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Strategic Management of Technology: Global Benchmarking (Initial Report)

by

Edward B. Roberts*

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MASSACHUSETTS
INSTITUTE OF TECHNOLOGY
50 MEMORIAL DRIVE
CAMBRIDGE, MASSACHUSETTS 02139

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David Sarnoff Professor of the Management of Technology, MIT;
Chairman, Management of Technology and Innovation Group,
MIT Sloan School of Management;
and Chairman, Pugh-Roberts Associates,
a division of PA Consulting Group, Inc.

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ABSTRACT

Extensive data collected from the largest R&D-performing companies in the United States, western Europe, and Japan demonstrate broad trends and regional differences in strategic management of technology. 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. 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. In carrying out product development European companies are less involved with their customers than are U.S. or Japanese firms, but, along with American companies, the Europeans are improving significantly in time required to bring new products to market. Timeliness of technical results and newness of the company's technology portfolio are key influences upon overall company R&D performance as well as on new product revenues. Company sales growth is statistically related to R&D meeting its multiple project-level objectives of schedule, technical performance and budgeted cost.

We report here initial results of our survey study of Strategic Management of Technology that we launched in a unique partnership begun in 1992 between the MIT Industrial Liaison Program and PA Consulting Group. We selected for study all of the largest research and development (R&D) spenders in North America, western Europe and Japan, those firms which cumulatively in each region expend about 80 percent of the total R&D dollars. Fewer than 250 companies spend 80% of the total R&D dollars in Europe, the U.S., and Japan, and we had a 40% sample response with very good distribution by size of these major R&D spenders in each region. The Appendix of this report provides more details of our study, including the methods followed, our sampling approach, and the responses we obtained.

This report covers four topics. First is what we learned about the technology strategy development process itself. Then we discuss changes that have occurred globally in strategic management of technology. Third we briefly examine what factors affect enhancement of R&D performance. Finally, we comment on our plans for moving forward in our research studies.

The Development and Acceptance of Technology Strategy

Ten years ago, from perspectives gained in MIT research and executive education activities, as well as from extensive consulting projects by me and my colleagues, I believed that very few companies worldwide were doing much with respect to developing overall strategies for the management of technology in the firm. However, in the past decade major changes have occurred globally with respect to 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 label here as 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 for each region and industry grouping as well. What is more important than the fact that strategy is being developed is that the process of developing and applying technology strategy produces results. Statistical correlations against a large number of measures of R&D performance demonstrate that in particular the degree of business-unit level development of technology strategy relates to performance even across our entire global sample of multiple regions and multiple industries. When we get down to 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.

Figure 1. Major Corporations Engage in Technology Strategy Development to a Moderate Extent.

An interesting relationship is now clear (in Figure 2) between the extent of doing strategic development of technology at the corporate and at the typical business-unit levels. Those companies that are strong in their technology strategy development at the corporate level clearly are also strong in technology

Figure 2. Strong Corporate-Level Technology Strategy Development Influences Strong Business-Unit Technology Strategy.

strategy development at the business-unit level. (p=.0005) If leadership exists at corporate in developing technology strategy and understanding and trying to bring direction and focus to technology management in the firm, either that role example or the methodologies that are developed or the power from the top or their combination causes the business units of the firm 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 of the firm. 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 presently occur at the business-unit level.

We tried to identify the principal issues that matter in technology strategy. As indicated in Figure 3 three perspectives are currently most important to senior

Figure 3. What is Most Important to Technology Strategy?

executives. (Most of the people who responded to our questionnaires are Chief Technology Officers or Vice Presidents of R&D, or their immediate planning and support staffs, a carefully selected set of respondents to be sure, the most senior technical management in the company, and clearly a responsible group of people.) They identify as the number one priority with respect to technology strategy the matching of R&D to market needs. This is significantly more important than the problem that has been proliferating 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.

A crucial question is how well tied is corporate strategy in the technology domain to overall corporate strategy. Here we find the first of the differences that are both important and that throughout this report cumulatively paint a picture of 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 4 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.

Figure 4. Corporate-Level Technology Strategy is More Strongly Linked to Overall Strategies in Japan and Europe.

Now of course numerous exceptions exist to this finding of weak U.S. strategic technology linkage. Robert Lutz, President and COO of Chrysler Corporation, for example, in his keynote address at our MIT symposium in December 1992, outlined how Chrysler's overall mission directs the way in which key aspects of its technology strategy and technology management proceed. But most American firms have not done as good a job in providing these overall ties. To emphasize the importance of this issue, later in this report 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 the technology investment of the company.

Figure 5. Who are the Keys to Linking Technology to Overall Corporate Strategy?

A related issue is who is central in achieving this linkage. In about 60% of the companies in all regions Chief Executive Officers (CEOs) 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 (CTOs). One difficulty is that many companies have no such person as the chief technology officer. We'll return to the CTO soon.

One observation from Figure 5 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 you look for the roles that people play with respect to this connection, the corporate marketing vice president tends to be insignificant in relating to technology. In many companies the corporate marketing VP is virtually non-existent or is a weak staff function. 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 carrying out the bargaining, the communication and the design and implementation of linkage structures.

One surprise from the survey is a role that we had not anticipated whatsoever. In fact we had thrown in the question with respect to possible involvement of chief financial officers (CFOs) 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 a third of the major technology-oriented companies in Japan the chief financial officer is seen as an integral part of 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. As I glanced casually at his card I was astonished to note that this one showed two business addresses, one of them in Cambridge, Massachusetts. In response to my questioning the R&D executive instantly 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 reflect for Japanese firms a very different understanding and appreciation of the roles that technology plays and the fact that it must be integrated into all levels of strategic thinking. We are going to come back to this point later when we look at the differentiated role in Japan versus the United States of the chief executive officer as a linkpin, because the helping role of the CFO in Japan I believe compensates and differentiates for how their CEOs see the relationship to technology. We need to learn from what the Japanese seem to have accomplished in the attitudes and teamwork of their senior executives toward technology.

Figure 6. Keys to Linking Technology to Business-Unit Strategy.

Let's answer the same set of questions relating to the business-unit level of the firm. When we move down to the level of business units and divisions, where in fact most R&D money is being spent, we find appropriately that 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 6 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 twice 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, reflecting where marketing has presence. The marketing organization does not have broad-based corporate presence in affecting technology; it instead 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 non-existent again in either the United States or Europe.

Let us now devote more attention to the Chief Executive Officer. I have a bias. 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. 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

Figure 7. More Japanese CEOs are Highly Involved in Technology Strategy.

find that fewer U.S. CEOs get very involved in technology content, strategy or direction-giving generally. More Japanese chief executive officers are involved in all 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 7 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 presently David Duke, both of whom served as Vice-Chairman of Corning. 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 when we carry out more careful analyses of the pharmaceutical industry, where we have a reasonable amount of data, we may find differences in the roles of U.S. CEOs with respect to content and directional contributions to the area of technology strategy.

The second key executive of interest to me is the Chief Technology Officer, the CTO. Our first problem is to define a chief technology officer, especially difficult given the wide variance in the roles that person plays across firms, for example in terms of membership on the company's board of directors or main managing board. In Japan Figure 8 points out that 95% of chief technology

Figure 8. Chief Technology Officers Have Board-Level Membership in Almost All Japanese Companies and Over Half the European Companies.

officers are members of main boards or boards of directors. Europeans drop significantly to 55%. But in the United States the chief technology officer is represented on the senior managing boards of only 20% of the companies sampled, and remember that these giant corporations are among those spending most on R&D in the world. In my opinion this single figure presents the strongest damnation of U.S. senior executive practice and prioritization. If U.S. firms want to compete effectively in a technologically intense world, then 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. An elevation of importance of the role of the chief technology officer can be a double-edged sword for some current senior R&D managers. Indeed, chief technology officers must be selected so that that person is appropriate to participate in main board discussion and 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 the 4-to-1 difference in Figure 8 between Japan and the United States, and 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 is really 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 further we seek more insights into the roles of the CTOs. We should be having difficulties in establishing strong statistical relationships because here, as in most cases discussed in this report, we are examining overall samples, across regions and industries. So many different industries represented in the database should blind generalizations. It would be easier if we just took chemical industry data, for example, and did a study of that one specific industry. But at the global level we again find Japanese chief technology officers more involved in overall corporate strategy. This is now not looking inward to technology, it is looking outward towards the corporation as a whole. As Figure 9 demonstrates significant differences also are evident in the

Figure 9. U.S. Chief Technology Officers Have Far Less Influence on Business-Unit Technology Direction.

extent to which the chief technology officer at the corporate level provides direction for technology development at the business-unit level of the firm. 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 in regard to the 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 what 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.

Trends in Global Strategic Management of Technology

We turn now from the issues of technology planning and strategy development to some key aspects of strategic management of technology. We obviously cannot talk about management without talking about budgets. Budgets critically reflect strategy. Earlier we emphasized some differences between the corporate and the business-unit levels of the firm. Now Figure 10 presents for the overall sample 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 dominance of development spending is prevalent.

Figure 10. R&D Budgets at the Corporate Level Clearly Reflect a Longer Term View than at the Business-Unit Level.

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

Corporate-level support of present product and process technology does account for over 20 percent of its budget. Clearly as we move downward in the firm from the corporate level to the business-unit level near-term support of both product and process 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 11 just to emphasize how

Figure 11. RD&E Budget Allocations are Very Different Across Industries.

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, how they are prioritizing their expenditures. Spending patterns by industry turn out to be very different.

Beyond the issue of budget is what ought to be the related consideration of control. Here we found quite a surprise. In the United States it is very clear that major companies have been moving for the last five or six years heavily towards decentralized control of both research and development. Control of both R&D budgets and activities has been moving from the corporate level to the divisional and business-unit level of the firm. Much to our surprise the same pattern of change is not occurring in Japan, nor in Europe to the same extent. Let's look at the data shown in Figure 12. For research almost all Japanese firms

Figure 12. U.S. is Rushing Toward Decentralized Control of R&D While Japan and Europe Behave Differently.

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" (*Inside R&D*, July 22, 1992). 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 "catchup" in regard to 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 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, 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 12 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 changes will indeed make U.S. firms more competitive in short-term performance. But the problem of business-unit control of R&D is that firms eventually stop investing in longer-term research and development, 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.

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 research and development efforts to the extensive use of outside partners. The survey data on moving to the outside world for technology, illustrated in Figure 13, are rather profound. The shifts have been occurring rapidly in the extent to which

Figure 13. Japanese Firms are Highly Leveraging External Sources for Technology, with the Rest of the World Following.

companies see themselves as increasingly and strongly reliant on external sources of technology. The anticipated changes here continue over the next three years. Note 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. Mr. Lutz describes Chrysler in this domain, as becoming more Japanese in management style, creating strong ties to outside vendors and suppliers, even of technology. Lutz labelled this a "virtual enterprise", with the firm's effective boundaries extended to include the capabilities of many collaborators.

The Industrial Research Institute's annual survey confirms this trend, showing that 48% of the U.S. firms that replied expect increased participation in alliances and joint ventures, with 16% expecting to increase their licensing from others (*Inside R&D*, November 18, 1992, p. 2). One of the more prominent recent examples is the announced controversial billion-dollar long-term research agreement between Scripps Research Institute and Sandoz Pharma (*Science*, vol. 258, December 4, 1992, p. 1570), since revised in its terms. In general the OECD indicates a thirteen-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 (as cited in *Inside R&D*, May 13, 1992, p. 4).

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 extract control of you due to your dependence. Others may perform contrary to your expectations or desires. But this situation can also be labelled 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. 60 percent of all major Japanese companies expect to be highly dependent upon external technology sources three years from now, compared with 25% 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 and 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 research and development 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 12 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.

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 14. For research work three clusters of influence

Figure 14. Internal Sources are Still Primary for Both Research and Development.

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 14 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 research, shown in Figure 14, 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* (November 4, 1992, p. 2). 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." We'll look further at the general role of universities momentarily. Keep in mind that many other possible sources of technology acquisition are involved in our survey questionnaire and did not make this list of top eight important contributors.

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 14 clearly prove that the principal source of technology acquisition for development is the company's own internal R&D within divisions. I inserted the heavy bar under that line in Figure 14 to communicate a three-to-one difference 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 now 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 alliance, the incorporation of supplier technology. Here we evidence clear distinctions between research management versus development management in terms of where one looks for sources of technological payoff. Our overall findings on development work are also consistent with a recent UK study: "In-house R&D is seen as the most significant source of technological innovation for industry", but by the mid-1990s "customers and suppliers are expected ... to become the most significant source". (S. Bone, "Chief Executives' Attitudes to Technological Innovation in UK Manufacturing Industry", PA Consulting Group, Hertfordshire, UK, 1992, p. 9)

As indicated above companies are moving heavily toward the use of external resources. In this regard we probed for further insights into the general role of universities with these major R&D-performing companies. Figure 15

Figure 15. Japanese Firms Gain Far Greater Benefits from University Programs.

indicates significant differences in the regional 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 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 historic 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 15 is also supported by our survey findings on mechanisms companies have adopted for monitoring technology. As shown in Figure 16 internal technology steering groups dominate, but university

Figure 16. Companies Use a Wide Variety of Approaches to Monitor Technology.

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" (*Christian Science Monitor*, November 23, 1992, p. 12), following the leading example of MIT's program launched in 1948.

We are very interested in the trend toward globalization of research and development activities. One of the problems we discovered is that we need to be

Figure 17. R&D Based in Foreign Countries is Growing.

more careful in how we define our terms. We asked companies for data relating to their R&D activity in foreign countries, but we really wanted 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 activities of European firms are overstated. 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 with detailed findings 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% of their R&D budgets abroad, up from 7.6% in 1985 (*Inside R&D*, May 13, 1992, p. 3). 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% annually abroad versus 3.5% domestically (*Inside R&D*, April 29, 1992, p. 7). 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" (as reported in *Inside R&D*, May 13, 1992, p. 3). In regard to Japan *Science* (vol. 258, November 27, 1992, pp. 1428-1433) 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 (*R&D Magazine*, May 1992, p. 21).

Enhancing R&D Performance

Our third area of research is influences upon technological effectiveness and R&D performance. We had an interesting time in trying to define performance, ending up with 16 different measures of R&D performance and R&D contributions to the firm, clustered into three categories. First are a large number of measures by which we attempt to assess competitive advantages in R&D efforts. Second we look at the project level of performance and identify several evaluators of how R&D projects stack up against expectations. Third we try to find strategic indicators that R&D performance matters and has had corporate impact.

We identified three key stakeholders for R&D or three key sets of customers, only one of which is outside of the firm, its end-user/customer. The other two R&D "customers" are (a) those senior officers of the firm who attempt to set direction and priority for the company and (b) internal manufacturing/ operations, the customer for process change and improvement as well as cost reduction within the company. Figure 18 shows the results of our asking companies to benchmark themselves and to identify how they are doing in satisfying these different stakeholders relative to their own most serious

Figure 18. Meeting the Needs of Key Stakeholders for R&D Efforts.

competition. Most companies principally emphasize satisfying end-use customers, with about a third of the firms worldwide feeling that they surpass competition in meeting their external customers' needs. Least important overall, as well as for U.S. and European firms separately, in their scale of values is the extent to which they surpass competition in satisfying manufacturing's technological requirements. However, this slight is not true for Japanese companies. Only 1 out of 8 U.S. and European companies self-assess superiority in supporting manufacturing through R&D. In contrast, Japanese firms perceive themselves significantly better than competitors in meeting the needs of their internal manufacturing customer. This difference in orientation, the stronger focus on manufacturing process, is a critical differentiator of strategy, as well as budget and other aspects of implementation of priorities. Our data show that Japanese companies are more concerned with, spend more money on, and consequently they are more satisfied with, how they are performing in regard to manufacturing technology. Earlier research by Edwin Mansfield provides strong corroborating evidence that Japanese companies spend a much larger fraction of their R&D budgets on process improvement and development than do comparable U.S. companies (*Science*, 30 September 1988, pp. 1970-1).

Next we examined linkages to the marketplace. Here Figure 19 indicates that the poor performer is not the American company. I think U.S. firms have

Figure 19. "Voice of the Customer" in Product Development.

gotten their acts together with respect to listening to end-customers and relating to the market, as has Japan. But across the board in one after another measure European firms seem far less connected to their markets than are American and Japanese firms. This deficiency is apparent when we look for explicit inputs by customers in providing data that affect the determination of technology strategy, the setting of program objectives, the development of product concepts, and the development of new product prototypes. I think that United States companies have over the last four or five years, largely as a result of the Total Quality Management (TQM) movement, shifted heavily towards understanding, appreciating and working more closely to implement the "voice of the customer" in all aspects of formulating and implementing technology development priorities. What U.S. firms need to do next is to recognize that there is more than an end-use customer; there are also the internal strategic customer and the internal manufacturing customer. And clearly European companies need to improve dramatically the connections between customer inputs and technology outputs.

We then looked at five different overall measures of R&D performance, listed in Figure 20. No significant regional differences exist among the sampled

Figure 20. Five Measures of Overall R&D Performance.

firms on any of these aspects of overall R&D performance: effective use of resources, efficiency, timeliness in moving products to the market, percentage of present sales coming from new products, or even production cost reductions. I am surprised a bit because the portfolios of technology that are being implemented around the world are indeed differentiated, with very different emphases among the major corporations of the U.S., Europe and Japan. Therefore, I had expected to see some differences in overall results that accrue these individual company differences of priority. Projected into the future, today's differences among R&D portfolios are expected to create important differences in future performance.

In examining data on portfolio composition of R&D spending, U.S. senior technology officers are much more dissatisfied than their counterparts elsewhere in regard to several issues. Americans are uncomfortable about their R&D

Figure 21. U.S. Executives are Concerned About Imbalance in their R&D Portfolios.

portfolio balance with respect to time, that is in regard to their own short-term, medium-term, and long-term trade-offs. The accelerating U.S. march toward the short-term is seen as dangerous. European and Japanese technology executives are more relaxed with respect to their time-orientation balance. American executives are also less content with respect to the balance between working on familiar versus unfamiliar areas. American executives feel that their technology portfolios are overly constrained to be familiar. Our studies elsewhere demonstrate that a company is likely to have higher success rate at the project level from working more familiar portfolios of technology. The flip side of this issue is that a company is not stirring up as many potential differentiators for its future if its current portfolio of R&D projects is overly familiar. A firm must strike some risk-based balance with unfamiliar areas of technology and market development to nurture the furtherance of its own future change. Finally, U.S. executives are concerned about their focus of product versus process, expressing discomfort at the small amount of process work, while Japanese executives are statistically more satisfied with this balance.

We also looked at the several measures of project-level performance, shown in Figure 22. At the project level North America, Europe and Japan are interestingly different, with European companies claiming to have higher levels of performance in all of five dimensions that we measured, including new product breakeven time, meeting various project objectives, and recent

Figure 22. Project-Level Performance.

improvements in project performance. However, the back-up data on trends and changes fail to support in any areas the claimed European advantages. This inconsistency may reflect standards of performance for projects that are quite different across the regions of the world. In my judgment we don't yet know enough to understand what is really taking place in performance at the project level.

However, both United States and European companies do appear to be improving dramatically with respect to all aspects of project performance, especially in time to market for new products. Time to market has become the buzz word for many people and organizations. Yet in benchmarking time-related measures one must be very careful to avoid comparisons across industries. For example, our data show on average a four-to-one spread across industries in break-even times, in bringing products to market and having them generate enough revenues so as to merely repay their development costs. Comparisons must be explicit by industry. In all industries but pharmaceuticals break-even times seem to be gradually decreasing. Companies have been able to shorten time to market and also shorten the time to bring in enough revenues and profitability to repay the costs of development, except in pharmaceuticals. Yet in pharmaceuticals not only is break-even time increasing but as you might expect the pharmaceutical industry has a far higher break-even time than does any other industry in our database. The data match the complaints that the pharmaceutical industry has had for years, not just about the length of the technology development process, but moreover about the severe regulatory environment, that combine to make time to market such a long, exasperating and expensive period.

Further to this issue of moving products to market, we tried to identify what matters. I am intrigued by the specific remarks of Robert Lutz, talking about what had been done in changing Chrysler to move products to market so much faster, more efficiently and competitively. Our overall survey data, drawn from around the world and across industries, demonstrate that the top three forces that have had high impact on time to market are precisely in agreement with Lutz's observations about his own firm. As indicated in Figure 23, the use of multi-functional teams is seen as having the highest statistical impact overall

Figure 23. Moving Products to Market.

in affecting speedup. Number 2 and a close runner-up in worldwide importance is having strong project managers, the kinds of high-level people that Lutz reported are in charge of Chrysler's platform teams. Number 3 is the presence and support of senior management sponsors, which clearly has been the case with the kind of reorganization structure implemented from the top down at Chrysler. Lutz did not comment on whether the QFD (Quality Functional Deployment) project planning method is an important contributor, the fourth highest cited factor in our overall studies. But since QFD was developed first by Toyota, and then introduced broadly throughout the automobile industry, I suspect that QFD too has played some part in helping Chrysler to carry out its highly improved product planning and implementation. These first three major impact factors are not strongly differentiated among regions, suggesting that companies in all regions of the world are moving in the same way to achieve accelerated time to market.

Our last cluster of measures are some strategic indicators of technological performance. What should we look for as indicators of strategic impact of technology management? We might look for changes in management support as indicative of satisfaction with R&D impact. We might seek changes in corporate sales and profitability, which we might hope would show up as related to technology management. Or we might look outside the firm at a company's reputation for R&D excellence among its peers and competitors. It turns out to be very difficult to find at the overall sample level any measures that show that regional differences in technology management significantly affect differences in overall performance.

One area of interest is the level of overall support from top management.

Figure 24. Top Management Support of R&D.

Japanese technology executives believe their top corporate managers are far more supportive than European and U.S. companies report. This may merely be a Japanese illusion, or perhaps a higher level of Japanese politeness toward their senior managers. But on the other hand every time I talk with American technology managers about relationships with their senior corporate managers I hear largely complaints about lack of senior level support for the pleas and problems of technology within the firm. CTOs who think they are being uniquely harassed may feel better to know that there are no global differences in the extent to which CTOs are content with the satisfaction of their budget requests. The level of complaints on budget satisfaction are characteristic around the globe and not differentiated either by industry or by region. Senior technology managers all share the same brotherhood of complaint that R&D really needs more money than anybody is willing to provide. Unfortunately, the lack of R&D budget satisfaction doesn't show up as statistically significantly related to anything under the sun, in terms either of R&D performance or corporate outcomes.

We did want to know how senior technologists evaluated each other's performance. Rather than publishing these popularity polls by region or industry, which our data do permit, I thought I would just indicate one overall result, shown in Figure 25. For the sample as a whole DuPont and IBM, despite

Figure 25. Reputation for R&D Excellence.

all of its recent problems, are still cited around the world as the most effective R&D performers across industries. Third in line globally and for all industries is Merck. (Incidentally, within the pharmaceutical group Merck and Glaxo come out as equals in how highly regarded they are by other pharmaceutical companies.) We have tried to relate this peer rating of R&D excellence overall with the other performance measures but nothing shows up very strongly statistically.

What aspects of R&D and technology management do impact overall corporate performance? The fundamental problem that the academic researcher faces is differentiating correlation from causality. We find many things that strongly relate to each other statistically. The question is does one factor cause the other, or do they both reflect other things that are taking place concurrently within the firm and/or industry, or indeed is one variable merely a definition of the other? I display in Figures 26 and 27 two brief examples of this dilemma, and at the same time indicate some clues as to what relates to effective R&D performance.

We have looked at how R&D meets stakeholder needs in three different areas: end-use customers, corporate strategy, and manufacturing. Listed in Figure 26 are the primary variables that turn out to be strongly related statistically to each of those separate aspects of meeting stakeholder needs, and

Figure 26. Key Correlates of Meeting Stakeholder Needs.

which to me suggest causality. The data suggest that a company that is more timely in getting out its R&D results causes a higher level of satisfaction of its end-use customers' needs. Similarly, technology leadership, measured by competitive assessments of where a firm's technology stands, is also indicated as contributing to satisfying end-use customers. But, in contrast, although revenues from new products does correlate significantly with end-use customers being satisfied, this is a measure of the result of satisfying end-use customers and not a cause of the satisfaction. Therefore, I've indicated its correlation in italics below the line, not in the upper text, of Figure 26. So revenues flow together with customer satisfaction. This is the kind of puzzlement that often exists. Similarly, let's examine the forces that help satisfy the manufacturing side. Two factors are statistically significant correlates. Yet, that satisfying manufacturing needs correlates strongly with reduction of production costs is almost a definition. Cost reduction is one of the most important features mentioned by companies that assert they are meeting strategic needs with respect to manufacturing. From a causal point of view, however, the survey results suggest that a balance in the R&D portfolio with respect to product and process emphasis is a key contributor to satisfying the internal manufacturing customer of R&D.

In this same regard, as shown in Figure 27, revenues from new products and processes can now be seen as influenced statistically significantly by three forces. Timeliness of new products is likely to cause increased revenues from those products. Newer technology relative to competition (measured by the degree of maturity of the product portfolio) also contributes to higher new product and new process revenue, as does a company's capacity to adjust to external changes. Three other factors sort of go with the flow of having high revenues from new products and new processes, and are listed in italics below the line.

Figure 27. Key Correlates of Revenues from New Products/Processes.

Next are those R&D factors that influence overall sales growth. In my opinion there are no questions that all three statistically significant variables listed in Figure 28 are causal. All are at the project level of performance and are, in rank order of influence: meeting project objectives in regard to time to market, technical specifications, and budgeted development costs. These are the critical roots for having R&D contribute to and develop overall sales growth of the company.

Figure 28. Key R&D Performance Contributors to Sales Growth.

The final level of analysis relates to overall corporate performance. The overall sample reveals no significant correlates of corporate profitability. That does not surprise us. Anybody that has looked at research studies on R&D and technology would have to be even more brazen than I to suggest that a large data-base analysis should be able to uncover direct linkages between technology measures and profitability. There are too many other intervening variables, particularly at the level of strategy development and implementation, to expect to find clear signs of technology ties to profitability. Similarly, for the overall sample there is no tie between R&D as a percentage of sales and anything of consequence, not surprising to me despite the many arguments in the strategy and economics literature that research and development intensity is a critical index.

In regard to the impact of the process of technology planning and strategy, for the total sample, unfortunately, the extent of development and acceptance of corporate technology strategy does not correlate significantly with any measure of R&D or corporate performance. However, the degree of development of business-unit technology strategies does correlate meaningfully with several different measures of overall technical project performance, including time to market and meeting budgeted development cost, and relates well to perceived top management support for R&D. The business unit is the level at which technology strategy is implemented and where results should come home to roost in overall measures of performance.

Different forces at work in the different industries tend to diminish all performance correlations for the total sample of companies. This is indicated, even in our initial somewhat casual industry analyses, by the much higher statistical correlations between strategy measures and outcome measures for various industry groupings. Despite the far smaller sample sizes of each industry relative to the total responses, the degree of development of corporate technology strategies within given industries correlates well with several measures of R&D results. For example, within the chemicals/materials group the extent of a company's corporate technology strategy development correlates strongly with 9 out of 16 measures of R&D outcomes, including among them satisfying corporate strategic needs, time to market, percent revenues from new products, and adaptability to external change. 5 of 16 R&D performance measures are strong correlates of the extent of electronics industry technology strategy development.

Finally, the degree of linkage between technology strategy and overall corporate strategy does correlate with some measures of R&D performance. This is especially significant at the industry level: e.g., for the chemicals/materials industry, the linkage between technology and overall corporate strategy has strong correlates with 10 of 16 R&D performance measures; linkage data from the combined electronics industries correlate significantly with 5 of 16 measures.

Moving Forward

Let me finish by telling you where we are are going next. We have at this stage completed what is merely an initial pass at analysis, albeit an intensive and expensive effort. Nevertheless a lot more statistical analysis even of the existing data has to take place, especially at the industry level. We have already initiated a process of graduate thesis involvement in these studies. Two members of the 1993 MIT Management of Technology Program, our unique mid-career executive development program, have recently completed theses that have expanded the data and analyses of the chemicals and materials industry and the petroleum industry. The chemicals/materials sample is now being further enlarged with new information being gathered from Mexico and some Latin American countries. Another graduate student has carried out preliminary analyses of our pharmaceutical industry data. We hope to encourage more graduate students to undertake data supplementation and analysis.

We have already started efforts aimed at sample expansion into other regions. A joint study is underway to cover Singapore firms, where we plan to include far smaller firms on average than those examined in our initial probe into North America, Europe, and Japan. We anticipate that we will broaden the database to encompass still other countries and other sizes of industrial firms. We also expect and we look forward to opportunities to engage in single company and single industry benchmarking studies. Finally, we are looking forward to continuing the global survey of major R&D performers in future years, reflecting corrections of design errors and other lessons to be learned from this year's activity, as well as new issues in the global strategic management of technology.

Conclusions and Implications

The major industrial performers of research and development in North America, western Europe, and Japan have become moderate adopters of technology planning and strategy development practices. 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 Chief Technology Officers (CTOs) and R&D vice presidents are the most important facilitators of the ties between technology and overall strategy, with Chief Executive Officers (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 Chief Financial Officers (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 Chief Technology Officers are members of the Boards of Directors or main Managing Boards of their companies. This enables technological considerations to enter into dialogues and debates in regard to 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.

Several major organizational developments are affecting the strategic management of technology. U.S. firms are engaged in a headlong rush toward decentralizing 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 consequences. Of great surprise to this author, Japanese companies are moving precisely in the opposite direction in 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 occurring roughly evenly in both upward and downward directions.

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. It 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.

Technology executives recognize demands that they satisfy three different sets of stakeholders: their firms' end-use customers, senior management who determine strategic direction and priorities, and internal manufacturing. Globally they express far greater confidence in their competitive performance with respect to meeting end-user needs than the other two sets of "customers". Only Japanese companies convey relative satisfaction in regard to providing the required technology for internal manufacturing priorities. Among other influences these perceived differences reflect real differences between Japanese companies and all others in regard to R&D budget allocations for process development and improvement. In contrast U.S. senior technology managers are especially concerned that their R&D portfolios are seriously inadequate in regard to process support. But Americans are also worried about portfolio imbalance with respect to time orientation (i.e., too much short-term) as well as risk orientation (i.e., too much "familiar" technology).

But U.S. companies are performing well in some areas of strategic change. For example, shifted practices over the past several years have brought the "voice of the customer" into a place of critical influence on many dimensions of product conceptualizing and development. In this area many European companies appear to be lagging American and Japanese practice in regard to extent and intensity of customer contact and influence on technology. Similarly, U.S. firms are rapidly improving in regard to time-to-market, with companies in all regions benefiting from combinations of multi-functional teams, strong project managers, and senior corporate sponsorship. Yet Japanese companies still appear to have the advantage in regard to considerably more top management support of overall R&D efforts.

At the overall corporate level for our complete sample of respondents, a limited number of key factors appear to be significantly influencing overall R&D performance. Timeliness of technical outputs affects both internal corporate strategic customers and external end-customers, while a more balanced product/process R&D portfolio generates significant impact on internal manufacturing results. Revenues from new products and processes are also most influenced in statistical measures by timeliness, as well as newness of the firm's technology. And sales growth is statistically most strongly affected by R&D meeting its multiple project objectives in regards to time to market, targeted technical performance, and budgeted costs. Not surprising to this observer, R&D intensity, as reflected by R&D as a percentage of a company's sales, does not correlate with any important outcome measure at the level of the overall sample. Of note is that the degree of linkage between technology strategy and overall corporate strategy does correlate well with several measures of R&D performance. This particular influence shows up far more strongly in the few industry-level analyses carried out thus far, for example for the chemicals and materials industry. Preliminary industry-level analyses suggest other clusters of strong cause-and-effect relationships between technology strategy variables and overall company performance, and even stronger results at the business-unit level of the firm. These and other insights will need to await much more in-depth analyses.

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 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 in the questionnaire development, with coordination throughout the study provided by Wendy Elliott of the ILP. Several members of the ILP Industrial Advisory Board pilot tested an early draft version of the questionnaire. Consulting staff of the Technology Management Group 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 and now of U.S. West, was very helpful in formulation of the overall questionnaire. Professor Ralph Katz and Varghese George of the MIT Management of Technology and Innovation Group consulted in regard to questionnaire design and analyses.

The survey includes three sections: Part I-Benchmarking, comprising about three-fourths of the questions in seven sections, seeks to establish measures of practice in global strategic management of technology, as well as measures of R&D and overall company performance; Part II-Special Research Topic: Managing Technology with Constrained Resources seeks to document worldwide responses to the current economic climate in terms of recent, current, and expected near-term actions affecting technical programs, staffing, resources, and controls; this special research topic is likely to be changed in future surveys to reflect critical issues perceived by senior technology managers; Part III-Growing Concerns: Future Research Topics seeks to identify emerging issues that are candidates for future Special Research Topics.

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 data from many sources (including the US 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 approach generated 109 firms, all but one headquartered in the United States, all spending more than $100 million on R&D during 1991. Now using $100 million as the lower limit, all companies with R&D expenditures at or above that level were included from western Europe 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 ranked technology-related officer of each company, as listed in the large number of directories and data sources used in the list compilation. Approximately two months after the initial mailing reminder letters and telephone calls were made by staff of the MIT Industrial Liaison Program and PA Consulting Group that led to some additional replies. About one-fourth of the replies were completed by a person whose title is Vice President or above, the remainder coming from persons whose titles indicate senior R&D or technology line or staff positions. Replies were mailed to a postal box of the MIT Industrial Liaison Program, recorded in a master file and assigned a code number by Wendy Elliott of that office, who removed all company-identifying information from the questionnaire. The resulting anonymous questionnaires were then turned over to Pugh-Roberts Associates for comprehensive data coding and analyses, resulting in a database with identifiers that permit sorting by principal industry and geographic location of corporate headquarters.

Of the total 244 companies sampled, useable responses were received from 95 firms, or 39%. 46 were from the United States (42% response), 27 from Europe (34%), and 22 from Japan (40%), providing an essentially balanced response by geographic area, with slight underrepresentation of European companies. (Among European countries the 3 replies from the 33 solicited German firms constituted an exceptionally small response rate (9%). Omitting Germany from the response analysis, the remaining western European countries had an overall response rate of 51%.)

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 two largest industrial groups are chemicals/materials, with 20 replies, and a composite electronics industry group, with 21 responses. Other large groupings are aerospace, petroleum, and pharmaceuticals. Neither the response rates nor the completeness or usability of the questionnaires reveal differences due to the use of English only in the survey instrument.

Detailed statistical analyses of the data discussed in this report were carried out by the team of Lauri Mitchell, Mark Bamford, and Edward Roberts.

Major Corporations Engage in Technology Strategy Development to a Moderate Extent

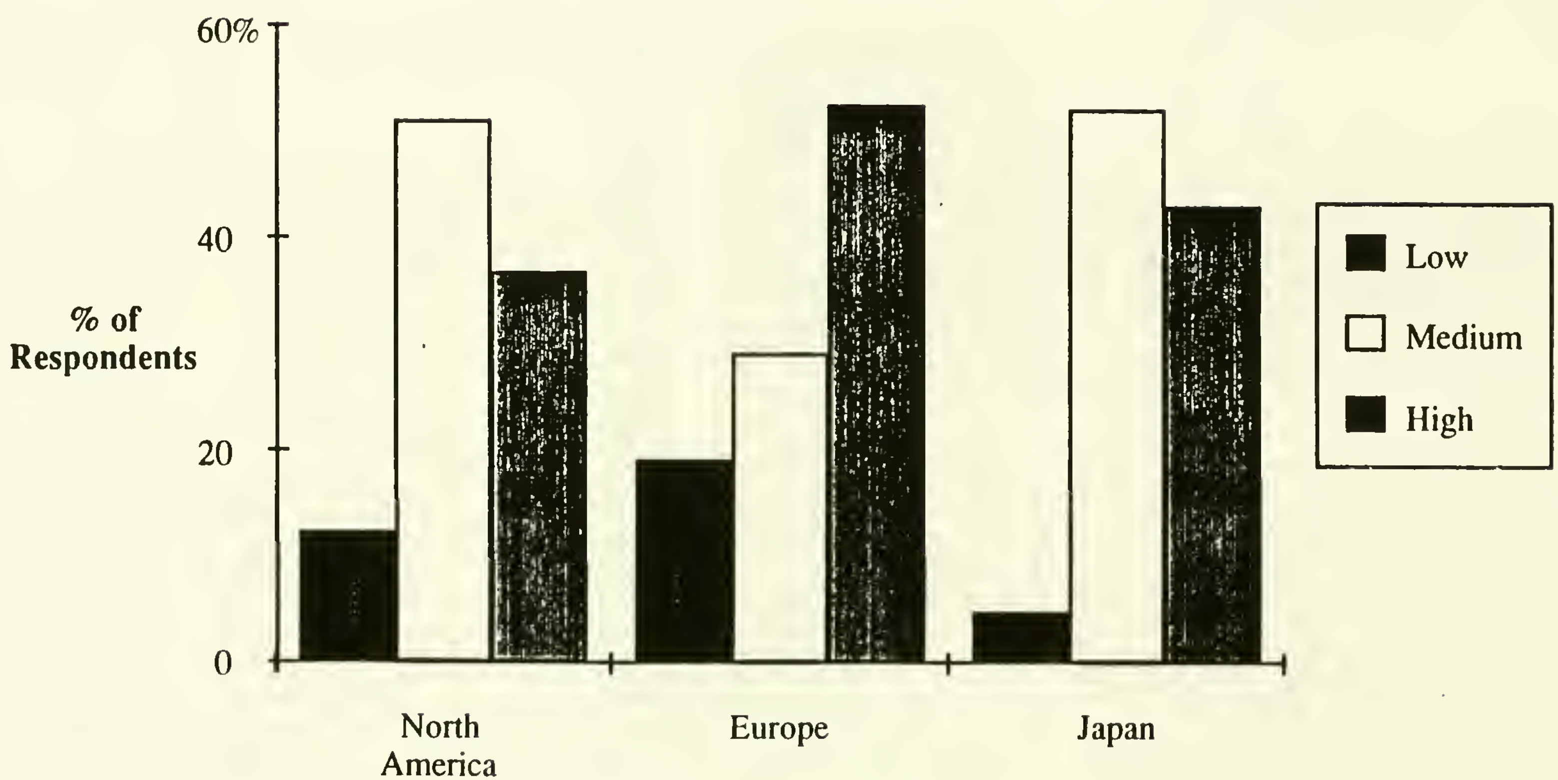


Fig. 1

Strong Corporate-Level Technology Strategy Development Influences Strong Business-Unit Technology Strategy

Business-level Technology Strategy

Corporate-level Technology Strategy	Strong	Vague
Strong	n = 30	n = 6
Vague	n = 20	n = 33

n = Number of Respondents

($p = .0005$)

Fig. 2

What is Most Important to Technology Strategy?

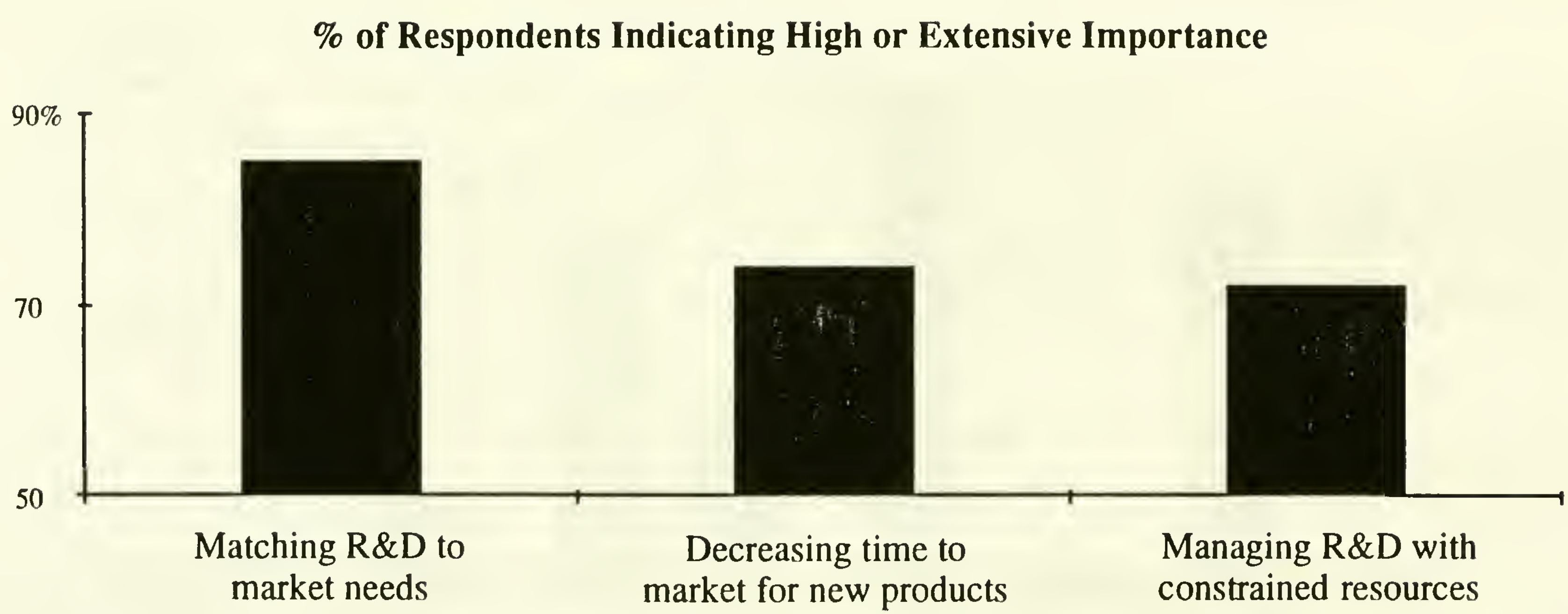
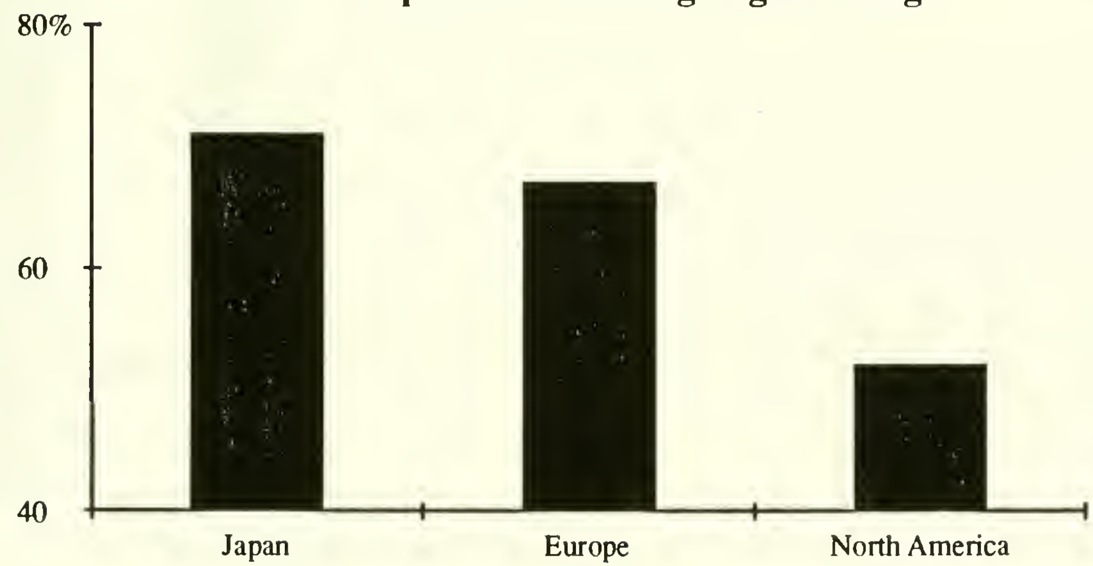


Fig. 3

Corporate-Level Technology Strategy is More Strongly Linked to Overall Strategies in Japan and Europe

% of Companies Indicating High Linkage



- Linkage relates well to several measures of R&D performance

Fig. 4

Who are the Keys to Linking Technology to Overall Corporate Strategy?

% of Respondents Indicating Importance of Role in Linkage between Technology and Overall Corporate Strategy

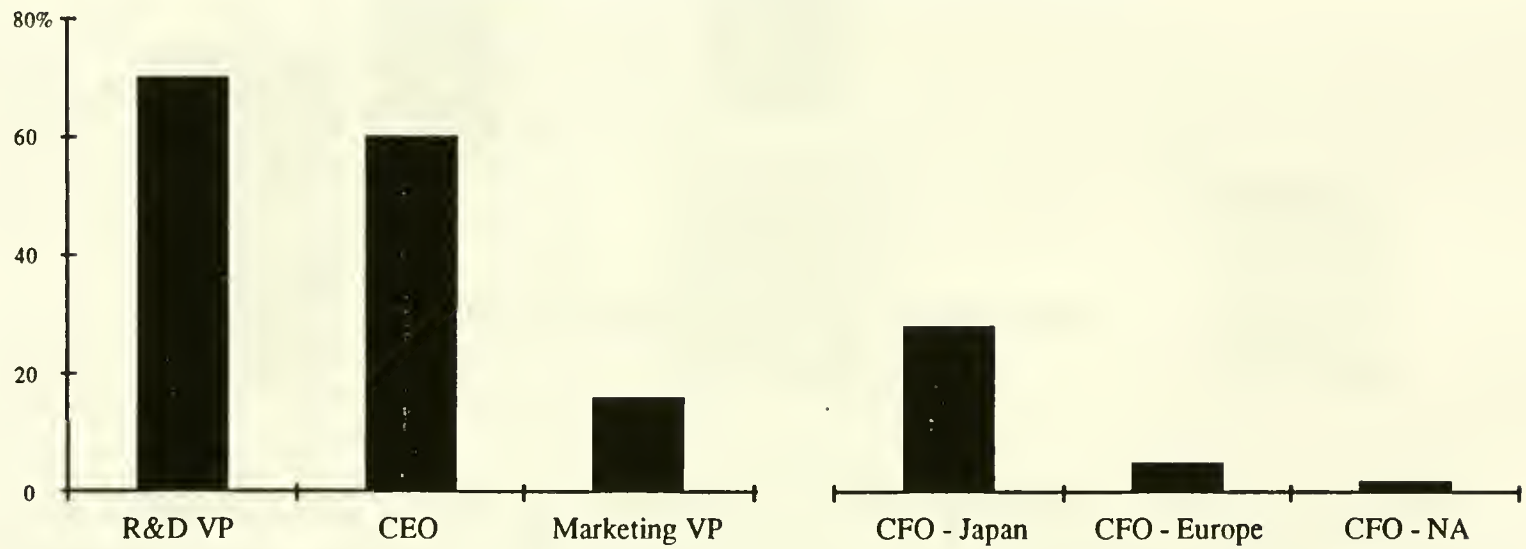


Fig. 5

Keys to Linking Technology to Business-Unit Strategy

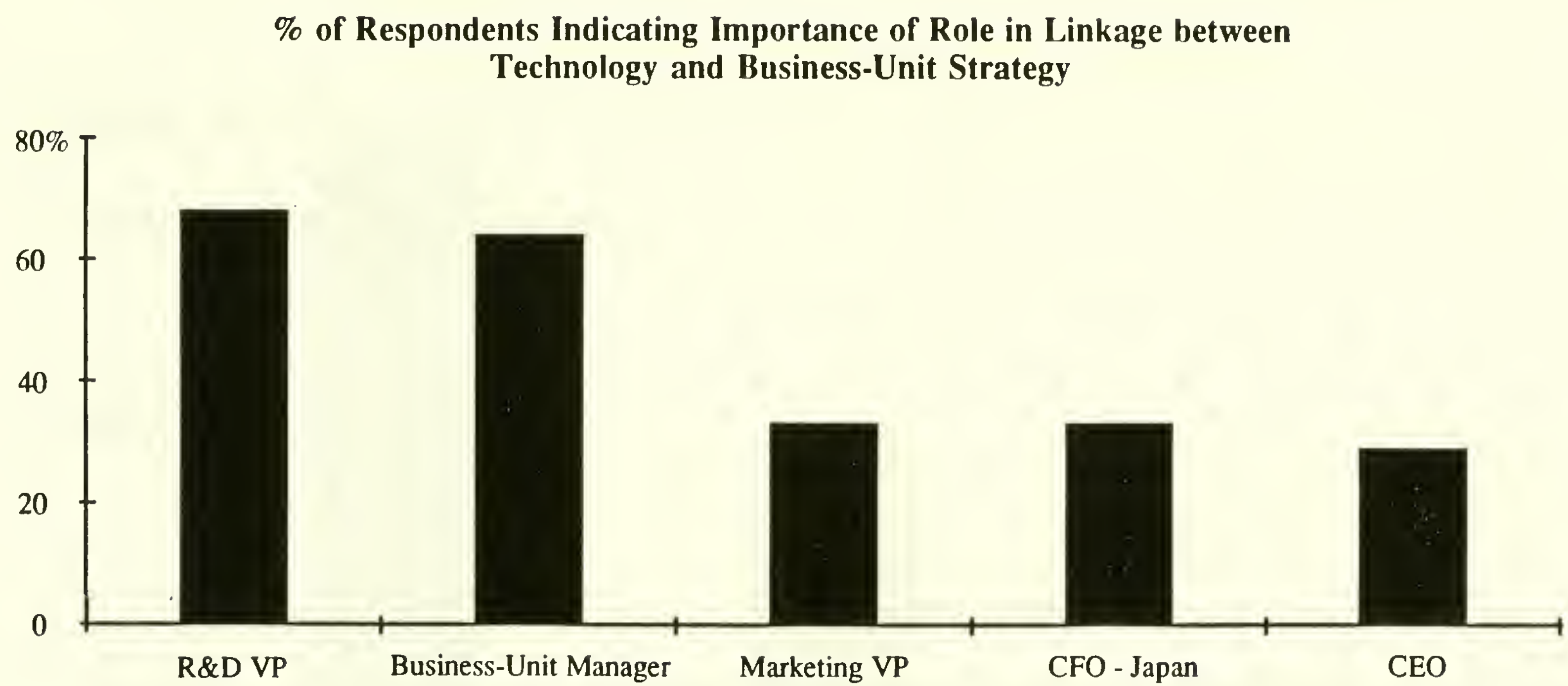


Fig. 6

More Japanese CEOs are Highly Involved in Technology Strategy

Activity	US	Europe	Japan
	% CEOs Highly Involved in Technology Strategy		
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

	US	Europe	Japan
	74	54	50

Fig. 7

Chief Technology Officers Have Board-Level Membership in Almost All Japanese Companies and Over Half the European Companies

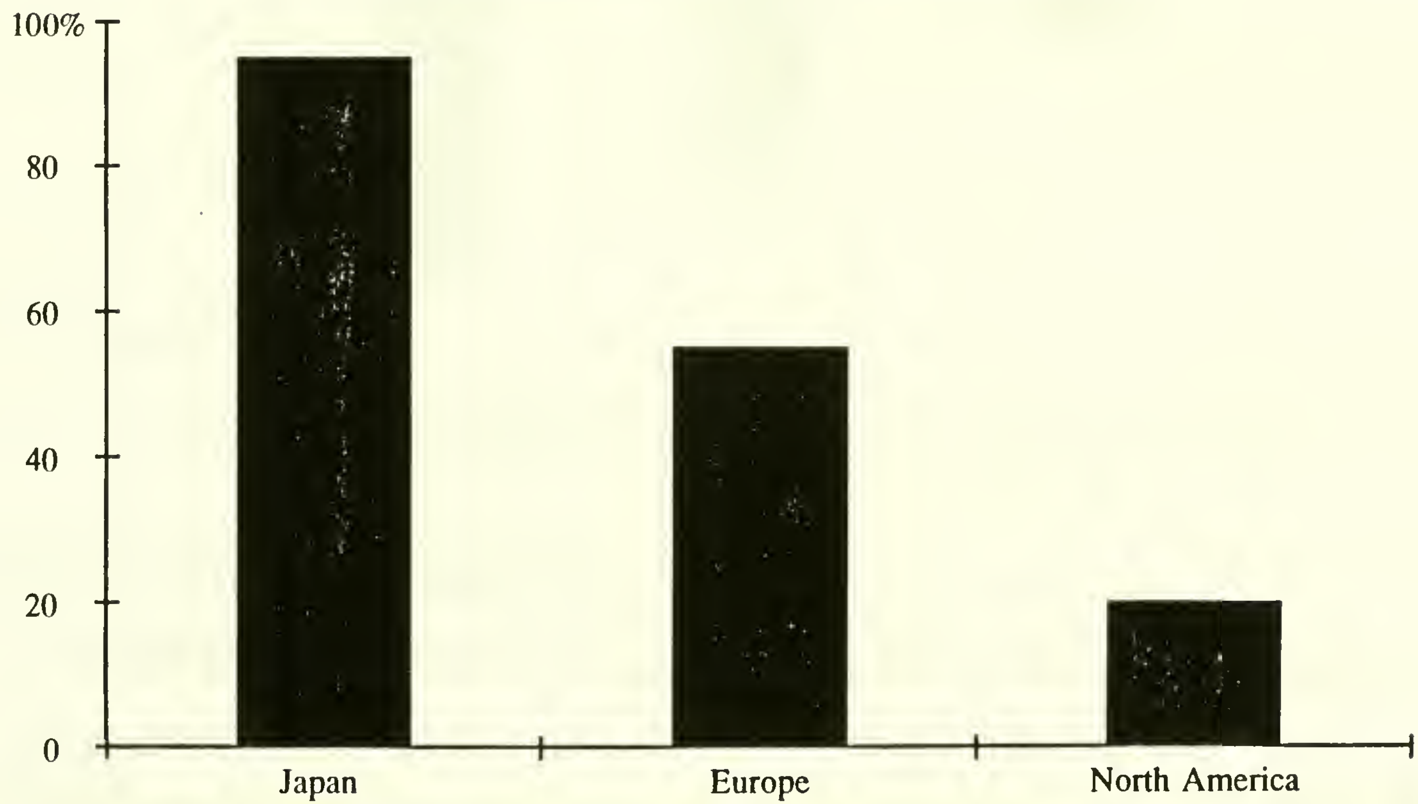


Fig. 8

U.S. Chief Technology Officers Have Far Less Influence on Business-Unit Technology Direction

% of Firms in Which CTO has High or Extensive Involvement in Directing Business-Unit Technology Strategy Development

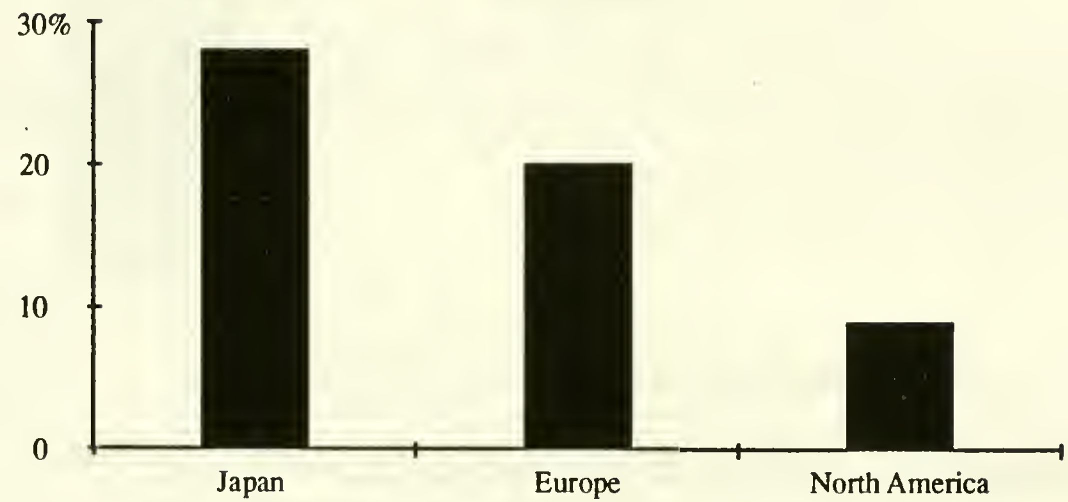


Fig. 9

RD&E Budgets at the Corporate Level Clearly Reflect a Longer Term View than at the Business-Unit Level

(Overall Sample)

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

Fig. 10

RD&E Budget Allocations are Very Different Across Industries

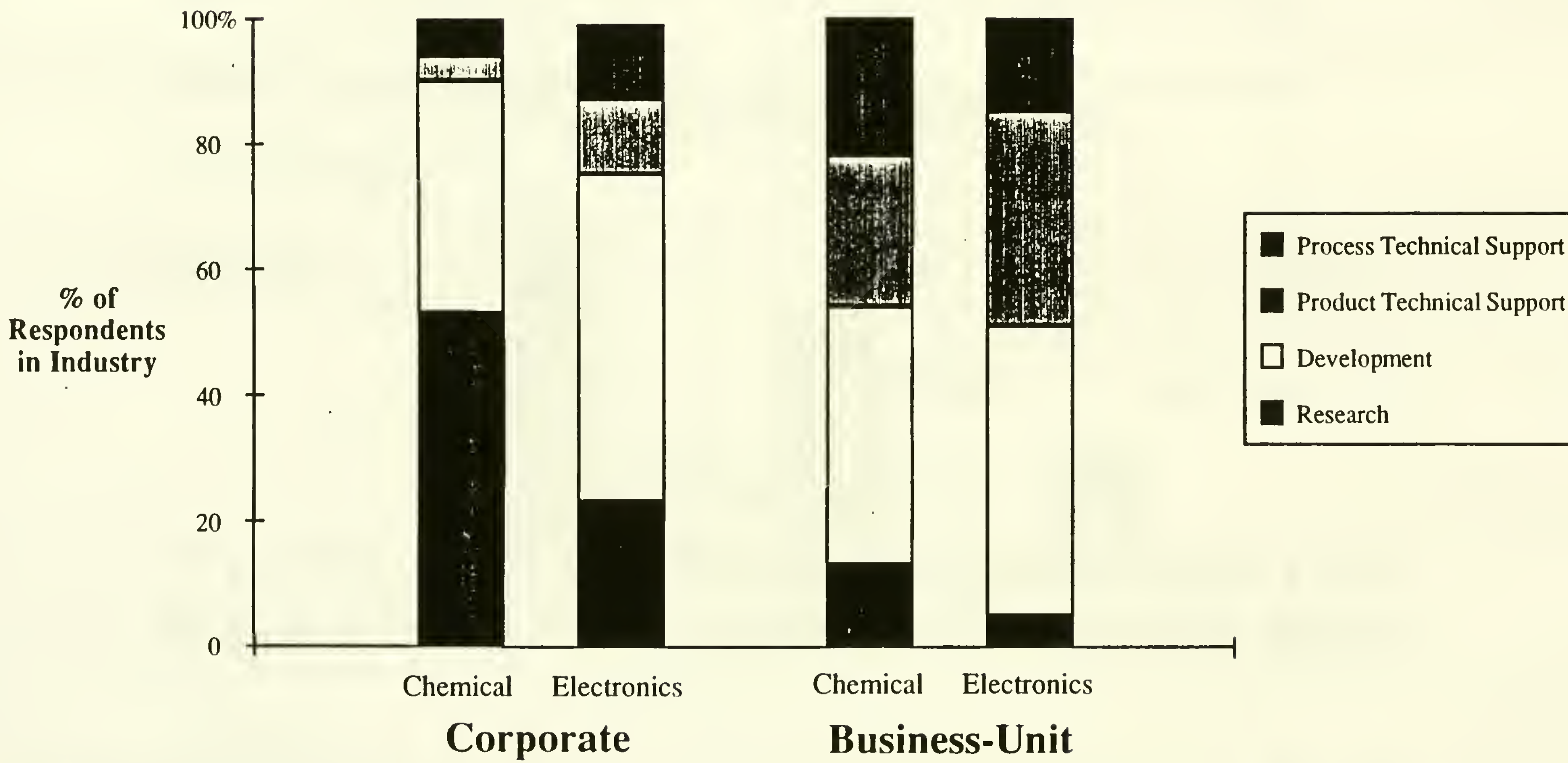


Fig. 11

U.S. is Rushing Toward Decentralized Control of R&D While Japan and Europe Behave Differently

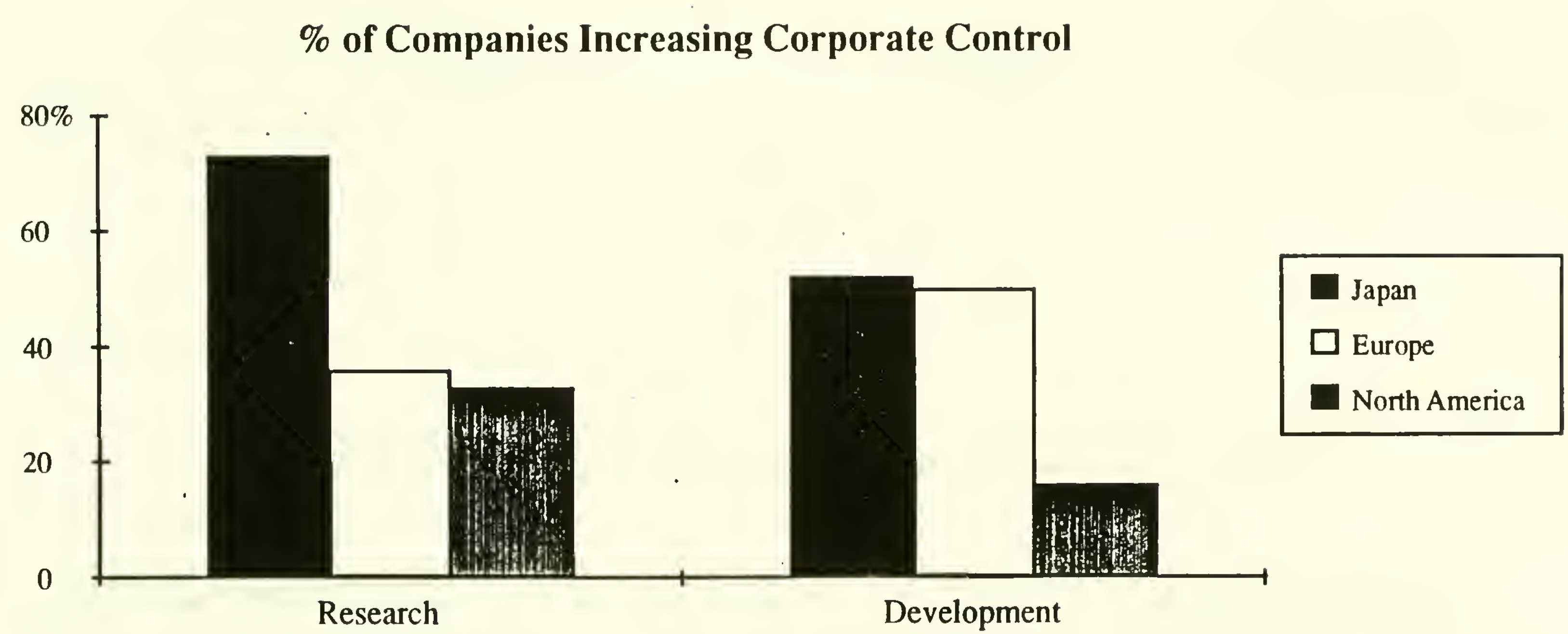


Fig. 12

Japanese Firms are Highly Leveraging External Sources for Technology, with the Rest of the World Following

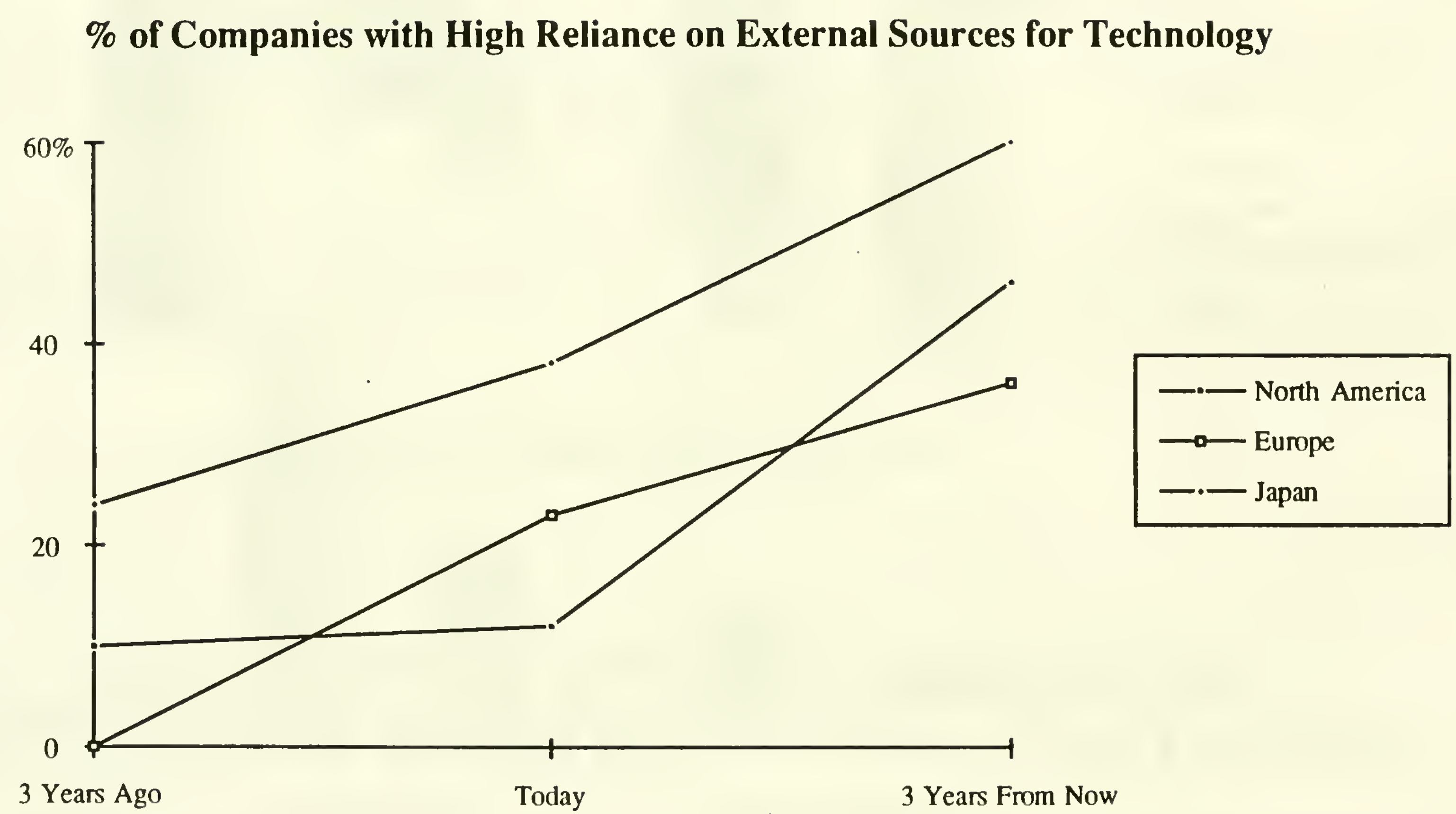


Fig. 13

Internal Sources are Still Primary for Both Research and 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

Fig. 14

Japanese Firms Gain Far Greater Benefits from University Programs

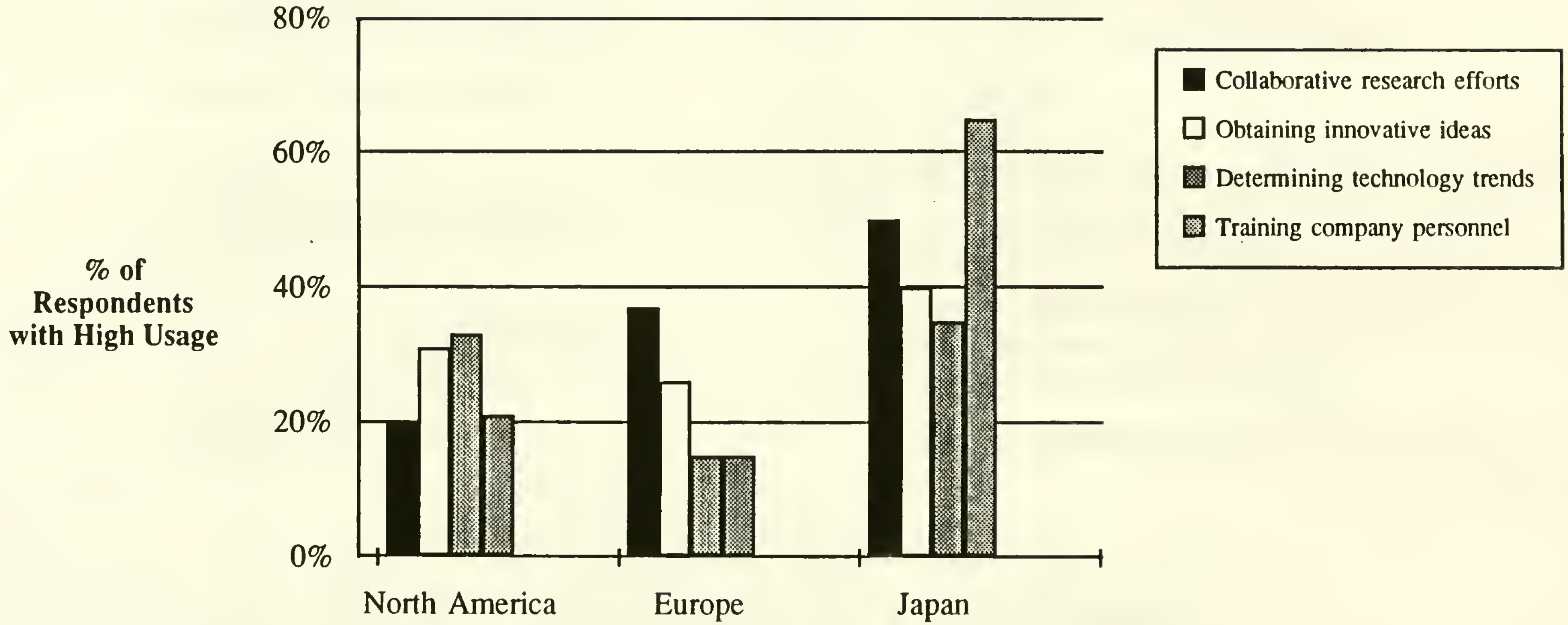


Fig. 15

Companies Use a Wide Variety of Approaches to Monitor Technology

(% of overall sample with high or extensive usage)

• Internal Technology Steering Groups	57%
• University Liaison/Affiliate Programs	31%
• Industry-based Consortia	28%
• University Research Consortia	23%
• Customer Panels or Input	16%
• Science/Technology Advisory Boards	14%
• Venture Capital Funds	7%

Fig. 16

R&D Based in Foreign Countries is Growing

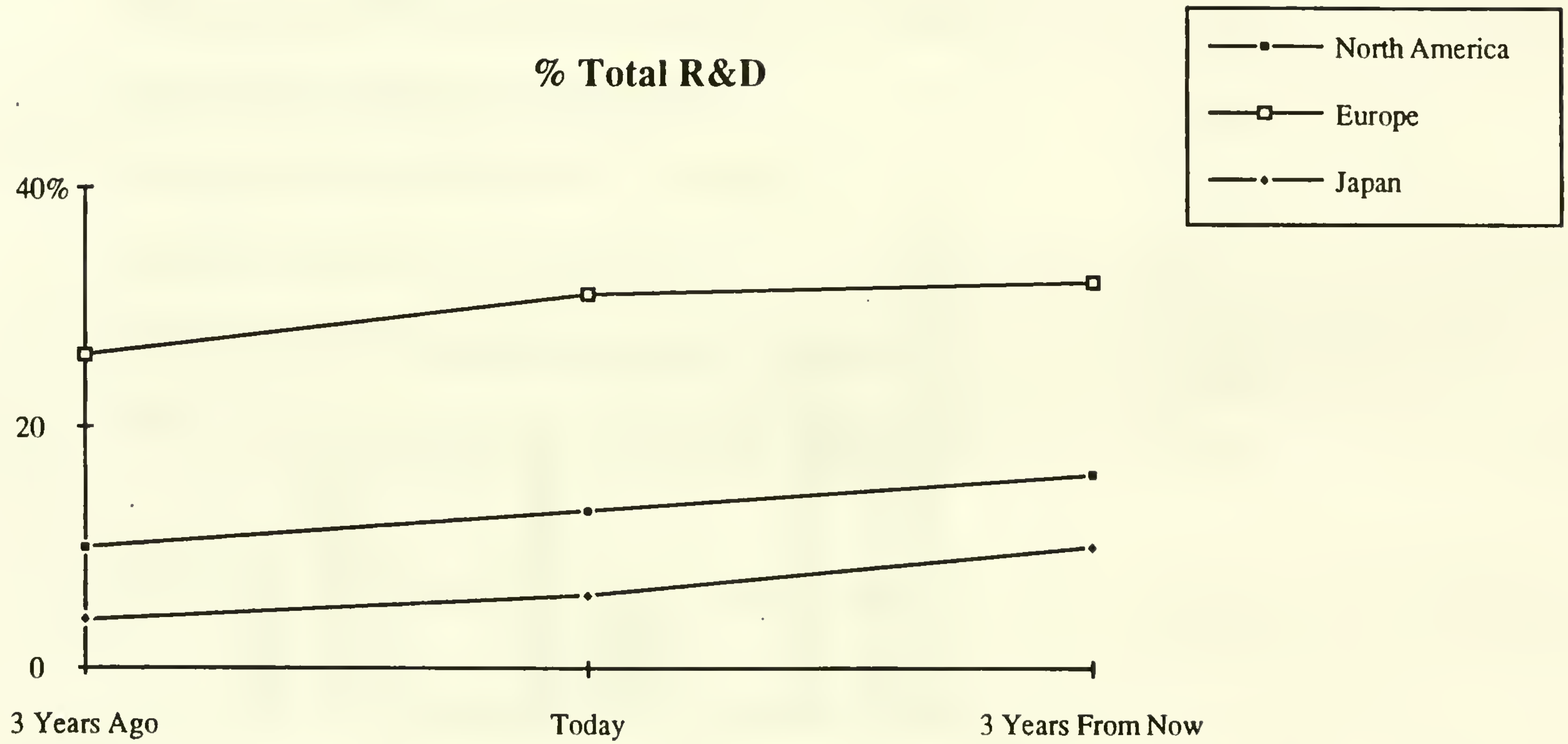


Fig. 17

Meeting the Needs of Key Stakeholders for R&D Efforts

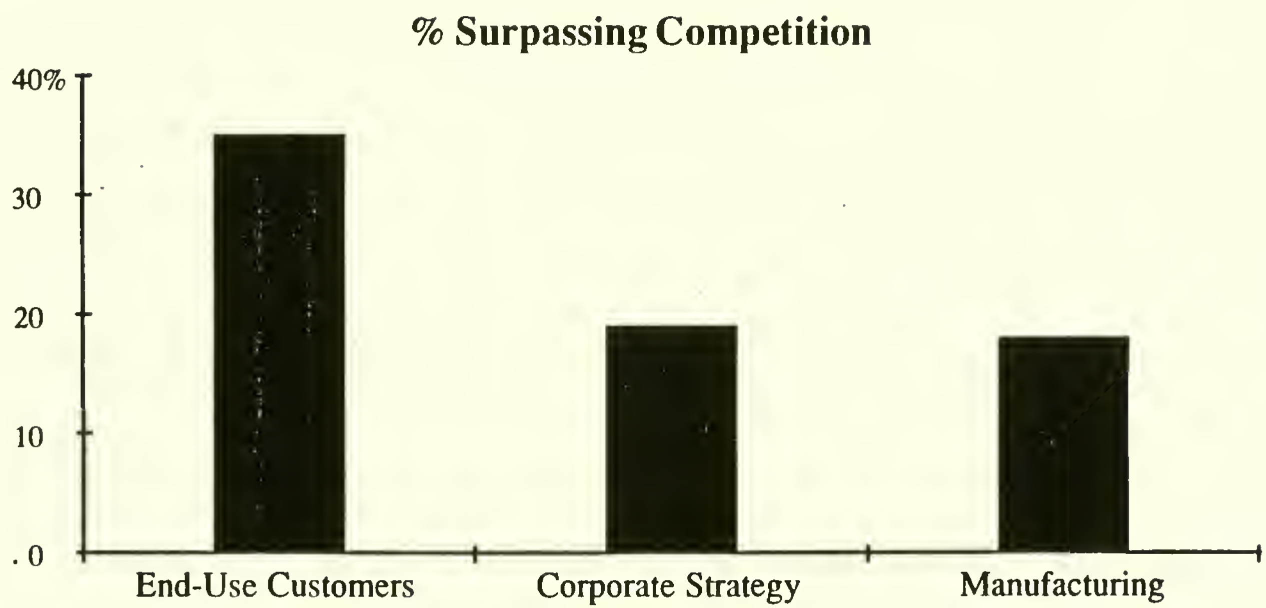


Fig. 18

"Voice of the Customer" in Product Development

Used for:	% Firms Claiming Extensive Market Inputs		
	US	Europe	Japan
Technology strategy development	81	55	89
Set program objectives	70	27	65
Concept development	34	18	40
Prototype development	48	23	45
Average	58	31	58

Fig. 19

Five Measures of Overall R&D Performance

- Effective use of resources
- Efficiency
- Timeliness
- Revenues from new products/processes
- Production cost reductions

No significant differences among regions on any of these 5 dimensions

Fig. 20

U.S. Executives are Concerned About Imbalance in their R&D Portfolios

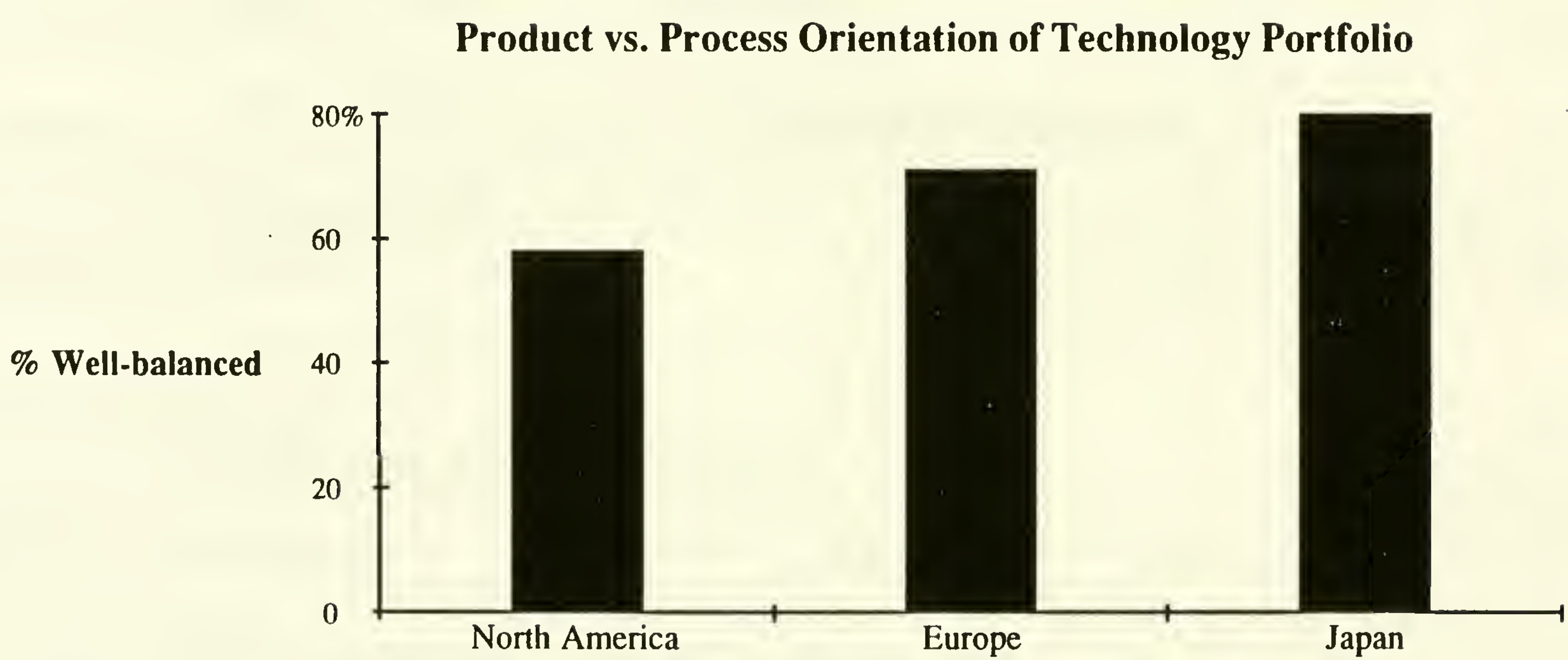


Fig. 21

Project-Level Performance

% of R&D Projects that Met Internal Objectives

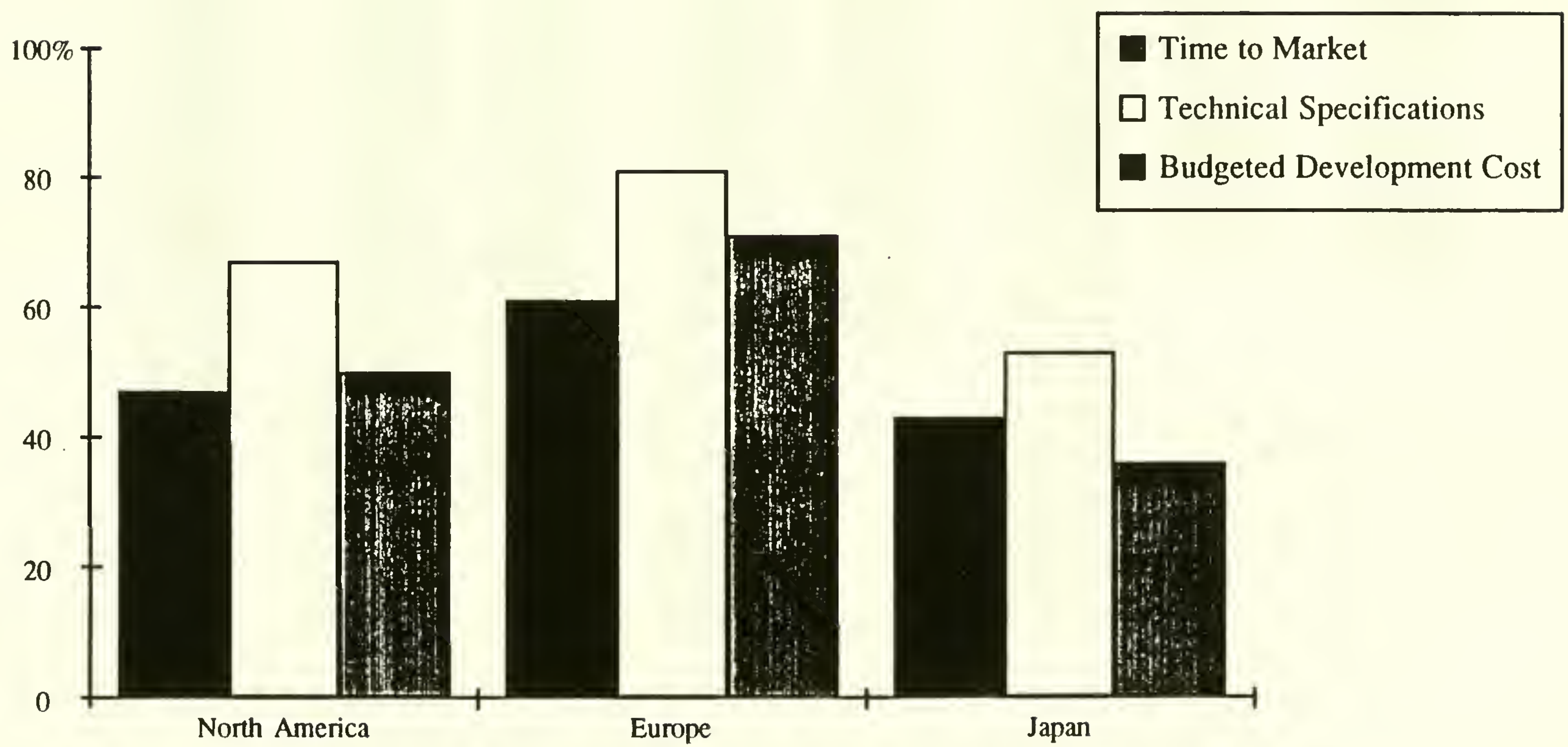


Fig. 22

Moving Products to Market

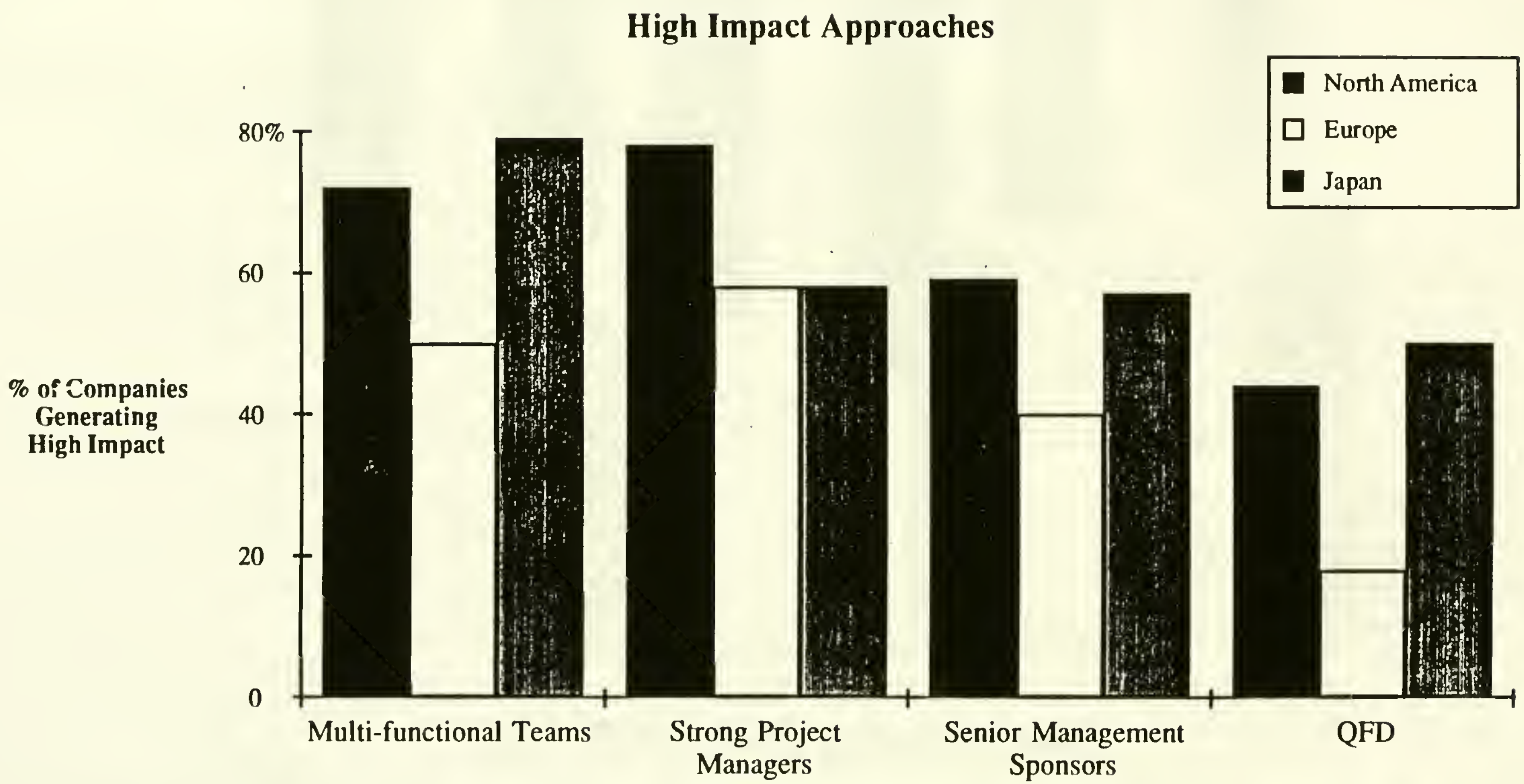


Fig. 23

Top Management Support of R&D

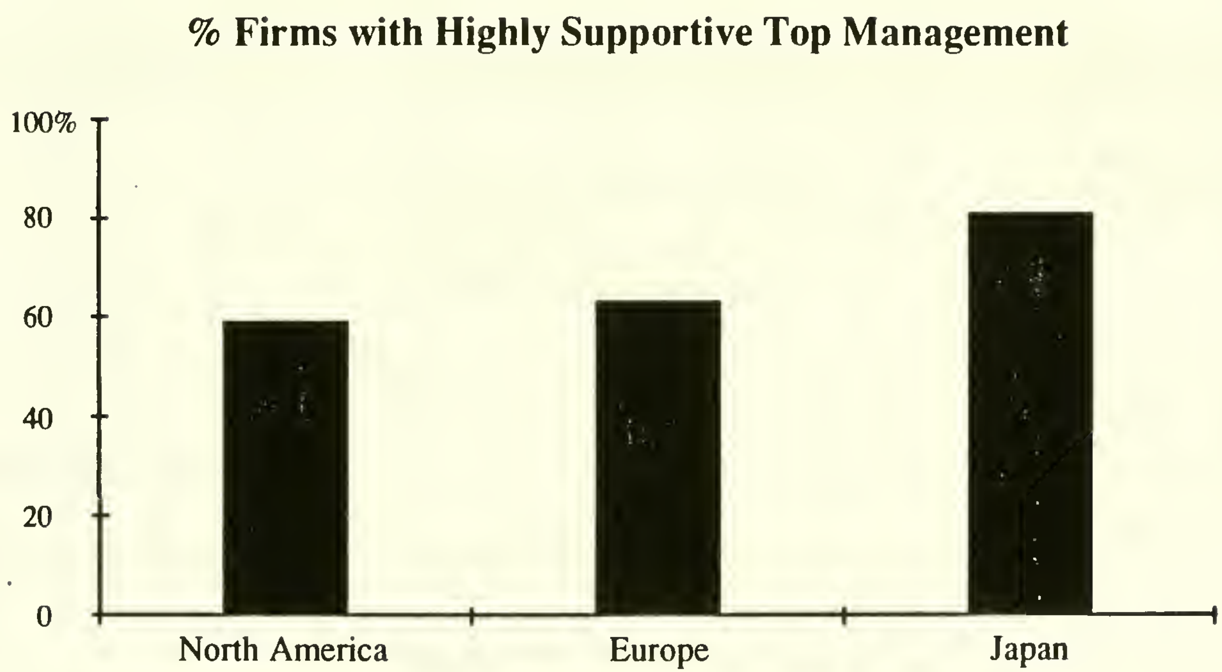


Fig. 24

Reputation for R&D Excellence

Top R&D Companies Cited by Overall Sample

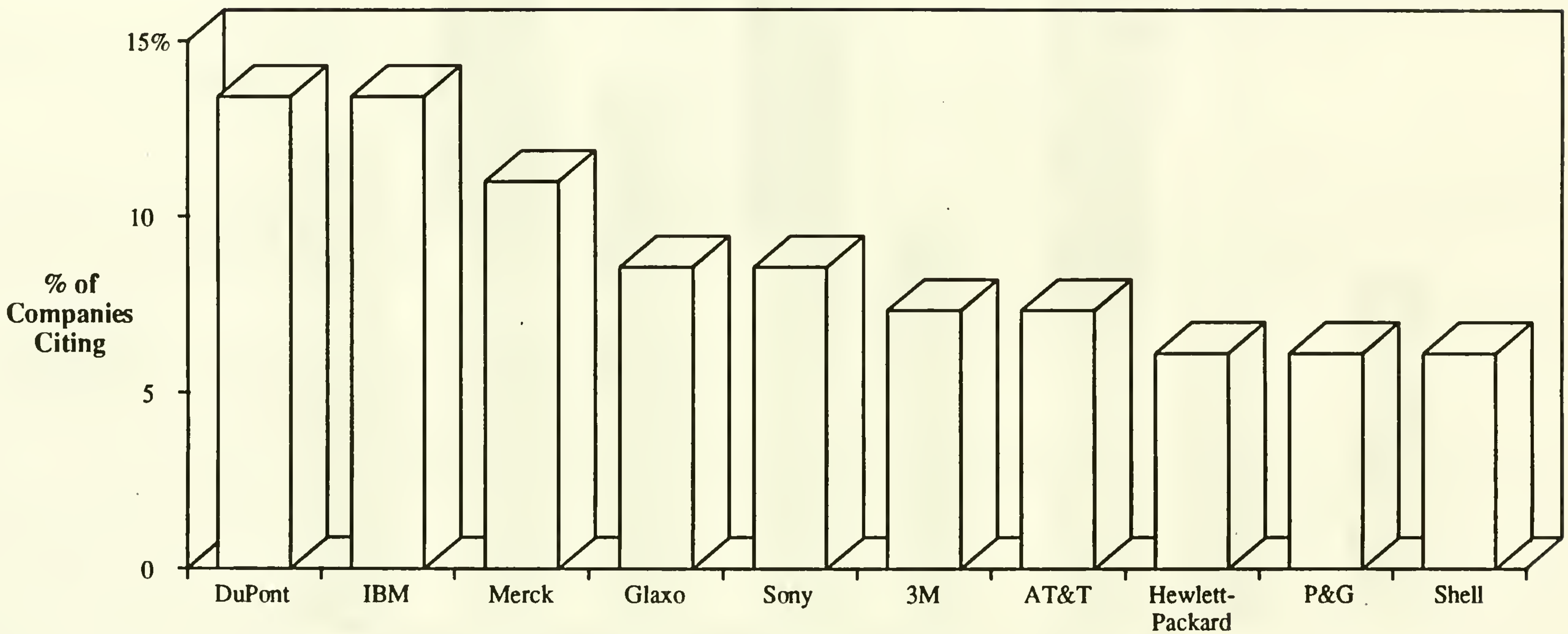


Fig. 25

Key Correlates of Meeting Stakeholder Needs

(in rank order of strength)

<u>End-Use Customers</u>	<u>Corporate Strategy</u>	<u>Manufacturing</u>
Timeliness	Adjustment to change	Product/process balance
Technology leadership	Timeliness	
Revenues from new products	*Revenues from new products*	*Production cost reductions*
Satisfying corporate strategy	*Effectiveness*	

Italics suggests consistency, not necessarily causality, of statistical relationship

Fig. 26

Key Correlates of Revenues from New Products/Processes

Timeliness

Newness of technology

Adjustment to external change

Satisfying corporate strategic needs

Effective use of R&D resources

Satisfying end-use customers

Italics suggests consistency, not necessarily causality, of statistical relationship

Fig. 27

Key R&D Performance Contributors to Sales Growth

Meeting project objectives in regard to:

- Time to market
- Technical specifications
- Budgeted development costs

Fig. 28