MANAGING TECHNOLOGY IN THE TOP-R&D-SPENDING COMPANIES WORLDWIDE—RESULTS OF A GLOBAL SURVEY

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Introduction

There is a common rule of thumb found in innovation literature, that innovative firms are twice as profitable as firms that stick to old products and processes (Tidd et al., 1997). With competition to a high degree driven by process and product innovation, the strategic dimension of technology and therefore the crucial meaning of industrial R&D for competitiveness are a commonplace in the scientific and industrial community. It is for this reason that the literature on the strategic importance of technology is constantly growing in economic-, policy-, and management-oriented literature (Tidd et al., 1997; Gerybadze et al., 1997). However, at the same time there is a constant dearth of empirical knowledge about how companies actually set up and implement their technology strategies.

This article is based on a survey among the top-R&D-spending companies worldwide and analyzes the practices in the strategic management of technology in large multidivisional corporations. A questionnaire was sent to senior R&D/technology officers of all companies in the Triad regions—North America, western Europe and Japan—whose R&D expenditures totaled $100 million or more. Our results presented here focus on two issues. First, we analyze the nature of current corporate technology strategies and their importance for corporate management. Second, we look at the ways in which companies provide the basis for these technology strategies, i.e., the instruments used to keep up-to-date with technological dynamics and to acquire the technological knowledge rated crucial for competitiveness. The analysis differentiates—whenever significant results came to the fore—between companies from the three regions.

Research Approach

Our global survey aims at establishing a series of global benchmarks on the strategic management of technology from the personal points-of-view of the senior R&D/technology officers of the world's most technology-intensive corporations. It is a follow-up to a similar study carried out in 1992 at the Massachusetts Institute of Technology (MIT) (Roberts, 1995a and 1995b). This research was jointly conducted by a team of researchers from MIT, the Fraunhofer Institute for Systems and Innovation Research in Germany, and the National Institute for Science and Technology Policy (NISTEP) in Japan.

Our approach has been the following. First, we compiled a list of companies whose R&D expenditures totaled $100 million or more for inclusion in the sample. The geographical scope of the survey includes the countries of the Triad, i.e., the U.S. and Canada (North America), western European countries, and Japan. The assignment of a corporation's nationality was based on the location of its headquarters. The sample comprised 438 companies: 182 companies in North America, 126 in Japan, and 130 in western Europe. This list of corporations whose R&D expenditures totaled $100 million or more was compiled from various sources and includes the main global players worldwide.

Second, a joint questionnaire was developed and sent to senior R&D or technology officers of all the companies in our sample.

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We asked questions regarding the strategic technology management on both the corporate level and the largest or most representative business unit of the corporation. Since the questionnaire was sent to the person responsible for R&D/ technology on the corporate level, the answers naturally have a bias to the corporate view. An English-language questionnaire was mailed to the North American companies by MIT and to the western European firms by the Fraunhofer Institute for Systems and Innovation Research. An exact Japanese translation was created by NISTEP and mailed to the Japanese companies.

Third, the companies were reminded several times by mail or phone to complete and return the questionnaire, so that we might collect data from a fairly representative number of corporations. The analyses reported here are based on data provided by 209 companies, which represents a rather high overall response rate of 48%. Our questionnaire was answered by 98 companies from Japan, 58 from North America, and 53 from western Europe. In the coding of the questionnaires by the receiving institutes, all company-related information was omitted, so that the resulting database was a collection of anonymous information.

Since nearly half of the responses are from Japanese corporations (which made up 29% of the entire sample), our data have a strong geographical bias. However, we differentiated the results presented here between the three regions—North America, Japan, and western Europe. Overall, the responding firms were quite representative of the sample firms within each region, in terms of the data collected regarding sector, annual sales, and R&D expenditures. The responding firms can be briefly characterized as follows:

- *Annual sales volume.* The Japanese companies are the largest, with an average annual sales volume of $67 billion in 1997, compared to an average annual sales of around $18 billion for both the western European and North American corporations.
- *R&D intensity.* The North American firms have the highest R&D intensity (percentage of annual sales spent on R&D), with a mean of 7.4%, compared to the Japanese (5.3%) and the western European (4.7%) companies. Most companies with an R&D intensity of 10% or more are from North America.
- *Sales revenue from abroad.* If one takes the percentage of sales revenues from nondomestic countries as a measure of the degree of internationalization, the western European firms are on average highly internationalized (51% of sales revenue from abroad) compared to the North American (41%) and the Japanese (23%) companies.

Our research is clearly focused toward large multidivisional and technology-intensive corporations that are internationally active. Since one selection criterion was R&D expenditure, our sample covers all industrial sectors in which the generation and use of technology play an important role for competition.

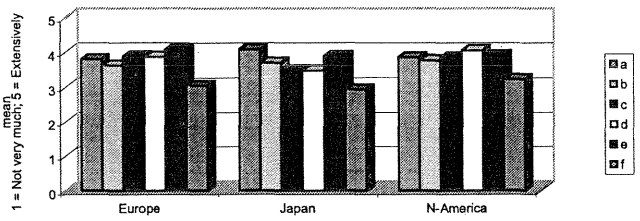
Formulating and Linking Technology Strategies

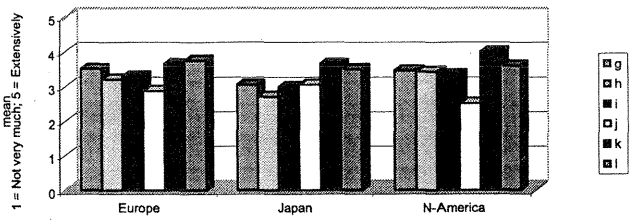
Explicit Technology Strategy. To understand the nature of technology strategy and its linkages to both overall corporate and business unit strategy, the existence of an explicit technology strategy was used as a first indicator. Most firms have either defined an explicit and differentiated technology strategy in writing (about 51% on the corporate technological level, 57.9% on the business unit level) or, where no technology planning document exists, the overall company strategy includes important elements of technological consideration (32% on the corporate level, 29.2% on the business unit level). The former, specifically a written, corporate-level document on technology strategy, is most popular in Japan, whereas western European firms prefer the latter mode. Only a small fraction of firms (less than 10%) practice a less strict form of strategy planning.

For firms that do have an explicit technology strategy, they mostly include the elements presented in Exhibit 1. Differences between regions exist: in North American firms, technology mission statements, external customer requirements, and strategy for protection of intellectual property rights are more popular. Internal customer requirements and defining core technical strengths/competencies are preferred by western European firms, and technology mission statements are preferred within Japanese firms.

Linking Technology Strategy To Corporate and Business Strategy. Compared with the North American and Japanese firms, fewer western European firms perceive that corporate technology strategy is linked to overall corporate strategy: 80% of the North American companies, 78% of the Japanese firms, and 55% of the western European firms stated that their corporate technology strategy is strongly linked to their overall corporate strategy. The significance of corporate technology strategy for overall corporate

Exhibit 1. Inclusion of single elements in the explicit corporate-level strategy

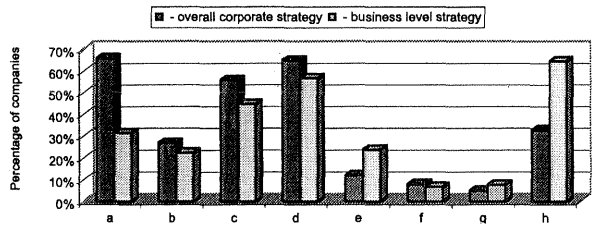




a. Technology mission statement
b. Competitive technology position
c. Internal customer requirements
d. External customer requirements
e. Defining core technical strengths/competencies
f. Life cycle stages of technologies

g. Evaluation of alternative technologies competing against yours
h. Internal developments, external access
i. Balance in your portfolio of technologies
j. Marketability of the technology to others
k. Strategy for protection of intellectual properties
l. Forecasting of future technologies

Exhibit 2. Roles or positions most critical in achieving linkages between corporate technology strategy and corporate and business unit strategy



a. Chief executive officer (CEO)
b. Chief operating officer (COO)
c. Chief technical officer (CTO)
d. R&D VP/director
e. Marketing VP/director
f. Finance VP/director
g. Manufacturing VP/director
h. Business unit general manager

strategy is impressively demonstrated by the fact that the chief executive officer (CEO), R&D director, and chief technical officer (CTO) play a very strong role in linking technology and corporate strategy (Exhibit 2). The chief operating officer and the vice presidents of marketing, manufacturing, or finance do not play a role here. The CEO is highly involved in decision-making on the overall R&D budget, technology strategy development, and selection of outside technology investments. However, she or he is not very involved in the selection and prioritization of R&D projects and internal technology resource allocation; decisions about these issues are made by the R&D managers.

As for the business unit, it is especially the business unit general manager's responsibility to keep the business unit strategy in line with corporate technology strategy. Further, the R&D vice president and the CTO also play an important role here (Exhibit 2).

Linking corporate technology strategy to overall corporate strategy seems to pay off for the companies studied. The strength of these linkages relates to various performance indicators and significantly and positively correlates with the following:

- Overall corporate sales growth rate,
- Percentage of 1998 sales from new products/services,
- Percentage of sales from new and improved products,
- Technology leadership,
- Perceived success in reducing production costs, and
- Perceived R&D timeliness in meeting new-product delivery schedules.

Allocation of R&D Funds. What percentage of funds is allocated to R&D activities on the corporate and business unit levels? Exhibit 3 shows that for all the companies studied, research and technology monitoring (in 1998) received a higher percentage of funds on the corporate level (29% and 10%, respectively) than on the business unit level (10% and 5%, respectively). In contrast, development and the technical support of existing products and processes were more supported at the business unit level than the corporate level. This is not surprising, since corporate R&D is more long-term and strategically oriented, whereas R&D of a business unit is more short-term and application oriented. However, two other points arise from our data: the regional difference in the allocation of funds and the development over time between the years 1991 (Roberts 1995a and 1995b) and 1998 (our data).

Regarding the regional differences, our data show that the Japanese firms allocated more funds to research on the corporate level (37% in 1998) than did the western European (23%) and North American (22%) companies. A higher proportion of funds

Exhibit 3. Funds allocated to the various R&D activities on corporate and business unit levels[a]

R&D activity	Funds (%) allocated for R&D activity in:									
	1998						Total 1998		Total 1991	
	Europe		Japan		N. America					
	Corp.	BU[b]	Corp.	BU	Corp.	BU	Corp.	BU	Corp.	BU
Research	23	9	37	10	22	9	29	10	42	13
Development	35	39	35	42	43	46	38	42	37	47
Technical support products	12	28	11	25	15	28	13	27	11	24
Technical support processes	14	19	10	16	8	14	11	16	10	15
Monitoring external technology	16	5	7	6	11	4	10	5	—[c]	—

[a]Rounded totals for each column equal 100%.
[b]BU, business unit.
[c]—, not asked.

is distributed to the technical support of existing processes on the corporate (14%) and business unit (19%) levels by the western European firms. Further, technology monitoring plays a stronger role on the corporate level in the western European corporations (16% in 1998) than in the Japanese (7%) and North American (11%) firms. We can conclude from these empirical data on resource allocation that less research activity on the corporate level seems to require greater technology monitoring activity.

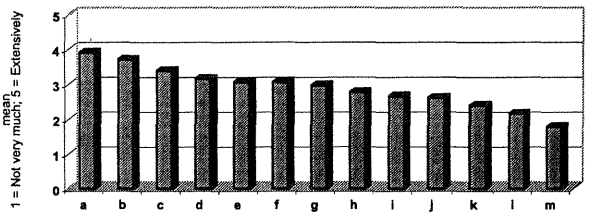
Regarding the development of the allocation of R&D funds over time, we compare data from Roberts' studies (1995a and 1995b) and from this study for the entire sample (Exhibit 3). However, in the 1998 survey we asked for the funds allocated to the monitoring of external technology—a question that was not asked in the preceding survey and which makes direct comparison difficult. There are two possibilities: to exclude technology monitoring or to assume that technology monitoring is very much a part of research. If we drop technology monitoring out of the data, the proportions of funds allocated to research on the corporate and business unit levels in 1998 (29% and 10%, respectively) are lower than the percentages distributed to research on the corporate and business unit levels in 1991 (42% and 13%, respectively). This would be a significant shift away from research on both the corporate and business unit levels toward more development and near-term product and process support activities. In contrast, if we assume that technology monitoring is, to a large extent, part of research activities, the percentage of funds allocated to research on the corporate level in 1998 (39%) would be only a bit lower than that in 1991 (42%). Accordingly, the proportion of funds distributed to research on the business unit level in 1998 (15%) would be a bit higher than that in 1991 (13%). In this case, the development of the allocation of R&D funds between 1991 and 1998 can be interpreted as relatively stable, with a slight shift from research on the corporate level to research on the business unit level in 1998.

Monitoring and Acquiring Technology

Monitoring Technology Worldwide. In our global survey, we have been interested in how companies monitor technology and acquire the requisite technological knowledge. The dynamics of environmental alterations may lead to radical changes of the foundations on which a company's technology strategy is based. Therefore, at least, foresight of future technologies is explicitly an important part of the corporate-level technology strategy of the companies studied (Exhibit 1). Another empirical study confirms this result and points out that the strategic importance of foresight activities has increased in large corporations and has become part of the strategic management of technology (Bürgel et al., 2000). The companies studied rely mostly on the following mechanisms to monitor technology (Exhibit 4; average mean value, 3.0 or more):

- Person responsible for core technology/research program,
- Internal technology steering group,
- Participation in technical professional societies,
- Customer panels or input,
- Industry-based consortia, and
- Participation in standard bodies.

Exhibit 4. Reliance on various mechanisms to monitor technology—whole sample



a. Responsible person for core technology/research program
b. Internal technology steering groups
c. Participation in technical professional societies
d. Customer panels or input
e. Industry-based consortia
f. Participation in standard bodies
g. University liaison/affiliate programs
h. Participating in publicly funded R&D programs
i. University research consortia
j. Specialized internal monitoring unit
k. External science/technology advisory boards
l. Networking with young technology-based firms
m. Venture capital funds

The great reliance on the persons responsible for the core technologies or core research programs in order to monitor technology seems to reflect the growing importance of concentrating the company's research activities and technologies on certain fields relevant to their businesses. The person responsible for a core technology/research program is an excellent partner in the corporate technology foresight activities on two counts. First, he or she has utmost interest in the latest and regular information on the specific topic of responsibility. Second, the responsible person is the "technological gatekeeper" in his or her field and an excellent internal point of contact, one who distributes information and may enter data in the companywide technology foresight system.

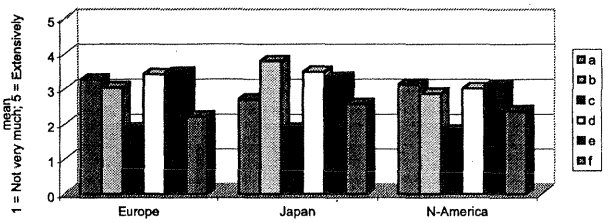
Regional differences in the use of mechanisms to monitor technology between the firms studied are moderate. However, the Japanese companies seem to put more emphasis on customer panels or input, and the North American firms rely more on technical professional societies than the other companies.

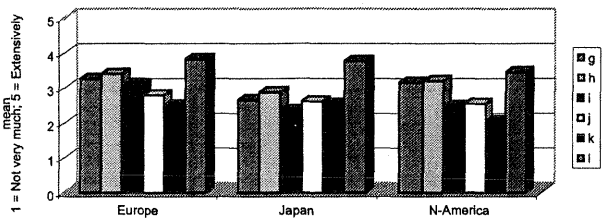
Given the variety of instruments to monitor technology and the growing importance of internationalization of R&D, companies also use a whole range of instruments to monitor technological developments around the globe, from owning laboratories abroad to sponsored research at foreign universities (Exhibit 5). For the sample as a whole, attending international technical conferences is the most important mechanism, and formal panels of outsiders is the least important instrument. While the differences between regions are relatively minor, one exception is the importance that Japanese firms attribute to their own staff liaison abroad as a technology antenna.

Acquisition of Technology.

Research. In contrast to the number of mechanisms used to monitor technology, the companies studied rely on fewer mechanisms to obtain technology for their research work. The

Exhibit 5. Intensity of the application of mechanisms to monitor technology developments abroad





a. Our own labs in other countries
b. Our company's staff liaison in other countries
c. Formal technical panels of outsiders
d. Newsletters, reports
e. Internet, online databank analyses
f. Consultants from other countries

g. Participation in international consortia
h. Participation in international standards groups
i. Participation in publicly funded R&D programs
j. Sponsored research at foreign universities
k. Liaison/affiliate programs at foreign universities
l. Attendance at foreign technical conferences

mechanisms most relied upon include (Exhibit 6; average mean value, 3.0 or more):

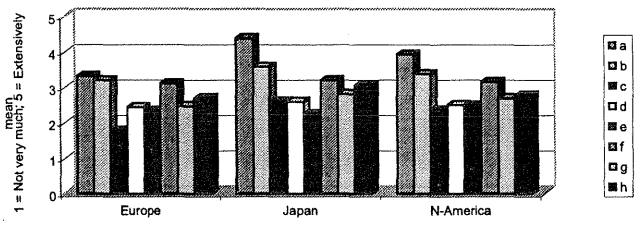
- Central corporate research,
- Internal R&D within divisions,
- Sponsored university research, and
- Recruiting students.

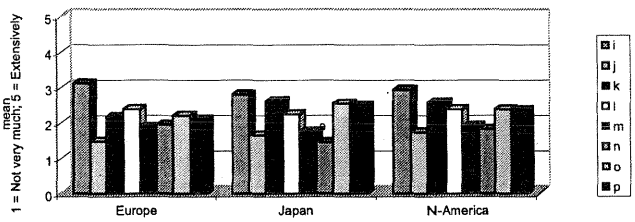
The Japanese companies rely heavily on their corporate research to generate technology, whereas R&D activities in the divisions seem not to be of such importance. Surprisingly, the same is true for the North American firms as well, whereas in the western European companies division-based R&D plays only a slightly less important role in obtaining technology than central corporate research. Studies on large Japanese corporations show that they have continuously invested in R&D and have kept an eye on a strong corporate research organization and long-term research—despite the long-lasting economic recession in the 1990s (Reger, 1999; Nihon Keizai Shimbun, 1998). Regarding regional differences, the Japanese firms rely to a larger extent on continuing education as a mechanism to obtain technology for their research.

Development. We wanted to know to what extent the companies rely on mechanisms to obtain technology for their development work (as opposed to research work). Firstly, most important are the internal R&D activities within the divisions, followed by corporate research, incorporation of supplier's technology, and joint ventures or other alliances with large companies. The still-strong relevance of corporate research to development work is due to the strong emphasis the Japanese companies place on corporate research for obtaining technology for development. The western European and North American firms studied do not rely so strongly on their central research regarding development. The incorporation of supplier's technology and joint ventures/alliances with other large firms play a larger role for conducting development, whereas sponsored university research and recruiting students are of greater importance for research activities.

The extent of the overall reliance on external sources for technology acquisition will increase in the future, according to our survey results (Exhibit 7). Taking into account the results of the prior benchmarking survey (Roberts 1995a and 1995b), a very important change in strategic technology management over the past decade is the increasing intensification of all companies' dependence upon external sources of technology. The number of companies that considered themselves to be highly dependent on external sources to acquire technology has dramatically increased: for the years 1991 and 1998, the percentages were 35% and 84% for the Japanese firms, 22% and 86% for the western European firms, and 10% and 85% for the North American firms (the 1991 data come from Roberts, 1995a & 1995b). Our results show that the importance of external sources for North American companies is growing stronger in comparison with the sample firms from the

Exhibit 6. Reliance on various mechanisms to obtain technology for research work

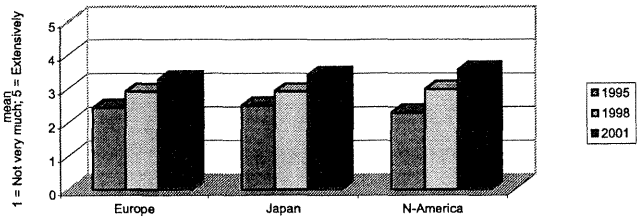




a. Central corporate research
b. Internal R&D within divisions
c. External licensing
d. Joint ventures or other alliances with other large companies
e. Consortia
f. Sponsored university research
g. University liaison/affiliate programs
h. Continuing education

i. Recruiting students
j. Equity investments in smaller firms
k. Consultants/contract R&D
l. Acquisition of technologies
m. Acquisition of products
n. Acquisition of companies
o. Incorporation of supplier's technology
p. Incorporation of innovative customer's technology

Exhibit 7. Reliance on external sources for technology acquisition

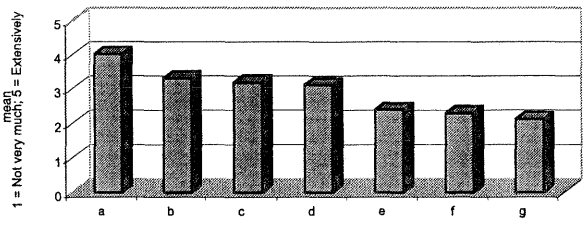


other two regions. The companies with their headquarters in North America obviously paid less attention to external technology acquisition in the past than did the western European and Japanese firms.

Decision criteria and partners for technology-related cooperation. The criteria for choosing between internal and external mechanisms for acquiring technology show significant differences regarding the region of origin of the companies studied. The most important selection criteria for the western European firms are external availability, time and sense of urgency, familiarity with the technology, and relative competence/ability. In contrast, the Japanese firms base their decisions especially on time and sense of urgency, intellectual property ownership, relative competence/ability, and familiarity with technology. The same ranking is mentioned by the North American firms, with one difference regarding the fourth point: the North American firms put slightly more emphasis on external availability than on familiarity with the technology. However, one can say that the Japanese and North American companies take intellectual property ownership more into consideration than their western European counterparts.

There are different possible partners with whom a company can cooperate in technological innovation activities. One—other divisions of the company—was cited by the firms as the most frequently sought partner for (internal) cooperation (Exhibit 8). Regarding external organizations, the most frequent partners are customers, suppliers, and universities, followed by government laboratories, early-stage, technology-based companies, and competitors. Since this question explicitly asked for the frequency of the collaboration, a less-frequent cooperation does not necessarily imply that the partner is less important. The regional differences between the firms are small, with the exception that the North American companies more frequently cooperate with young, technology-based firms.

Exhibit 8. Frequency of collaboration with organizations in technological innovation activities



a. Other divisions of your own company
b. Customers
c. Suppliers
d. Universities
e. Government laboratories
f. Early-stage technology-based companies
g. Competitors

Our data do not convincingly show if the partner location is the home country or abroad, because only a small number of respondents answered this question. Other empirical studies point out that the number of technology-related alliances (business-to-business cooperations) between western European and U.S. companies has increased since the 1980s (Commission of the European Communities, 1998). The same is true for the Japanese firms studied, i.e., the number of alliances with U.S. companies has also grown since the 1980s. This indicates, on the one hand, a stronger internationalization of technology-related cooperation for both western European and Japanese firms and, on the other hand, that the cooperation seems to be clearly oriented towards the U.S.

Concluding Remarks

The results of our empirical analysis of the strategic management of technology in large multidivisional corporations can be summarized as follows. First, R&D and technology have become cornerstones of the corporate and business strategies of the companies studied. Most firms have defined an explicit and differentiated technology strategy in writing or included important technical elements in their corporate and business strategies. Further, most of the firms studied have linked the corporate technology strategy to their overall company strategy. On the corporate level, the CEO, R&D vice president, and CTO play a prominent role as "linking pins." The strong involvement of the CEO illustrates the high awareness of top management. The business unit general manager, R&D vice president, and CTO are the most important linking pins in the strategic integration of corporate technology and the business unit. The allocation of funds to the various R&D activities on the corporate and business unit levels demonstrates a greater importance of technology foresight—especially in the case when basic and applied research activities decrease. The shrinking of the corporate R&D organization mainly in North American and western European firms in the past decade and the decreasing budget for research on the corporate level obviously suggest the need for more technology foresight activities, i.e., to spend more time scanning and monitoring the newest technology and optimizing their own research agenda instead of performing research internally. If one includes technology foresight as part of research, our data show only a slight reduction of research activity on the corporate level and a slight increase of research activity at the business unit level between 1991 and 1998. This points to an even stronger division of labor between corporate R&D and business unit R&D. The shrinking down of research activities has obviously come to an end—with the role of business units/divisions in research growing even stronger.

Second, there is a growing tendency among the firms studied to acquire technology from external sources. Technology-related horizontal and vertical networking with external partners is performed even in core technology areas of the company. The high level of reliance on external sources for technology by all the companies studied is a very important change in the strategic management of technology over the past decade and for the future.

While there are very similar patterns of external technological cooperation—customers, suppliers, and universities are most often mentioned—the motives to appropriate external technological knowledge differ among the three regions considered. Other empirical research (Commission of the European Communities, 1998) shows that cross-border, technology-related alliances (with a clear orientation to partners in the U.S.) are also of growing significance.

Acknowledgments

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