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Benchmarking the Strategic Management of Technology -- I

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Author's Biography

Edward B. Roberts is the David Sarnoff Professor of Management of Technology at the Sloan School of Management, Massachusetts Institute of Technology, Cambridge Massachusetts, where he heads the Management of Technology and Innovation Group. He is co-founder and chair of the MIT Management of Technology Program, a 12-month executive education program aimed at developing future technological leaders, and is co-director of the MIT International Center for Research on the Management of Technology, a research consortium with twelve global corporations. He has authored over 125 articles and 11 books, the latest being *Entrepreneurs in High Technology: Lessons from MIT and Beyond* (Oxford University Press, 1991). Roberts co-founded and is chairman of Pugh-Roberts Associates, now a division of PA Consulting Group. He has co-founded several other companies, including Medical Information Technology (Meditech) and the Zero Stage/First Stage Capital group of venture capital funds, and has served as a director of many emerging technology firms, including Advanced Magnetics, Digital Products, Laser Science, SelfCare, SofTech and Tyco Laboratories. Roberts received four degrees from MIT, including S.B. and S.M. in electrical engineering, S.M. in management, and Ph.D. in economics.

Overview

Extensive data collected from the largest R&D-performing companies in the United States, Western Europe, and Japan reveal that top management linkages and resource leverages are the keys to effective technology strategy. In terms of linkage, Japanese chief executive officers are more heavily involved in integrating technology with overall corporate strategy. Chief technology officers of Japanese companies have stronger board-level participation and greater influence on overall company strategy. U.S. firms are rapidly decentralizing control of R&D activities to their business units, while Japanese companies are moving in the opposite direction. In search of resource leverage, companies worldwide are experiencing major shifts to acquiring technology from outside sources, relying increasingly on universities for research and on joint ventures and alliances for development. These and other findings on strategic management of technology arise from a global benchmarking study of the 244 companies that account for approximately 80 percent of the R&D expenditures in Europe, Japan and the United States.

Benchmarking the Strategic Management of Technology - - I

Ten years ago, from perspectives gained in MIT research and executive education activities, as well as from our consulting projects at Pugh-Roberts Associates, I believed that very few companies worldwide were doing much to develop overall strategies for their management of technology. However, in the past decade major changes have occurred globally in formal efforts to develop and implement strategic planning and strategy development for the technology side of the business. As indicated in Figure 1, what we define as a moderate overall corporate level of acceptance has occurred with respect to technology strategy development practices, although high variance does exist among firms and between regions. One level down from corporate management, at the division or business or SBU level of the firm, significantly greater acceptance and use of technology strategy clearly exist now. These findings are true overall, and also for each region and industry grouping in our database (see "Appendix: Survey Methods" for more details on the study).

What is more important is our finding that the practice of developing and applying technology strategy produces results. Statistical correlations against many measures of R&D performance demonstrate that, in particular , the degree of development of technology strategy at the business-unit level relates significantly to performance, even across our entire global sample of multiple regions and multiple industries.

The reader should be aware that it ought to be difficult to find statistically significant generalizations between technology management practices and outcomes across all industries and regions. As Arthur Chester, senior vice president, research and technology, for GM Hughes, points out from his benchmarking of 16 companies, "in technology management the processes and structures that are optimum for one company may not fit another company at all ... the optimum procedures for R&D management often depend upon the traditions of the company and upon the personal preferences of the CEO and the CTO."[1] Applying the much more reasonable process of investigating industry-specific information, the development and implementation of technology strategy relates even more strongly to many different industry indices of R&D performance.

Insert Figure 1.

Acceptance in the Business Units

Our data clearly show that those companies that are strong in developing their technology strategies at the corporate level clearly are also strong in technology strategy development at the business-unit level (this relationship is statistically significant at the level of p=.0005). If leadership exists at corporate in developing technology strategy and understanding, and in trying to bring direction and focus to technology management in the firm, either that role example, the methodologies that are developed, the power from the top, or their combination causes the business units to move forward with implementation of comparable strategic planning.

But weakness at the corporate level does not necessarily mean weakness at the business-unit level. Some business-unit general managers do an excellent job of developing and implementing technology strategic planning and action without the leadership of their corporate bosses. And I believe that the primary benefits of developing strategic planning and strategy creation in technology are now realized at the business-unit level.

Our study attempted to identify the principal issues that matter in technology strategy. As indicated in Figure 2 three perspectives are currently most important to senior executives. (Most of the people who responded to our

Insert Figure 2.

questionnaires are chief technology officers or vice presidents of R&D, or their immediate planning and support staffs. This is a carefully selected set of respondents to be sure -- the most senior technical management in the company, and clearly a responsible group of people.)

Respondents placed the highest priority on matching R&D to market needs. This is significantly more important than the problem that has been proliferating in the literature recently of decreasing time to market for new products, which in turn is a bit more important than our survey's topic for special study during 1992 -- the management of R&D with constrained resources. No significant differences exist by region in the relative importance of one criterion versus another for focusing technology strategy.

Linking Technology to Strategy

The first key concept measured repeatedly in our study is that of "linkage". How well is corporate strategy in the technology domain tied to overall corporate strategy? Here we find the first of the benchmarked differences that are both important and that, throughout this report, cumulatively picture how U.S. strategic management of technology differs especially from Japanese management of technology at the top levels of the firm. The data of Figure 3 demonstrate that Japanese, and close to them European, companies have far stronger linkages at the top between technology and overall corporate strategy than do firms in the United States.

Insert Figure 3.

Now, of course, numerous exceptions exist to this finding of weak U.S. strategic technology linkage. For example, Robert Lutz, president and COO of Chrysler Corporation, in his keynote address at our MIT symposium on this study, outlined how Chrysler's overall mission directs the way in which key aspects of its technology strategy and technology management proceed. And both most recent ex-CEOs of Motorola, Robert Galvin and then George Fisher, are noted for their leadership in integrating technology to strategy. Fisher has commented, "Nothing this company has ever done would have been successful if we hadn't had the fundamental notion that R&D is the driver of it all."[2] But most American firms have not done as good a job in providing these overall ties.

To emphasize the importance of this issue, in Part 2 of this report in the next issue of *Research/Technology Management* we show that the extent of linkage between technology and overall corporate strategy, even in as diverse a sample of industries as we have studied, has strong statistical relationships with a number of different measures of overall R&D performance. The data demonstrate that if a company is trying to gain higher performance from research and development, a major influence is the connection between R&D strategy and the overall corporate strategy. Neglecting that critical tie and critical source of direction diminishes the likelihood and magnitude of overall benefits from a company's technology investment.

Insert Figure 4.

A related issue is, who is central in achieving this linkage? In about 60 percent of the companies in all regions, chief executive officers are seen as an important linkpin in tying technology to overall corporate strategy. But as one might expect, the primary linkpins worldwide are the R&D vice presidents and chief technology officers. One difficulty is that many companies have no such person as the chief technology officer. I shall return to the CTO shortly.

One observation from Figure 4 is perhaps easily explained but nevertheless deserves comment. Despite so many companies telling us that matching R&D to market needs is their highest priority, when we look for the roles that people play in making this connection, the corporate marketing vice president tends to be insignificant in relating to technology. Some companies do not have a corporate marketing VP. In other firms, that office is a weak staff function, providing company-wide market research services. But many other firms do have strong marketing VPs who still do not see technology linkage as part of their responsibilities. If indeed at the top of the firm a most important action is to tie the market place and technology together, I would argue that both sets of constituencies, marketing and technology, need senior level representation for design and implementation of effective linkage structures, and for carrying out the communication and the bargaining on future product needs.

The Chief Financial Officer Surprise

One surprise from the survey is a role that we had not anticipated whatsoever. We threw in a question about possible involvement of chief financial officers merely for completeness, expecting (because of the bias of our own experiences primarily in the United States and Europe) that we would not find any important observations about the CFO's role in tying technology together with overall corporate strategy. Indeed, our anticipations were correct, so long as we looked only at the United States and Europe. In those two regions, the CFO is immaterial to the broad linkage between technology and strategy. But this is not true in Japan. In fully one-third of the major technology-oriented companies in Japan, the CFO is seen as an integral part of the linkage between technology strategy and overall corporate strategy.

These data remind me of an incident, which at the time I regarded as totally unique, that occurred during one of my visits a few years ago to Tokyo. At the end of discussions with the Associate Director of R&D of a major Japanese steel company, he politely handed me another business card and suggested we get together on his next visit to the United States. I was astonished to see that this card showed two business addresses, one of them in Cambridge, Massachusetts. In response to my questioning, the R&D executive replied that he spent half-time in the U.S., monitoring his company's sponsored research programs in advanced materials at eight different major universities. My further quizzing brought out that in addition to a secretary/translator and a part-time assistant, the only other occupant of his company's Cambridge office was the associate treasurer of the firm, also half-time. After all, he pointed out, these research programs are really long-term investment activities!

Who better to relate to investment than a senior finance executive? Obviously, the survey data indicate that many other Japanese companies also see the CFO's office as importantly involved in the firm's R&D investments, an attitude generally lacking in American and European companies.

The data for Japanese firms reflect a very different understanding and appreciation of the role that technology plays and the fact that it must be integrated into all levels of strategic thinking. I believe the helping role of the CFO in Japan compensates and differentiates for how their CEOs see the relationship to technology. We need to learn from what the Japanese seem to have accomplished concerning the attitudes and teamwork of their senior executives toward technology.

Insert Figure 5.

At the Business-Unit Level

When we move down to the level of business units and divisions, where most R&D money is being spent worldwide, we find (appropriately) that the company chief executive officers are about half as involved as they were at the corporate strategy level. At the divisional level, the corporate CEO has decentralized overall managerial responsibilities downward; in fact, Figure 5 reveals that one of the most important people in the linkage is the business-unit general manager, just as we should expect.

The business-unit general manager is about two- to three-times as important as the CEO in providing strategic linkage for the typical division. At the business-unit level, the marketing vice president becomes more important. The marketing organization does not have broad-based corporate presence in affecting technology; rather, it has focused business-unit presence, looking at the markets of individual business units and helping to tie in technology development. Again, the chief financial officer in many Japanese companies is an important linkpin of business-unit strategy, but still non-existent in either the United States or Europe.

The CEO as Technology Strategist

For years, I have been concerned that chief executives need to be groomed, selected, and assisted within the organization to relate strongly to technology. This is quite different from assuming that they themselves need to be technologists. Indeed, *Business Week* finds that engineering is the most popular undergraduate major among U.S. top 1000 CEOs, but that more CEOs started their careers with jobs in finance and accounting than in any other area.[3]

When we developed our study questionnaire I was determined to treat this issue. I must confess that as an American I am rather disappointed to find that

Insert Figure 6.

fewer U.S. CEOs get very involved in technology content, strategy or direction-giving generally. More Japanese chief executive officers are highly involved in the content aspects of technology strategy. For four different dimensions of technology strategy -- the process of its development, project selection and prioritization, internal resource allocation, and selection of outside technology investments -- Japanese CEOs play a more prominent role than do U.S. or European CEOs.

In only one important area do U.S. CEOs stand out, statistically anyway. That is with respect to their involvement in setting R&D budgets. Figure 6 shows that the prominent differentiater between U.S. CEOs and their European and Japanese counterparts is the bottom line on the chart, which indicates that three-fourths of American CEOs are highly involved in overall R&D budget control, considerably more than European and Japanese chief executives.

I interpret this picture to mean that in Japan in particular, more chief executive officers have identified as a critical priority of their own job the development, enhancement and tying together of technology with the mission and priorities of the company. The Japanese chief financial officer is often enlisted as an aid to his boss in further facilitating the connections between technology and overall strategy. In the United States, the CEO has primarily found that keeping the R&D budget under control is the "bubble-up" from technology that comes to his office.

I know that there are exceptions within every industry. For example, Jamie Houghton, CEO of Corning, has always worked very closely with his chief technology officers, first Tom MacAvoy and currently David Duke, both of whom served as vice-chairman of Corning. In a presentation at the Harvard Business School (December 15, 1993), MacAvoy asserted that the Houghton family had, and projected, a vision that Corning would be a leader in technology, and that they envisioned a consistent niche market strategy. However, in our searching across our data base at the aggregate level, we have yet to find industries in the United States in which overall exceptions arise. Perhaps careful analyses of our pharmaceutical industry data may reveal differences in the roles of U.S. CEOs with respect to content and directional contributions to the area of technology strategy. Indeed, my MIT colleague Rebecca Henderson claims that

pharmaceutical industry top managers have preserved excellence and market domination of firms founded 20 and 30 years ago. She sees the key to success as deriving from staying abreast of scientific changes and integrating this knowledge to serve changing market conditions.[4]

The Chief Technology Officer's Role

The second key executive of interest to me is the chief technology officer. Our first problem is to define a CTO. This is especially difficult given the wide variance in the roles that this person plays across firms, for example in terms of membership on the company's board of directors or main managing board. In Japan 95 percent of CTOs are members of main boards or boards of directors (Figure 7). Europeans drop significantly to 55 percent. But in the United States,

Insert Figure 7.

the CTO is represented on the senior managing boards of only 20 percent of the companies sampled -- and remember that these giant corporations are among those spending the most on R&D.

In my opinion, this single figure presents the strongest damnation of U.S. senior executive practice and prioritization. The excuse may be the well known fact that U.S. firms have fewer insiders on their boards. But this excuse has a critical consequence: If U.S. firms want to compete effectively in a technologically-intense world, the first step toward competing should be to elevate the position of the company's senior technology manager to a level where he or she can dialog with other senior executives on overall strategic direction of the firm, on priority formulation and implementation of company strategy. The "voice of technology" needs to be heard on a regular basis in the executive and board suites. But, similarly, senior technology managers need to hear first-hand the arguments and concerns of their executive colleagues from the market side, from strategy, and from finance, among others. This direct face-to-face linkage at the top is critical to determining competitively-effective strategic direction.

Elevating the role of the chief technology officer can be a double-edged sword for some senior R&D managers. Indeed, a CTO must be selected so that that person is appropriate to participate in main board discussions and in the determination of overall company direction. In 3M, for example, the CTO has typically advanced through positions of increasing general management responsibility, including heading major business groups, prior to promotion to the senior vice president-R&D post. This is true of the past three persons to hold the 3M job: Les Krogh, Ron Mitsch and George Allen, reflecting an apparent conscious executive development policy for grooming senior 3M officers. But I consider the 4-to-1 difference in Figure 7 between Japan and the United States, and the 2-to-1 difference between Europe and the U.S., in the role and representation of senior technology managers in board-level discussions and debates to be shameful testimony to the lack of American managerial appreciation of the long-term, substantial, competitive differences that appropriate strategic management of technology can ensure for the firm.

Probing the database for more insights into the roles of the CTOs, we again find Japanese chief technology officers more involved in overall corporate strategy. This is not looking inward to technology but outward toward the corporation as a whole. As Figure 8 demonstrates, significant differences also are evident in the

Insert Figure 8.

extent to which the corporate CTO provides direction for technology development at the business-unit level. These influences include such elements as top-down perspectives about prioritization, standards, staffing considerations, quality control for technology, global competitive analysis on the technological dimensions of the firm. And again we find in ranking that in Japan more powerful CTOs are more prevalent than in Europe, and significantly moreso than in the United States.

I believe that many firms are structured inappropriately at the top of their own technological endeavors to provide a centrality of focus, direction and leadership, particularly with respect to strategic linkage. I am not arguing here about questions of centralized or decentralized management of R&D, nor of how technology must be tied effectively into individual product lines. I am talking instead of how the firm creates a strategic vision of which technologies it needs, how the technology is to meet overall corporate objectives and corporate priorities, how the technology is to be developed and/or acquired, and how technology development across the firm can benefit from coordination and synergy. Those objectives are far more likely to be fulfilled if a senior (e.g., chief) technology officer who is capable of tying technology to overall corporate strategy is working at or near the board level of the firm.

Budgeting for R&D

One obviously cannot talk about management without talking about budgets. Budgets critically reflect strategy. Earlier I emphasized some differences between the corporate and the business-unit levels of the firm. Now, Figure 9 presents for the overall sample of companies the percentile breakdown of R&D spending at the corporate level, where an orientation toward research spending is evident, versus the business-unit level, where spending for development

Insert Figure 9.

dominates. Significant regional differences do exist, partly reflecting different industry compositions of these regions. Japanese companies overall allocate far more of corporate-level budgets to development (44 percent vs. U.S. 36 percent and Europe 33 percent) and far less to research (32 percent vs. U.S. 42 percent and Europe 49 percent) than other regions, but this is changing.

Corporate-level support of current product and process technology does account for over 20 percent of its budget. Clearly, as we move from the corporate to the business-unit level, near-term support of both product and

process technology rises markedly, as does near-to-intermediate term development spending. The percent of budget allocated to research is quite small at the business-unit level.

Note that these numbers do not serve as a model for any particular firm to copy because they are really averages across industries. A corporation must analyze industry-specific data to benchmark R&D budgets. For example, two different industry breakouts are displayed in Figure 10 just to emphasize how

Insert Figure 10.

dramatically different these percentile scores are at the industry level. Both at the corporate and the business-unit levels two quite different industries -- chemicals and materials on the one hand and electronics on the other -- employ very different patterns of R&D expenditures. Benchmarking how a firm ought to be spending its R&D money is inherently dangerous, especially if carried out against dissimilar firms. Specifically a company ought to look to its own industrial base and on trying to develop ways of comparing what its competitors are doing, how they are spending their money, and how they are prioritizing their expenditures. Spending patterns by industry turn out to be very different.

Decentralizing Control -- Except Japan

Beyond the issue of budget is what ought to be the related consideration of control. Here we found quite a surprise. Industry observers have long known that U.S. companies are more diversified, and therefore have tended to be more decentralized, than comparable European and Japanese firms. But it is now very clear from the data that for five or six years the major companies in the United States have been moving even more heavily towards further decentralized control of both research and development. Control of both R&D budgets and activities has been moving rapidly from the corporate level to the divisional and business-unit level of the firm. Chester warns that "a research department that reports to a business unit rather than a corporate laboratory will develop a shorter time horizon, and will limit its focus to the charter of the business unit." [5]

Much to our surprise the same pattern of change is not occurring in Japan, nor in Europe to the same extent. Consider the data shown in Figure 11. For

Insert Figure 11.

research, almost all Japanese firms continue to be moving control upward in the firm away from the business-unit level toward more centralized control at the corporate level. "At Hitachi," for example, "control over R&D is shifting from individual profit centers to administrative divisions with broader access to market research".[6] This is clearly not what is occurring for research in the United States and Europe.

Of course, many Japanese companies are in the process of playing "catch-up" in research, rapidly increasing their expenditures after years of neglect. Rapid increases in any effort are often seen as most easily carried out

centrally, providing one possible explanation for the increasing Japanese corporate-level control of research. But, coupled with other clues already discussed, this trend may well reflect a greater Japanese sensitivity to the corporate strategic nature of research direction.

I believe that these control changes take place in R&D organizations in cycles, especially for research, with about seven-to-ten years for the half-cycle. In the U.S., my opinion is we are nearing the end of the half-cycle of decentralization of R&D control, i.e. moving control of budgets and programs down to the divisional or business-unit level. I expect that within a few years U.S. companies will start to recentralize control of R&D as they find the problems of technological blindsiding and short-term investment management begin to dominate competitive issues at the business-unit level. American firms will again begin to make longer-term investments, perhaps by creating corporate centers of excellence in areas of core technology, putting more money into longer-term corporate research. I think that will begin to happen within the next three years. What's interesting is that the current pattern in the U.S. is not occurring elsewhere. The rest of the world may just be out of phase or perhaps merely behaving more rationally.

Similar distinctions are arising in development. We again observe in Figure 11 heavy momentum in the U.S. towards decentralized control of development. In Europe and Japan it is about 50-50 as to whether control of development work is shifting upward or downward. United States companies are clearly differentiating themselves in moving toward the business unit. We all know the benefits of decentralized control in terms of responsiveness to customers and short-term ability to implement changes in current product lines.

These moves create a quandary in regard to the linkage concept that I have emphasized: they provide tighter linkage between technology and business-unit tactics, while weakening possible ties at the corporate strategic level. These changes will indeed make U.S. firms more competitive in short-term performance, bringing the locus of R&D closer to the end-customers being served. But the problem with business-unit control of R&D is that the firms eventually stop investing in longer-term R&D, the strengthening of core capabilities and the creation of new core strengths. Consequently, the trend in the United States toward decentralized control may well spell future technological and competitive disaster, if continued much longer.

Searching for Leverage

Beyond the importance of linkage to company results is the concept of "leverage". The survey data on industry's moves to the outside world in search of relevant technology, illustrated in Figure 12, are rather profound. Shifts have

Insert Figure 12.

been occurring rapidly in the extent to which companies see themselves as increasingly and strongly reliant on external sources of technology. For example, in his 1992 MIT address president Lutz of Chrysler made the important point that

in its Liberty program, as well as in other projects, Chrysler had shifted substantially from predominantly internal management of R&D efforts to the extensive use of outside partners. The anticipated changes here continue over the next three years. Note in the figure the dramatic difference in positioning among Japanese, European and American companies with respect to their historic dependence on external sources of technology, their current reliance and their anticipated future position. Japanese firms clearly see themselves as reliant and dependent upon outsiders far more than does anyone else. Lutz describes Chrysler, in this domain, as becoming more Japanese in management style, creating strong ties to outside vendors and suppliers, even of technology. He labeled this a "virtual enterprise", with the firm's effective boundaries extended to include the capabilities of many collaborators.

The Industrial Research Institute's annual forecast confirms this trend, showing that 47 percent of the U.S. firms that replied expect increased participation in alliances and joint ventures, with 18 percent expecting to increase their licensing from others.[7] One of the more prominent recent examples is the announced controversial billion-dollar, long-term research agreement between Scripps Research Institute and Sandoz Pharma,[8] since revised downward in its terms.[9] In general, the OECD indicates a 13-fold increase in the creation of multinational inter-firm technological agreements from 1973 to 1988, with more than half being joint ventures and joint R&D.[10]

This situation can be described in two very different sets of terms. Reliance or dependence upon "others" has a clearly negative connotation. "Others" may limit access to their best technology. Others may exact control of you due to your dependence. Others may perform contrary to your expectations or desires. But this situation can also be labeled by the more positive but risk-inferring term of leveraging. Internal technological resources can be leveraged by effective access to, and use of, external technology. The Japanese seem to be in the vanguard of this leveraging movement. Sixty percent of all major Japanese companies expect to be highly dependent upon external technology sources three years from now, compared with 25 percent just three years ago. European firms expect only half as much external dependency over the next three years.

Many companies have not yet adequately dealt structurally from a managerial point of view with this new situation. How does a firm manage the acquisition of technology being supplied primarily by companies not under its own control? It is difficult enough to try to control and manage internal R&D staffs, but to be able to manage dependencies upon another organization's R&D efforts is an order of magnitude more difficult.

I believe that companies are going to find themselves increasingly in trouble due to failures arising from the management of external sources of technology. This is not to say that firms shouldn't be moving outward. This is to argue the need for worrying about how overall management systems and staffing are being geared up for management and integration of external technology sources. The increasingly central control of R&D evidenced by Japanese

companies in Figure 11 may be a response in part to requirements generated by external sourcing. Companies need to develop new and critical skills inside to be able effectively to interface with and manage technology acquisition outside. Outsourcing cannot mean denuding internal capabilities or the process will fail.

Looking for Technology

Turning more broadly to the question of sources of technology, from where does a major company's technology come? We again differentiate the research side of the firm from development activities, with sources of both rank-ordered in importance in Figure 13. For research work three clusters of influence

Insert Figure 13.

exist. The data show that the central corporate research organization is clearly the primary source of supply of technological information and advance, across all regions and in most industries. The solid line in the table under "central corporate research" indicates a significant gap in perceived contribution from anything else on the research side of the company. Number two in contribution to research is the R&D carried out within the divisions of the firm. The budgeting patterns shown in Figure 10 confirm that some research is being carried out even within divisional R&D activities. Indeed, in both the aerospace and the pharmaceutical industries, divisional R&D is perceived as an even more significant overall contributor to research than the corporate labs.

What I find very pleasing as an academic is that number three in the Figure 13 list of important research inputs is sponsored research at the universities, quite close overall to the perceived value of divisional R&D. An increasing volume of strategy and policy discussions, at both corporate and national levels, is focusing on whether corporations are gaining adequate benefits from sponsoring university research. I am glad to report that overall, across all regions, large corporations are finding sponsored research at universities to be a primary contributor to their research knowledge acquisition. Furthermore, the next cluster of important contributors to industry's research know-how, shown in Figure 13, also includes several different university-related activities. Recruiting students is seen by itself as a critical contributor to research knowledge acquisition, along with membership in university liaison programs and continuing education.

The growing role of universities in regard to research work is supported by recent analyses by *Inside R&D* newsletter.[11] For "several reasons ... industry is seeking out more joint research projects with universities. Companies are conceding that the academic labs are better at the basic sciences and discovery than industry's labs. The companies now feel that their own natural habitat is development. ... Companies get schools involved to share the expense... A number of universities are seeing a rise in interest among companies to share research projects."

Richard Florida of Carnegie Mellon University has just completed an analysis of 1058 university-industry research ventures in the United States,

involving total spending of $2.66 billion on R&D, overshadowing the National Science Foundation's prominent university research budget of $1.69 billion.[12] (Many other possible sources of technology acquisition are involved in our survey questionnaire and did not make this list of top eight important contributors.)

In-House R&D

The other side of technology acquisition is development, where most R&D money is spent in all regions and in all industries. Despite the rapid growth in external sourcing, the study data underlying Figure 13 clearly prove that the principal source of technology acquisition for development is the company's own internal divisional R&D . The heavy bar under that line in Figure 13 is intended to communicate the three-to-one difference we found in the perceived contribution of divisional or business-unit R&D relative to any other source of technology. Divisional R&D still has almost a stand-alone role with respect to its importance, for all regions and across all industries. But note that Number two on the development side is not internal but, rather, has already shifted to the outside world: the contribution of joint ventures and alliances with outside companies. This is clustered with the contribution of central corporate research and with a second form of external alliance: the incorporation of supplier technology. Here we see clear distinctions between research management versus development management in terms of where one looks for sources of technological payoff.

The Role of Universities

As indicated above, companies are moving heavily toward the use of external resources for technology leveraging. In this regard, we probed for further insights into the general role of universities with these major R&D-performing companies. Figure 14 indicates significant differences in the regional

Insert Figure 14.

patterns of university utilization, with Japanese companies most involved with tangible endeavors such as training and research collaboration, while U.S. firms are least engaged in those activities and most involved with discussions and visits that help obtain new ideas and assess technology trends. European companies display a mix of the U.S. and Japanese practices. But for all four of the key university activities cited, Japanese firms are statistically significantly more intense in their usage.

The significantly greater Japanese appreciation of, and leveraged benefits from, universities clearly reflect attitude not access. Most of the universities cited are in the United States, some in Europe. The Japanese overcome far greater distance, language and cultural barriers to take advantage of these resources. Japanese companies are no doubt using universities to compensate in part for their historically lower internal spending on the research side of R&D, but this fact alone does not explain their more intensive exploitation of academic access.

The overall high company utilization of universities to determine technology trends evidenced in Figure 14 is also supported by our survey findings on mechanisms companies have adopted for monitoring technology.

Internal technology steering groups dominate monitoring methods, but university liaison and research consortia, as well as other industry consortia, play a critical role. The prominent role of university liaison programs in part reflects the changed attitudes of many universities toward these relationships. A 1988 Federal "General Accounting Office (GAO) report found that of 107 universities surveyed, 41 had initiated industrial liaison programs to encourage ties with industry",[13] following the lead of MIT's program launched in 1948.

Globalization of R&D

We are very interested in the trend toward globalization of research and development activities. Foreign R&D potentially combines both improved linkage of technology investment to local market needs as well as improved leverage from accessing multi-regional resources on behalf of overall corporate objectives.

One of the problems we discovered is that we need to be more careful in

Insert Figure 15.

how we define our terms. We asked companies for data relating to their R&D activity in foreign countries, but we were really interested in getting information on R&D activities in regions other than the firm's "home base". Thus, the "foreign" regional efforts of North American and Japanese companies are correctly portrayed in the data, but the data on European firms misrepresent by overstatement what we intended to seek. For example, our respondents classify all the work that a company headquartered in France carries out in Germany as "foreign", even though it is within the same geographic boundaries we have defined as a region for the purposes of this study. Correcting for the differences in baseline, all regions are tending upward in their foreign R&D percentages. On an absolute basis Japanese companies are still doing only a small fraction of their R&D outside of Japan, but are accelerating somewhat more rapidly than U.S. firms, which are growing more rapidly overseas than is Europe.

OECD data support the trends shown in our survey that much of the foreign R&D spending in Europe is financed by U.S. companies. In 1988, according to the OECD, "U.S. companies spent 10.5 percent of their R&D budgets abroad, up from 7.6 percent in 1985.[14] The National Science Foundation reports continuation of this U.S. pattern, with R&D expenditures for major U.S. firms rising from 1990 to 1992 about 5.7 percent annually abroad versus 3.5 percent domestically.[15] To complement these expenditures the OECD also reports that "foreign companies spend as much on R&D in the United States as U.S. firms spend abroad".[16] With regard to Japan *Science*[17] published two news commentaries about Japanese firms' increased rate of establishing U.S. basic research labs in electronics and biotechnology, in addition to increased Japanese-U.S. university research and company alliances. This is paralleled in part by the rise of foreign R&D centers in Japan, as reported by its Ministry of International Trade and Industry, especially in the fields of chemicals and pharmaceuticals.[18]

Summing Up

Relative to U.S. corporations, the giant, technology-intensive, Japanese and European companies have more thoroughly linked their technology strategies to overall corporate strategies, with the degree of this linkage relating strongly to enhanced R&D performance. Globally CTOs and R&D vice presidents are the most important facilitators of the ties between technology and overall strategy, with CEOs being close in importance at the corporate level, and divisional or business-unit general managers being vital linkpins at the business level. In many Japanese companies, CFOs are actively involved in this integration, perhaps reflecting an underlying Japanese attitude that R&D needs to be treated as long-term investment.

Chief executives in Japan are far more engaged than their European and American counterparts in technology strategy development and implementation. They spend more time in assessing both internal and external technological investment opportunities. In contrast, U.S. CEOs are distinguished statistically only by their higher involvement in controlling R&D budgets.

Nearly all Japanese CTOs are members of the boards of directors or main managing boards of their companies. This enables technological considerations to enter into discussions of all strategic issues of Japanese firms. Similarly, perspectives gained from overall corporate participation inevitably influence these CTOs' insights and decisions. But of the major U.S. firms included in our study, only 20 percent of the CTOs have these board-level positions of rank and influence. In my opinion, this deficiency acts to dismember technology from an intimacy with overall corporate strategy.

Japanese chief technologists are also perceived to be much stronger statistically than their global colleagues in their upward influence on overall corporate strategy, and far more influential as well in downward impact on the R&D programs of their firms' divisions and business units. If U.S. companies insist on boards of directors that are essentially devoid of insiders, then they ought to develop senior management committees comparable to many British main boards, whose members focus on the strategic, not operational, aspects of the major functional areas of the firm, almost inevitably including a board member for technology.

Several major organizational developments are affecting the strategic management of technology. U.S. firms are engaged in a headlong rush toward decentralizing even further the control of their research, and especially their development efforts, down to divisional and business-unit levels. This represents a somewhat cyclical reaction to business pressures for more responsive R&D, leading almost inevitably to improvement of short-term performance in generating new and improved products and processes. But the flight to bottom-level control also predestines the erosion of support for research and longer-term development, with predictable negative consequences.

Of great surprise to this author, Japanese companies are moving precisely in the opposite direction with regard to research, moving control more strongly

upward to the corporate level. Increased corporate control of research permits Japanese companies to develop and exercise greater strategic control over their own technology-dependent futures. Control of development in Japanese firms is remaining more-or-less stationary in the aggregate, with control shifts between corporate and business-unit levels occurring roughly evenly in both upward and downward directions. Although I predict an eventual turnaround in U.S. R&D decentralization, the sooner companies begin to reinvest in their longer-term futures the better.

Companies worldwide are evolving rapidly toward increased dependence upon external sources of technology. This is true in research, where the university is becoming a strong complement to internal sources. This movement is paralleled in development by dramatic increases in the uses of joint ventures and alliances to provide product and process advances. Japanese companies are already more involved with these external sources than European and American companies, and are accelerating their movements toward outside dependencies. The "virtual R&D organization" is an idea that is growing in conceptual importance, but is still far from practical implementation. Yet all companies worldwide need to develop their own balance between internal and external sourcing of technology, with the effectiveness of external acquisition requiring skills and organizational structures not yet in place in most firms.

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Appendix: Survey Methods

The Global Survey on the Strategic Management of Technology was developed by a team headed by Professor Edward B. Roberts of the MIT Sloan School of Management and chairman of Pugh-Roberts Associates, a division of PA Consulting Group, assisted by Lauri Mitchell, formerly of Pugh-Roberts Associates. The staff of the MIT Industrial Liaison Program (ILP), directed by Thomas Moebus, collaborated closely, with coordination provided by Wendy Elliott. Several members of the ILP Industrial Advisory Board pilot tested an early draft version of the questionnaire. Consulting staff of Pugh-Roberts Associates, as well as members of the global technology management practice of PA Consulting Group, commented on various questionnaire drafts. Eric Wiseman, previously of Pugh-Roberts Associates, helped formulate the overall questionnaire. Professor Ralph Katz and Varghese George of the MIT Management of Technology and Innovation Group consulted on questionnaire design and analyses.

The two primary data collections of the survey are: Benchmarking, comprising about three-fourths of the questions, to establish measures of practice in global strategic management of technology, as well as measures of R&D and overall company performance; and the Special Research Topic (for this initial survey): Managing Technology with Constrained Resources, to document worldwide responses to the changing economic climate in terms of recent, current, and expected actions affecting technical programs, staffing, resources, and controls.

The survey was sent during 1992 to those firms performing the largest amount of research and development work (as measured by their 1991 expenditures) in Western Europe, Japan, and North America. The list of companies sampled was determined from many sources (including the U.S. National Science Foundation, *Business Week*, and *Inside R&D*) by starting with the largest R&D spender in North America and including all North American firms in order of decreasing expenditures until the cumulative amount exceeded 80% of the total R&D performed in this region. This generated 109 firms, one headquartered in Canada and the rest in the United States, all spending more than $100 million on R&D during 1991. Using $100 million as the lower limit, all companies with R&D expenditures at or above that level were included from Western European countries (including Scandinavia), producing 80 companies, and Japan, with 55 firms. The resulting sample of 244 firms therefore accounts for approximately 80% of the R&D performed in Western Europe, Japan, and North America.

The 11 page English-language questionnaire was mailed to the highest ranking technology-related officer of each company, followed later by reminder letters and telephone calls. Replies were mailed to the MIT Industrial Liaison Program, recorded in a master file and assigned a code number by that office, with all company-identifying information removed from the questionnaire. The resulting anonymous questionnaires were then turned over to Pugh-Roberts Associates for comprehensive data coding and analyses, producing a database

that permits sorting by principal industry and geographic location of corporate headquarters.

Of the 244 companies sampled, useable responses were received from 95 firms, or 39 percent. 46 were from the United States (42 percent response), 27 from Europe (34 percent), and 22 from Japan (40 percent), providing an essentially balanced response by geographic area, with slight underrepresentation of European companies.

To further rule out apparent self-selection biases, demographic comparisons were made of the respondents versus the survey population in terms of R&D spending. Frequency analyses in terms of overall spending amounts, as well as cumulative spending analyses for all respondents versus the survey population, demonstrate that the size distribution of respondents matches almost precisely with the size distribution of companies surveyed, for the overall global sample as well as for each of the three geographic areas.

The statistical analyses of the data discussed in this article were carried out at Pugh-Roberts Associates by the team of Lauri Mitchell, Mark Bamford, and Edward Roberts.

Figure 1. Major corporations in North America, Western Europe, and Japan are, on average, moderately engaged in formal practices of developing and applying technology planning and strategy at the overall corporate level. The extent of acceptance of these practices correlates significantly with many measures of successful R&D outcomes.

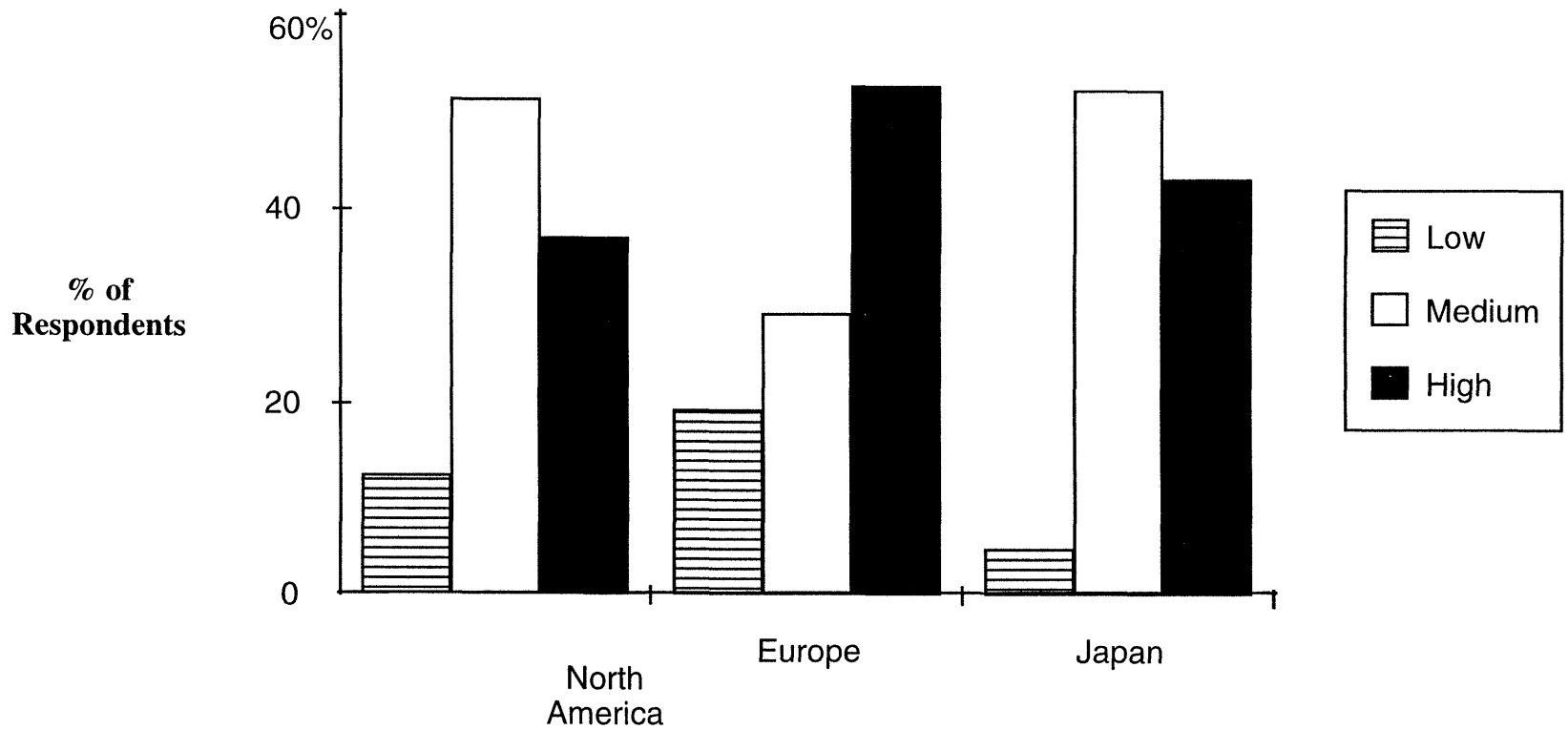

Figure 2. The primary driver of most companies' technology strategies is matching R&D to their perceived market needs. A special aspect of that match is decreasing the time required to bring new products to market.

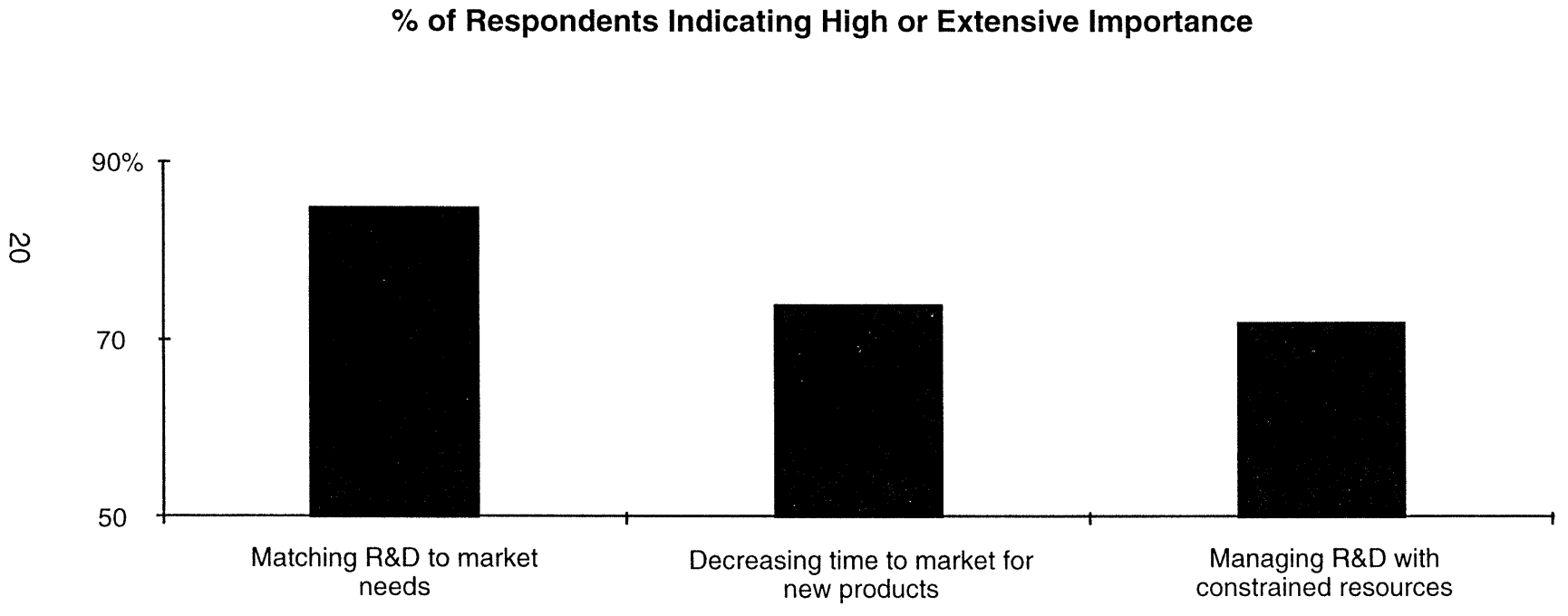

Figure 3. Over 70 percent of Japanese firms have strongly linked their technology and overall corporate strategies, in contrast to about 50 percent of U.S. companies. "Linkage" correlates strongly to many different measures of R&D performance.

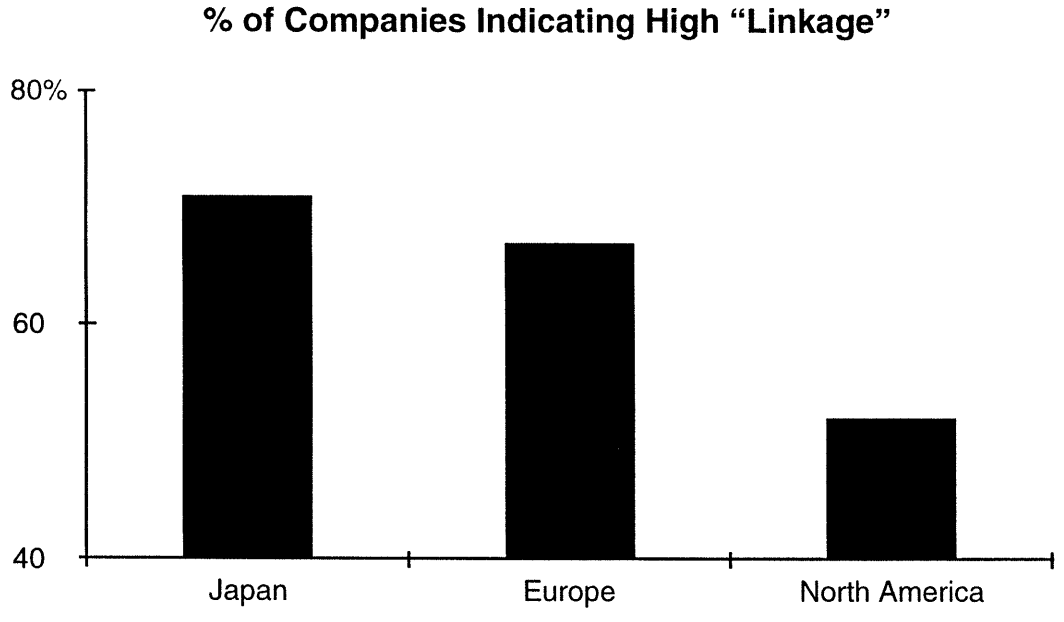

Figure 4. The main players in overall corporate technology-strategy linkage are the Chief Executive Officers and Chief Technology Officers. In one-third of Japanese firms the Chief Financial Officer provides critical support in this linking function.

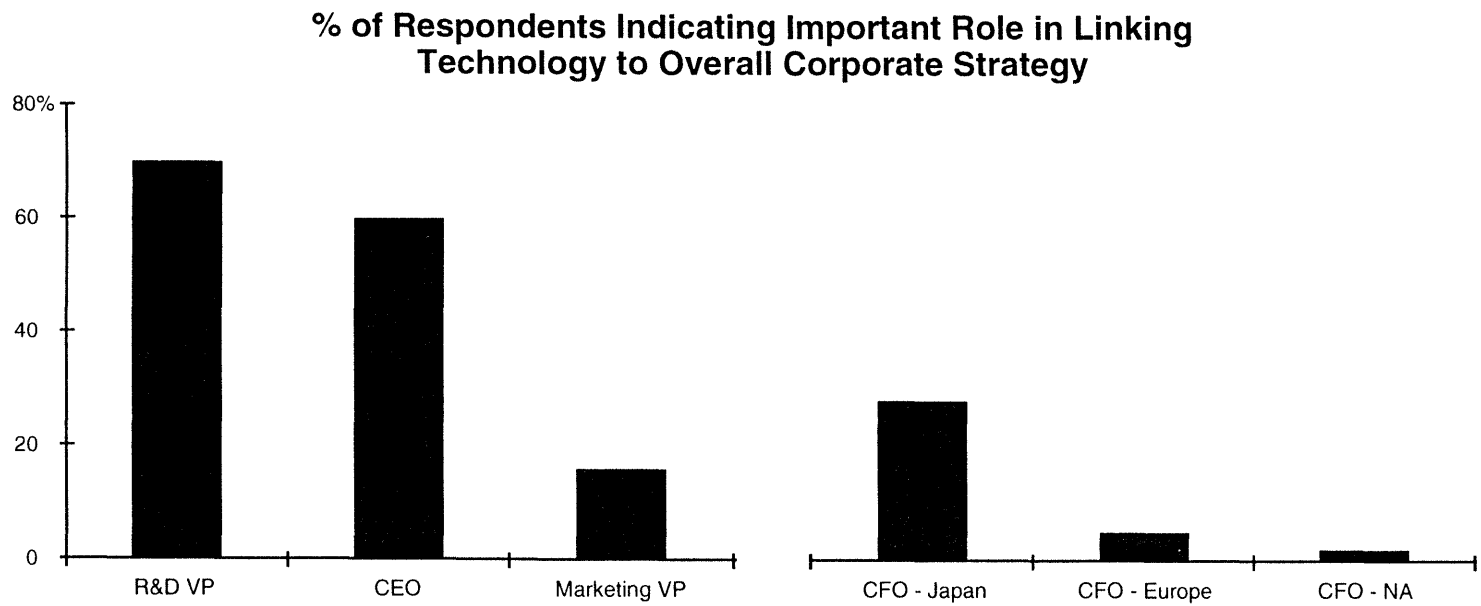

Figure 5. At the business-unit or divisional level the R&D vice president and the business-unit general manager provide primary technology-strategy ties. Again, Japanese companies reflect important CFO support, even at the business-unit level.

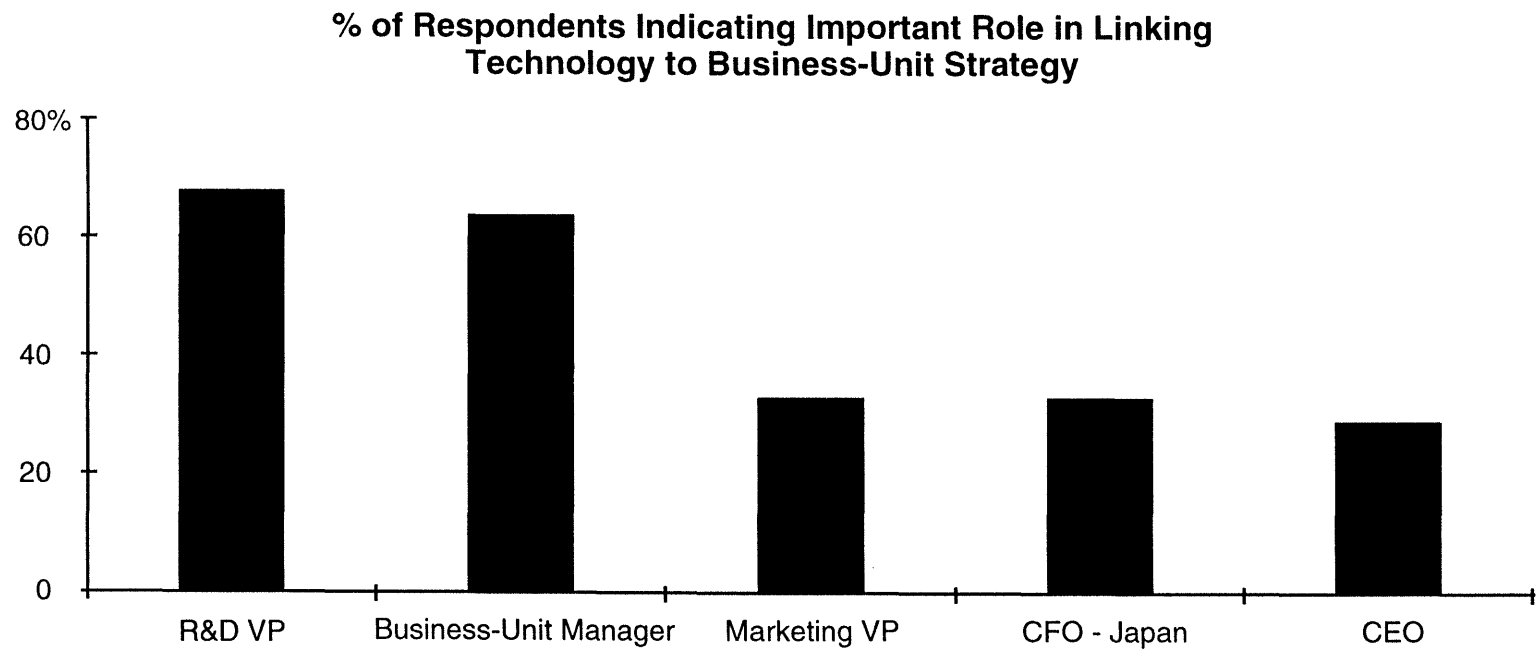

Figure 6. More Japanese CEOs are highly involved in the content aspects of technology strategy than their European or American counterparts. Most U.S. CEOs have the dubious distinction of higher involvement in establishing R&D budgets, suggesting a control orientation instead of a "vision" perspective for technology direction.

	% CEOs Highly Involved in Technology Strategy		
Activity	**US**	**Europe**	**Japan**
Technology strategy development	34	37	46
Project selection/prioritization	24	41	41
Internal technology resource allocation	24	18	32
Selection of outside technology investments	40	27	45
Average	31	31	41

- But US CEOs are far more involved in establishing overall R&D budget

74	54	50

Figure 7. Chief technology officers (CTOs) have board-level membership in almost all Japanese companies and over half the European companies. Only 20 percent of U.S. CTOs are on their firms' boards, depriving the rest of the opportunity for ongoing strategic dialogue.

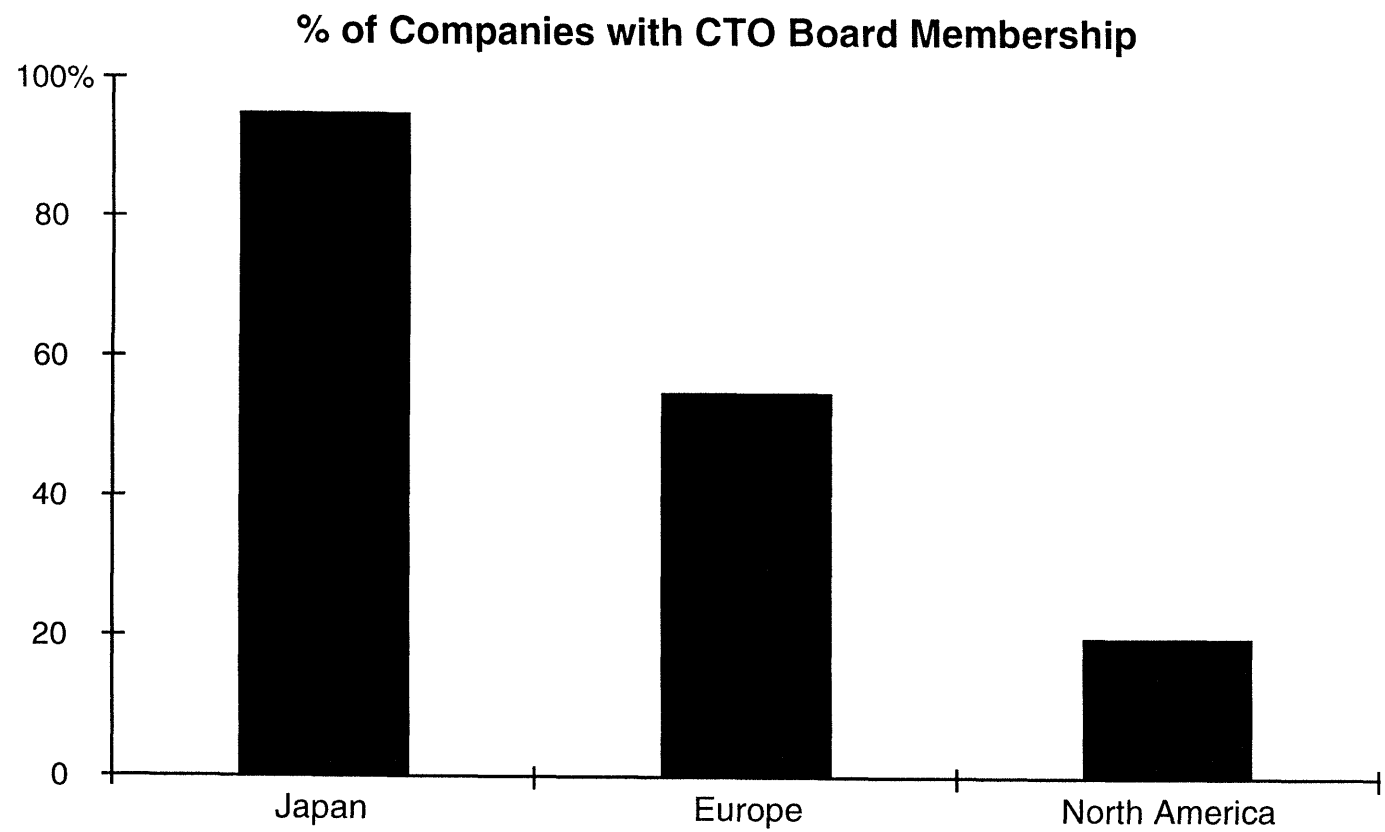

Figure 8. U.S. chief technology officers have far less influence on business-unit technology direction than their Japanese and European counterparts, perhaps reflecting greater U.S. tendency towards decentralized control.

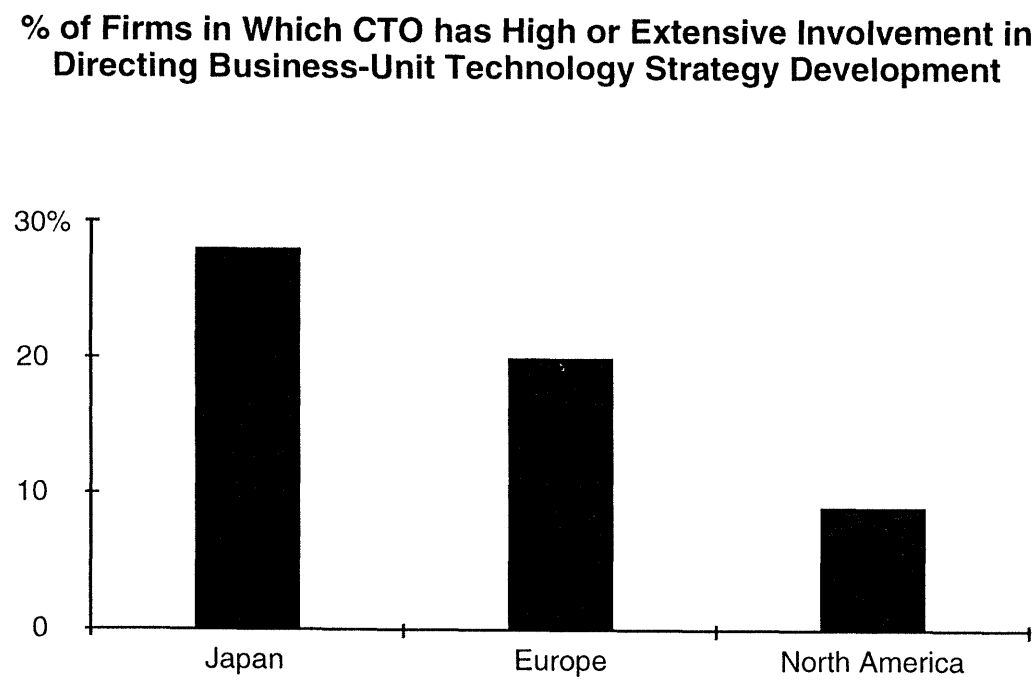

Figure 9. RD&E budgets at the corporate level clearly reflect a longer term view than at the business-unit level. But significant differences exist in regional spending patterns, with Japanese firms spending far less on research and far more on development at the corporate level than either U.S. or European companies.

Overall global sample's R&D spending pattern

	Corporate	*Business-Unit*
Research	42%	13%
Development	37	47
Product Technical Support	11	24
Process Technical Support	10	15
	100	99

Figure 10. RD&E budget allocations are very different across industries, making "budgetary benchmarks" for R&D risky at best, unless carried out against quite comparable firms.

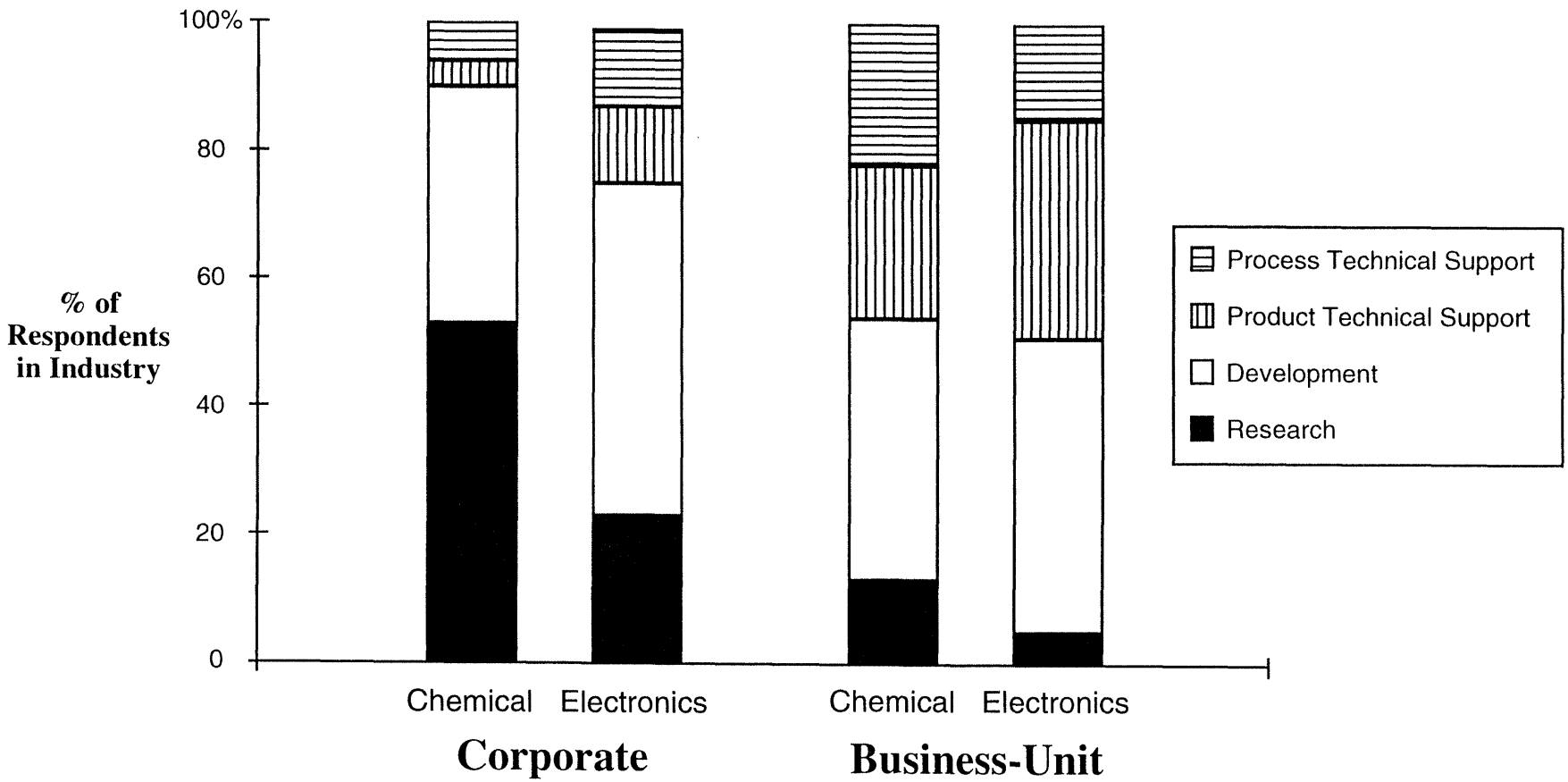

Figure 11. The U.S. is rushing toward decentralized control of both research and development while Japan and Europe are behaving differently. Japanese companies are actually rapidly increasing centralized control of their research efforts.

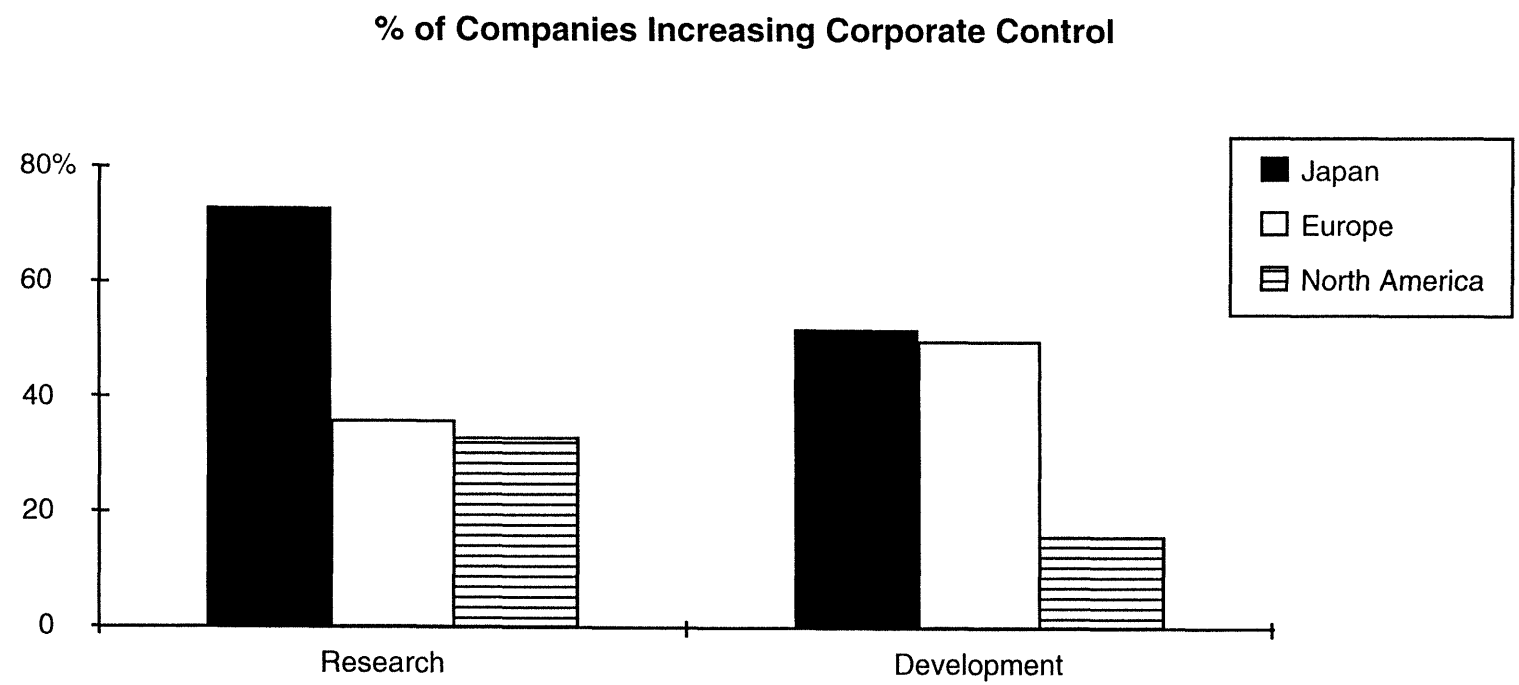

Figure 12. Japanese firms have a longer history of highly leveraging external sources for technology, with the rest of the world following behind. Most major companies worldwide are expecting to become increasingly dependent on "outsiders".

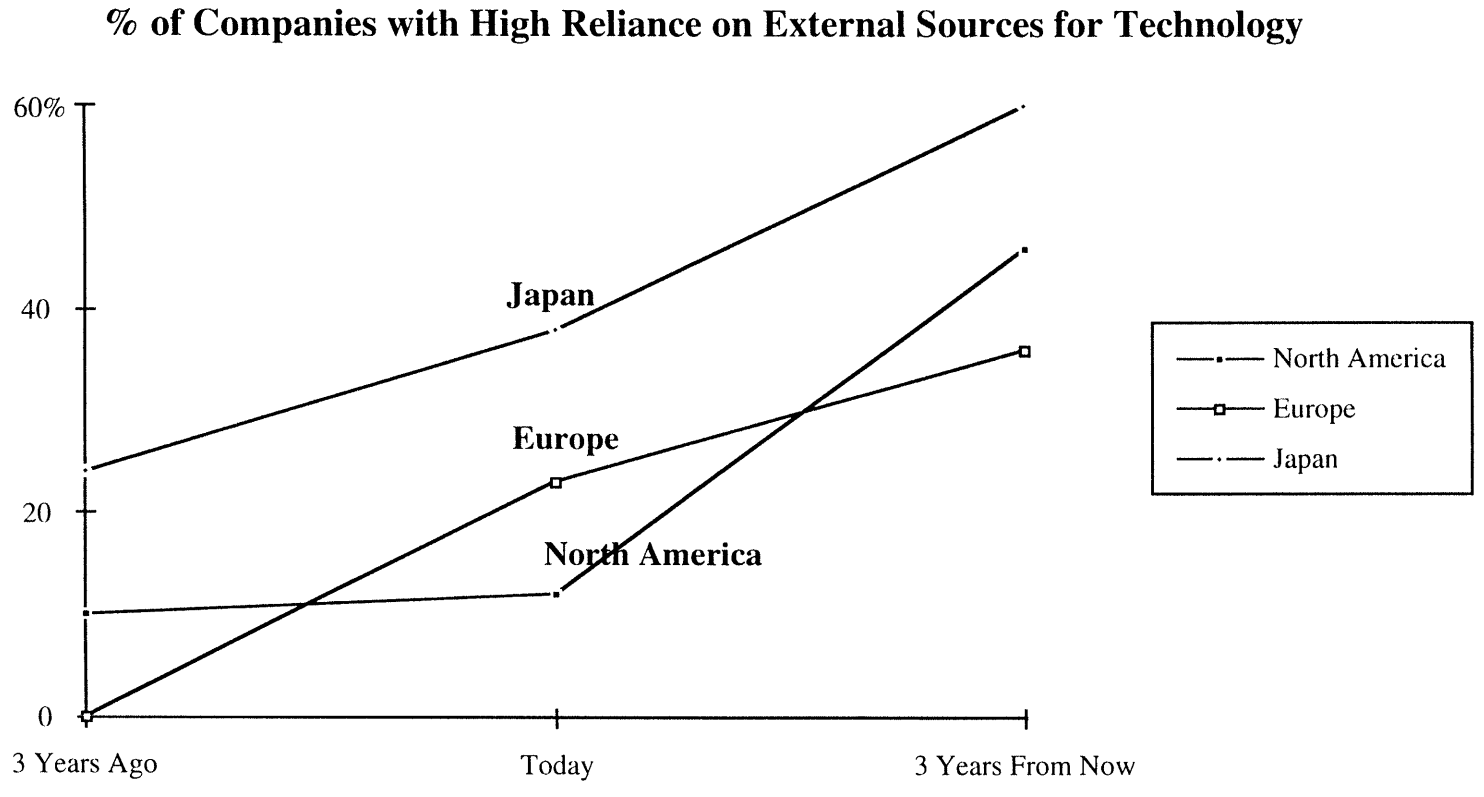

Figure 13. Internal sources are still primary for both research and development. But universities are moving up fast as supplements to internal research, and joint ventures, alliances and suppliers are increasingly keys to technological development.

Overall rank-ordered importance of sources

	For Research Work:	For Development Work:
1.	Central corporate research	Internal R&D within divisions
2.	Internal R&D within division	Joint ventures/alliances
3.	Sponsored university research	Central corporate research
4.	Recruiting students	Incorporating supplier technology
5.	University liaison programs	Licensing
6.	Consultants/contract R&D	Acquisition of external technologies
7.	Continuing education	Acquisition of products
8.	Joint ventures/alliances	Consultants/contract R&D

Figure 14. Japanese firms gain far greater benefits from university programs than European companies and especially than North American firms. The data clearly show far greater Japanese commitments to collaborative research and extensive personnel training and development, both requiring movement of their scientists and engineers onto university campuses in the United States and Europe.

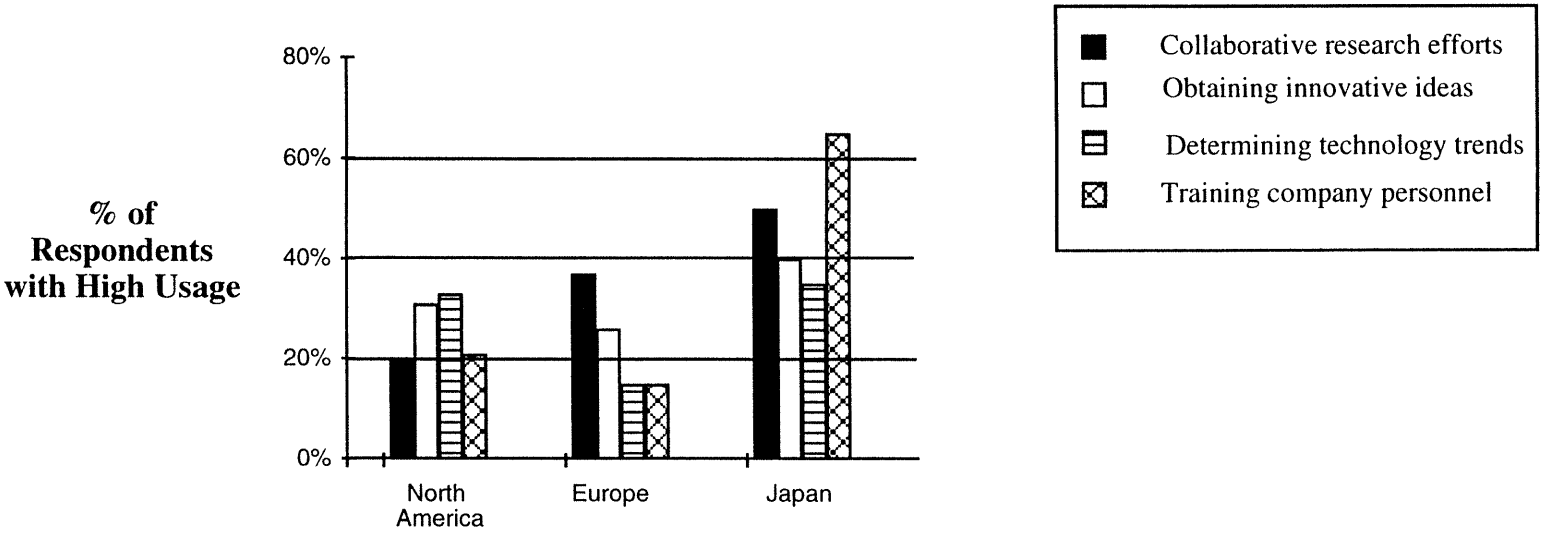

Figure 15. R&D based in foreign countries is growing, but the percentages for all regions remain considerably smaller than their overall foreign capital investments or, in particular, their foreign revenues. Japanese R&D spending is still almost entirely domestic, reflecting perhaps a 10-year lag behind U.S. internationalization.