science and technology through government regulation and incentives. In this category, Advanced Technology Program (ATP) is a good example. On the other hand, international scientific agreements also promote cooperation between scientists. In many times this kind of agreements are signed to fulfill the needs of scientists. Rather, they are signed because of politics

As to economic factors, risk-sharing and cost-sharing are the main motivations for collaborative R&D. Nowadays, although firms more than ever rely heavily on product and process innovation in order to stay ahead of or in parallel with their competitors, they seem to be withdrawing from the significant support for basic research. Even governments seem to be shifting the portfolios of research they support toward the areas and kind of projects that promise short-run and specific results (Ostry and Nelson, 1995). The main reasons for that lie in the facts that R&D is often with high-risks and large amount of investment. Here, cooperation in R&D between firms and between private and public sectors become alluring.

Improvement of infrastructure also contributes to the increasing of R&D cooperation by making cooperation more efficient. Lederberg and Uncapher (1989) from NSF argue that, with new electronic technologies (mail, teleconferencing, databases, supercomputers, remote accessing and so on), new types of cooperation are the combination of technology, tools, and infrastructure that allow scientists to work with remote facilities and as if they were co-located and effectively interfaced. The collaboration will provide a seamless access to colleagues, instruments, data, information and knowledge. Researchers celebrate the ability of information technology to make distance and time constraints virtually meaningless and through this way they constitute a "virtual community" (Blanchard and Horan, 1998).

The Modern Scientific Culture

The most important propensity of cultural change in scientific communities in response to the above endogenous and exogenous driving forces is that in modern times R&D is more group oriented than ever. Price (1963) compares what he calls "little science" and "big science" and notes that as a result of the transition from the former tot the latter, scientists tend to communicate person to person instead of paper to paper, in the most active areas they diffuse knowledge through collaboration, and they seek prestige and the recognition of themselves through peer reviews. Crane (1972) emphasizes the importance of informal communication system in basic science in which knowledge is disseminated through personal contacts. Saxenian (1994) argues that informal networks among scientists in Silicon Valley are critical to its technology development. Informal networks in Silicon Valley are formed through repeated interaction between scientists with common employment history and common education background.

Numerous conferences in science ad technology fields provide opportunities for scientists not only to exchange information but also to build relationship between each other. Scientific conferences are held much more frequently all over the world than before. It is quite common for a scientist to make his decision to attend a conference mainly because of the opportunity provided for meeting people face-to-face in order to establish relationships for future cooperation.

Therefore, although more cooperation increases social capital in scientific community, it also heightens the entry barriers to this activity, keeping others away from some of the sources of relevant knowledge (Leveque, Bonazzi, and Quental, 1996). Social capital in scientific community is typically a bonding one.

The trend that R&D is now more group-oriented than before does not necessarily mean the traditional culture of scientific community has been overturned. Rather, it is just that scientist group has replaced individual as a unit to struggle for higher position in science hierarchy and to compete with others for priority of scientific discoveries. One analysis of how such dynamics work to ensure the development of science and technology ahs been called actor-network theory (Latour, 1987). Science proceeds through the development around a specialty of heterogeneous networks which involve non-human as well as human actors. A group of researchers will use a variety of strategies to convince others that their view of nature is dominant. The extent to which the group persuades other to enroll in the network depends on the degree to which it is seen as representing all of them and their interests. Collins (1985) uses a similar idea of a core–set to describe the small group of experienced and qualified persons who actively contribute to scientific debate. However, change within the constitution of the community often occurs not through the development of knowledge but as the result of pathology which distorts its boundaries. Membership of the core-set is thus as much a question of power and control as of knowledge and expertise. Crane (1972) describes how conflict between groups of collaborators occurs as follows. In their early stages of rapid growth, the productive scientists have not had time to develop sizable groups of colleagues. Interaction between them and other members of the area is unrestrained. After a number of years, the same scientists have established themselves at the centers of clusters of collaborators and students. They tend both to defend their own ideas and to resist ideas put forward by newcomers. Sometime they discount new ideas as being not really new.

THE IMPACT ON R&D: SCIENTIFIC CULTURE VS. NATIONAL CULTURE

National Cultures and Their Impacts on R&D

Besides scientific culture, national culture may have impact on R&D collaboration behavior as well. Both scientific culture and national culture may be influential in creation of social capital in R&D collaboration. Norms, values, shared cognitive structures, belief systems, and relational networks arising in the national societal context to a large extent determine the way individuals and organizations behave. Scientists and other actors in R&D perform not only in scientific communities but also in a much broader environment – the national society. Their behaviors cannot be separated from social lives, including customs, morals, and habits of the society. For any kind of R&D activities – individual, group-based, or organizational networks, one might expect that there to some extent exists a relationship between national culture and R&D performance.

At national level, there are significant cultural differences among societies. National cultures may reveal themselves in patterns of differences among norms, attitudes, and values. Harrison (1997) compares North and South America and finds that Canada and the United States have been powerfully influenced by Anglo-Protestant culture, in which those and other progress-prone values are emphasized. Latin American has been powerfully influenced by Ibero-Catholic culture, which accords lower priority to those values. Fukuyama (1995) indicates the levels of trust between people are not equal in various societies. High trust societies have higher level of social capital and lower level of social capital may be found in lower trust societies.

National cultural differences may be well seen through a comparison between the United States and Japan. Lipset (1996) notes that, as a relative new society, the United States lacks the emphasis on social hierarchy and status differences characteristic of postfeudal and monarchical cultures. He addresses that Americans place less emphasis on obedience to political authority and on deference to superiors; they have a vision of a weak state and powerful private institutions; and they have weak group-oriented commitments due to their religious tradition which emphasizes individualism and personal rights. Unlike the United States, Japan has a national culture of deference to authority, collectivity orientation, conflict aversion, and respect for age (Abegglen, 1958). Japanese organizing principles reflect the group-oriented norms of the postfeudal, aristocratic *Meiji* era. Japanese society still emphasizes hierarchy in interpersonal relations and places heavy reliance on its directing role. Okimoto (1989) describes the Japanese deep-seated values as the emphasis on the group over the individual; the stress on harmony; cooperation and competition; achievement and ascription; hierarchy and equity; obligation; long-term, no-exit commitments; reciprocity; the sharing of risks, cost, and benefits; and mutual trust.

If cultures influence behaviors and their differences are significant at national level, their effects should be visible cross-nationally. This notion is highly appreciated by culture relativists in explaining economic performance and social structure in different nations. Holding the example

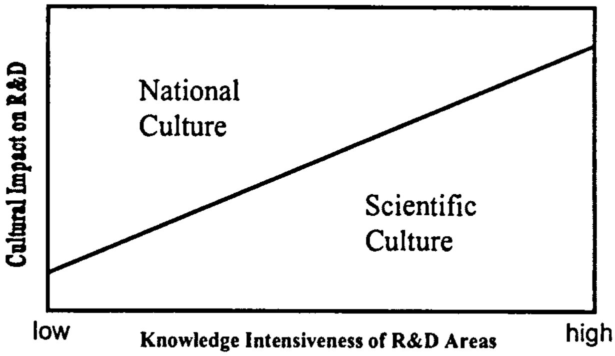

Figure 1. *Cultural Impact and Knowledge Intensiveness in Areas of International R&D Collaboration.*

of the contrast between the United States and Japan, given the fact that individualism being favored by the former and collectivism emphasized by the latter, one may expect some patterns of different behaviors in R&D activities. With regard to decision-making in R&D, one would expect to see that in the United States tradition is competitive, individualistic, and go-it-alone, while in Japanese culture for centuries decisions have been reached only by participation of all involved parties via repeated, iterative conversations (Kline, 1989). As to training of people in R&D, one would expect that while the United States puts less concern for fairness and humane treatment of scientists and, thus, pays less attention to development of human resources, Japan treats all people with dignity with a recognition that intelligence and knowledge should be shared and takes development of human resources as an important objective. As to distribution of tasks among cooperators in R&D, one may expect that in the United States tasks are often broken down to single individuals, while in Japan tasks are distributed to cooperative groups.

If the above expectations may come true, one would conclude that social capital in R&D is much higher in Japan than in the United States. However, so far no evidence has been found strongly supporting this notion, especial in high technology fields such as information, biotechnology, and advanced materials. The reason for that is that national culture is not the only determinant, another culture – scientific culture is effective in R&D as well.

Scientific Culture vs. National Culture

Social capital theory may be utilized in different levels: organizational, national, and international. When international level applies, two cultures appear to be influential to the formation of social capital in R&D: national culture and scientific culture. Now the key question becomes: which culture, scientific culture, or national culture, dominates the cultural aspect in international R&D collaboration?

This paper argues that national culture and scientific culture jointly influence R&D activities. The extent to what each culture plays depends on the knowledge intensiveness of the R&D area. The more knowledge intensive an R&D area is, the stronger role scientific culture plays in this area. Similarly, the less knowledge intensive an R&D area is, the stronger role national culture plays. The framework is shown in Fig 1.

For scientists, although international R&D cooperation may have something to do with nations from different cultures, national culture has much less impact on the collaborative behavior in R&D than scientific culture does. In other words, scientific culture is superior to national culture in scientific community. This notion is consistent with patterns of behavior of scientists. Merton (1969) provides the most enduring exposition of behavioral patterns in scientific community. He argues that four sets of institutional imperatives – universalism, communism, disinterestedness, and organized skepticism – are taken to comprise the ethos of modern science. Several points may be derived from the above characteristics. First, according to universalism, communism, and organized skepticism, the scientific community has a strong tendency to eschew particularism, to share openly the results of its discoveries, and to test all knowledge claims to the limit. Scientists share common creeds (discusses above) and usually have their own terms (common language) in a particular field to express themselves. All scientists, bounded by these norms, try to translate knowledge claims into certified knowledge regardless their social and geographic location.

Second, because of disinterestedness, scientists search for truth for its own sake, apart from the interest of class, status, nation, or economic or other rewards. In the field of philosophy of science, there is a strong argument saying that science is value free (Lacey, 1999; Proctor, 1991). That is, science has its own values systems (common criteria and understanding) and is free of traditional values or norms, such as religions, morals, etc. In other words, science is neutral – science and social values only touch; they do not interpenetrate.

Other reasons for superiority of scientific culture over national culture in scientific community may be found in the nature of tasks of R&D and in the quality of scientists. On the one hand, in doing R&D scientists deal more with data, equipment, and papers than with people. Thus, social values count less in R&D than in most other fields. On the other hand, scientists are those people who have relatively higher education. They have opportunities to access cultures of other nations. They are more flexible and more adaptive than people in other areas in collaboration with colleagues from other nations.

Based on the notion that in scientific communities scientific culture is superior to national culture, one would think that cultural impacts are different in different R&D fields. In R&D areas that are extremely knowledge intensive, for example, high-technology areas, because the main actors in R&D are scientists, scientific culture dominates. If international R&D collaborations occur in low technology fields, more engineers and skilled workers may be involved and more emphasis should be give to various national cultures.

SOCIAL CAPITAL AND INTERNATIONAL R&D COOPERATION

Forms of International R&D Cooperation and the Role Social Capital Plays

To study international R&D cooperation, it is necessary to identify actors and forms. In this paper, actors of international R&D cooperation are divided into three levels: individual, research group, and organization. Universities, public research institutions, and firms (domestic and multinational) are regarded as actors at the organizational level. Accordingly, individuals and research groups within the above organizations are seen as actors at individual level and group level respectively.

Forms of collaboration are diverse. At the level of individual and research group, it takes the forms of joint scientific projects, scientific exchanges, sabbatical years, and international flows of students. While at the organizational level, joint ventures for specific innovative projects, productive agreements with exchange of technical information and/or equipment, and multinational firms are dominant. Table 1 lists some examples of networks for international R&D collaboration. Here, collaboration is divided into two categories: formal cooperation and informal cooperation. Formal cooperation is represented by large facilities, specific programs of support and activity governed by contacts and scientific agreements. Informal cooperation is undertaken by scientists as they travel, communicate and exchange ideas and materials without embodying the relationship in a contract (Georghiou, 1998). Networks exist in various kinds of informal and formal cooperation.

Neither informal nor formal R&D cooperation can stand alone without social capital. Two factors, bargaining power and mutual trust, are critical to the efficiency and successfulness of a network in all three levels of cooperation. Bargaining power decides the role an actor plays and the benefits he/it can get from cooperation. It enables an actor to appropriate as much of the value-added associated with the information and knowledge created as possible and helps the actor to preserve the central role in managing the web of relationships. Mutual trust is necessary to avoid any potential conflict in the network and it is built on the base of bargaining power.

With regard to informal cooperation, bargaining

Table 1. Examples of Networks for International R&D Collaboration.

Actors	Individuals	Groups	Organizations
Individuals	Scientific exchanges, Research partners	Scientific exchanges Research partners Joint projects	Visiting scientist Access to facilities
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Formal vs. Informal collaboration	Informal ——→ Formal		

power are mainly academic reputations actors have built for themselves through publication, patenting, and peer review. Other relationships like common experience in education, employment, and conference are also helpful to the creation of bargaining power. Mutual trust in informal cooperation has at least two aspects. On the one hand, actors should share relevant information with their partners without hiding. That is, actors should make as big as possible contribution to the cooperation. On the other hand, there should be no cheating in research through the whole process. Taking it as a basic function of the traditional culture of science community, scientists are always critical to the work of other fellows. Once a cheating by a scientist is found, he on longer has any academic reputation.

Formal cooperation results from formal agreements and contracts between organizations. Social capital is the key to assure success collaboration. This is because that no matter what kind of agreements or contracts, human beings are always involved in the process, and that whenever people are involved in cooperation, social capital matters. First, within an organization which is involved in cooperation, a group of scientist may work together to be responsible to the agreements or contracts with other organizations. Second, inter organizational relationship is often maintained by individual people.

Social capital is necessary to assure a successful collaboration. Openness and efficiency in information change within a network that provides cooperative organizations with new sources of efficiency and opportunities for innovation is crucial to gain advantages over others. For formal cooperation lack of social capital, it is most likely highly conflicting, mired in contractual disputes and suffering of lack of coordination. However, with plenty of social capital, a network is with high performance and is good at collaboration. Social capital increases the ability to create and utilize informational capital because trustful relationships increase information flows and bring richer meaning to information (Fountain, 1998).

Two points deserves more attention. First, social capital encompasses not only shared access to vast amounts of timely information but also many positive properties of interdependence, such as shared values, goals, and objectives; shared expertise and knowledge; shared risk, accountability, and trust; etc. Second, entry barriers to the network remain very high, especially to actors who are short of bargaining power.

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Neither informal nor formal R&D cooperation can stand alone without social capital. Two factors, bargaining power and mutual trust, are critical to the efficiency and successfulness of a network in all three levels of cooperation. Bargaining power decides the role an actor plays and the benefits he/it can get from cooperation. It enables an actor to appropriate as much of the value-added associated with the information and knowledge created as possible and helps the actor to preserve the central role in managing the web of relationships. Mutual trust is necessary to avoid any potential conflict in the network and it is built on the base of bargaining power.

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Social capital is necessary to assure a successful collaboration. Openness and efficiency in information change within a network that provides cooperative organizations with new sources of efficiency and opportunities for innovation is crucial to gain advantages over others. For formal cooperation lack of social capital, it is most likely highly conflicting, mired in contractual disputes and suffering of lack of coordination. However, with plenty of social capital, a network is with high performance and is good at collaboration. Social capital increases the ability to create and utilize informational capital because trustful relationships increase information flows and bring richer meaning to information (Fountain, 1998).

Two points deserves more attention. First, social capital encompasses not only shared access to vast amounts of timely information but also many positive properties of interdependence, such as shared values, goals, and objectives; shared expertise and knowledge; shared risk, accountability, and trust; etc. Second, entry barriers to the network remain very high, especially to actors who are short of bargaining power.

Why does International R&D Collaboration Increase in Science-based Technologies?

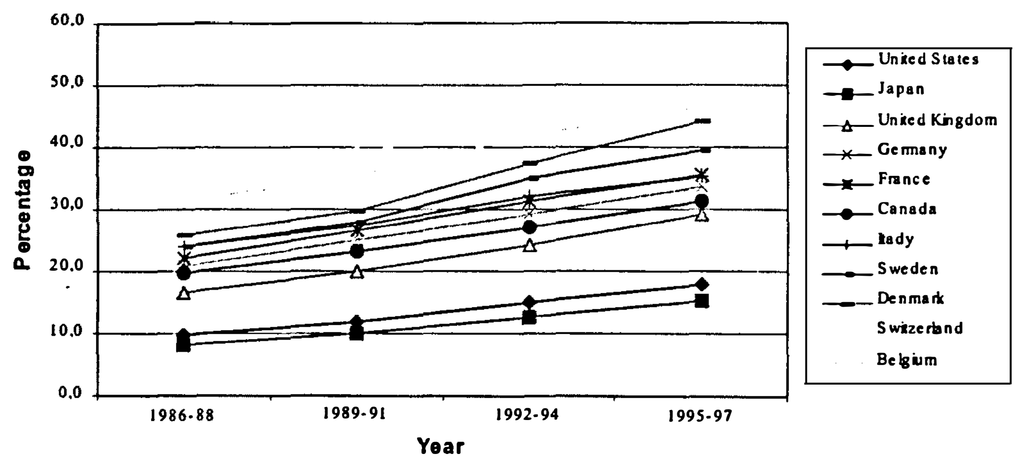
In the previous sector, several causes for increasing R&D collaboration have been discussed. The main causes are as follows: the endogenous complexity of science and technology, the political factors such as government-initiated programs and international agreements, the economic factors such as risk sharing, investment sharing, and long-term planning, and the better infrastructure such as telecommunications and transportation systems.

In discussion of why international R&D collaboration increases in science-based technologies, in addition to the causes mentioned above, some notions need to be addressed. On the one hand, science base and talent pools are distributed in various locations across national borders. Not a single nation would declare that it is in a leading position in all science and technology fields. The distribution of highly-advanced scientific and technological knowledge bases requires international cooperation in order to achieve efficient generation of knowledge. Thus, it is important for leading company to think about acquiring knowledge from other nations, whether the company is based in a large country with a powerful and advanced research capability in the particular fields, or whether there is only a small, less-developed R&D base in the home country (Gerybadze and Reger, 1999). For example, Ericsson from Sweden in communication, Philips from Netherlands in consumer electronics, or Roche from Switzerland in pharmaceutical/biotechnology.

On the other hand, international R&D cooperation increases because of country-specific conditions. The global distribution of customer-related knowledge pools and of country-specific conditions makes it necessary for learning from advanced users. Customer requirements are also important determinants (Gerybadze and Reger, 1999). A good example is in the pharmaceutical industry because countries may have different regulation of drug production and sells.

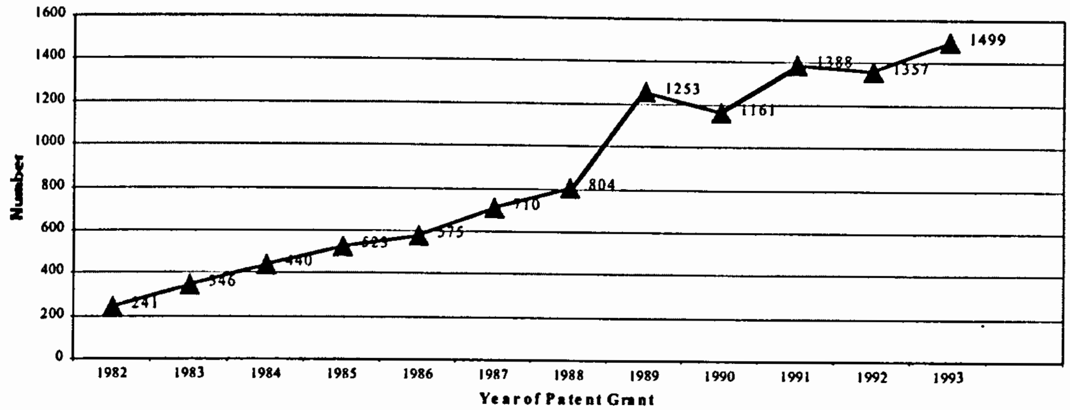
Increasing International R&D Collaboration: Evidences

Globalization of R&D is a major topic for academic researchers and for decision-makers in government. A particularly strong trend towards the globalization of R&D began in the 1980s and now no end to this process is yet in sight. International R&D cooperation serves as a vehicle for the diffusion of knowledge and technological expertise (Archibugi and lammarino, 1999). Evidence of increases in international R&D collaboration will be provided in terms of co-authorship in scientific papers, co-inventors of patenting in the United States, globalization of R&D in multinational firms, and formation of international strategic technology alliances. Cooperation resulted from the above involves both formal and informal patterns. Again, for both informal cooperation and formal



Source: Data compiled from National Science Board, 2000

***Figure 2.** Percent Internationally Co-authored Papers.*



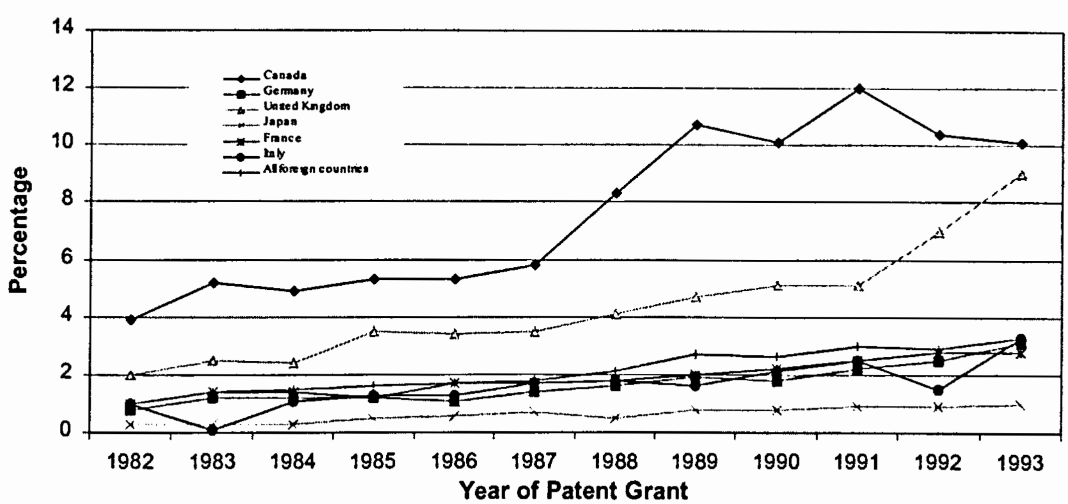
Source: Data compiled from Brown and Hirahayashi, 1996

Figure 3. *Number of Utility patent Grants with US and foreign Resident Co-inventors.*

cooperation, social capital is key to ensure the successfulness and efficiency.

Co-authorship in Scientific Papers

According to National Science Board (2000), co-authorship in scientific papers increases sharply for international cooperation. Compared the period of 1995 to 1997 with the period of 1986 to 1988, the percentage of co-authored papers in the world rose by 46%, while percentage of international co-authored papers rose by 115%. In 1995-1997, 15% of world scientific papers ere written by international teams. Figure 2 indicates some features of increasing international co-authorship in scientific papers for selected countries.



Source: Data compiled from Brown and Hirahayashi, 1996

Figure 4. *Percentage of all US Utility Patents with Foreign Resident Inventors also naming a US Resident Invent, by country of residence of the foreign inventor.*

Table 2. *R&D intensities and R&D internationalization in 20 companies.*

Ranking in annual R&D expenditure	Company	R&D intensity 1993 in percent	Share of foreign R&D 1993 in percent	Industry
1	Siemens	9.2	28	Electrical engineering
2	IBM	7.1	25	Computers
3	Hitachi	6.7	2	Electrical engineering
4	Matsushita Electric	5.7	12	Consumer electronics
5	ABB	8.0	90	Electrical engineering
6	NEC	7.8	3	Telecommunications
7	Philips	6.2	55	Electrical engineering
8	Hoechst	6.2	42	Chemical / pharmaceutical
9	Sony	5.8	6	Consumer electronics
10	Ciba-Geigy	10.6	54	Chemical / pharmaceutical
11	Bosch	6.7	9	Electrical engineering
12	Roche	15.4	60	Chemical / pharmaceutical
13	Mitsubishi Electric	5.2	4	Electrical engineering
14	BASF	14.5	20	Chemical / pharmaceutical
15	UTC	5.4	5	Advanced engineering / aeroengines
16	Sandoz	10.4	50	Chemical / pharmaceutical
17	Sharp	7.0	6	Consumer electronics
18	Kao	4.6	13	Chemical / cosmetics
19	Eisai	13.2	50	Chemical / pharmaceutical
20	Sulzer	3.4	27	Advanced engineering

Source: (Gerybadze and Reger, 1999)

Co-inventors of Patenting in US-foreign Cooperation

Co-patenting is also a good indicator of international R&D cooperation. Figure 3 and 4 are evidence of US-foreign cooperation. From 1982 to 1993, the number of utility patent granted in the United States with US and foreign resident co-inventors increases from 241 to 1439. Percentage data shown in Figure 4 indicate steady increases in cooperation for all the selected countries. It is quite reasonable that Canada and United Kingdom have much high rates than other countries given their geographical location and historical relationship with the United States.

Globalization of R&D in Multinational Firms

Large multinational firms are the drivers for the internationalization. Gerybadze and Reger (1999) list 20 companies which are among the leading R&D performing industrial firms worldwide. Many of them are technology leaders in their specific businesses, and they are far advanced in terms of R&D internationalization (Table 2). Note that companies in high technology fields, such as computers and chemical/ pharmaceutical, have higher shares of foreign R&D, compared with firms in other industry fields.

Formation of International Strategic Technology Alliances

Industrial firms increasingly have used global research partnerships to strengthen their core competencies and expand into technology fields they consider critical for maintaining market share. In these partnerships, organizations can expand opportunities and share risks in emerging technologies and emerging markets. In early 1970s, strategic alliances were almost nonexistent, but they began expanding rapid late in the decade. R&D-related international strategic technology alliances increased sharply throughout the industrialized world in the early 1980s, and in early 1990s decreased sharply for a couple of years and then started rapid increase again (National Science Board, 2000). Figure 5 shows the pattems

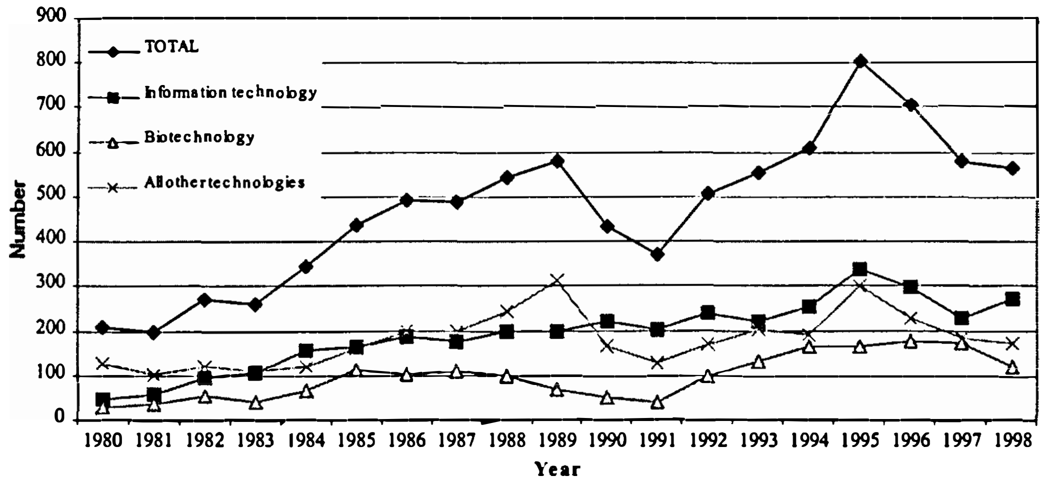
Intemationalization Pattems in Different Countries

It is very interesting to compare globalization patterns in different countries. From the evidence provided above, one can easily find out that sharp differences exist in the United States, Japan, large European countries, and small European countries. Large European countries with a predominant academic base in their home country tend to concentrate a significant part of their research in the country of origin, such as Germany, France and Italy. Small European countries are much more active in participating foreign research pools. For example, countries like Denmark, Belgium, and Switzerland. Large firms in small European countries, for example, Philips, ABB, Ciba, Roche, Sandoz/CH, tend to be more intemationalized than firms from other countries. Japan has the lowest rate of cooperation both in terms of intemational co-authorship and co-patenting. All Japanese firms listed in Table 2, such as Sony, Sharp, Hitachi, NEC and Mitsubishi Electric, have foreign R&D ratios well below 10%. The United States, based on their strong national research base, are less intemationalized with respect to R&D investments than European countries, but somewhat more active than Japan.

CONCLUSIONS

The theory of social capital provides a framework for analyzing international R&D collaborations between individuals and between organizations through investing cultural factors, such as trust, norm and network, in scientific communities. An investigation indicates that traditional scientific culture is not supportive to creation of social capital within scientific communities. Traditional scientific culture is characterized by two patterns: hierarchy and competition. The former may be described as a system of stratification with elitist in the extreme. The latter notion may be derived from the race for recognition of priority in scientific discoveries and technological inventions. As a result, on cannot expect a high level of trust between scientists and a low level of social capital in scientific communities is seen.

Although at present time traditional scientific culture still counts and sometimes even dominates behavior of scientists, scientific culture has been experiencing a switch from individual oriented to more group-oriented. First, increasing complexity in science and technology provides endogenous incentive for R&D cooperation among scientists. Second, extemal factors like economic and political



Source: Data compiled from National Science Board, 2000

***Figure 5.** New Intemational Stragegic Technology Alliances, by technology.*

forces also drive the norms in scientific community towards group-oriented. The political factors, such as government-initiated programs and international agreements, and the economic factors, such as risk sharing, investment sharing, and long-term planning systems, encourage or force scientists to work together, and better infrastructures such as telecommunications and transportation make group work more convenient.

However, the trend that R&D is now more group-oriented than before does not necessarily mean the traditional culture of scientific community has been overturned. Rather, it is just that scientist group has replaced individual as a unit to struggle for higher position in science hierarchy and to compete with others for priority of scientific discoveries. Although more cooperation increases social capital in scientific community, it also heightens the entry barriers to this activity, keeping others away from some of the sources of relevant knowledge. Social capital in scientific community is typically a bonding one.

In discussion of impact of culture on international R&D cooperation, both national and scientific cultures may be influential to the formation of social capital. Besides scientific culture, social norms and values may well influence individual as well as organizational behaviors in R&D collaboration. The extent to what each culture plays depends on the knowledge intensiveness of the R&D area. The more knowledge intensive an R&D area is, the stronger role scientific culture plays in this area. Similarly, the less knowledge intensive an R&D area is, the stronger role national culture plays.

International R&D collaboration is divided into two categories: formal cooperation and informal cooperation. Informal cooperation is based on non-contractual relationships between scientists. Formal cooperation results from agreements and contracts between organizations. Neither informal nor formal R&D cooperation can stand alone without social capital. Social capital is the key to assure efficiency and successfulness of almost all kinds of formal cooperation.

In order to reduce the investment and risk, to achieve efficient generation of knowledge, to make full use of scientific talents all over the world, and to focus on specific conditions of some particular nations, individuals and organizations have engaged much more in international R&D cooperation in the past one or two decades. Evidence from co-authorship in scientific papers, co-inventors in US-foreign patenting activities, globalization of R&D in multinational firms, and the formation of international strategic alliances all confirm such a trend. In the process of expanding international cooperation, the scientific culture which is more group-oriented than ever plays an important role.

NOTES

[1] Leveque, Bonazzi, and Quental (1996) differentiate three modes of industrial R&D: (1) exploratory R&D, which is typical of the innovative firm to general large technological changes; (2) exploitative R&D, which targets the largest markets through obtaining new products out of well known methods; and (3) imitative R&D, which takes advantage of competitors' innovations by copying.

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