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Benchmarking the Strategic Management of Technology -- II: R&D Performance

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Overview

Extensive data collected from the largest R&D-performing companies in the United States, western Europe, and Japan reveal several key factors that influence technological effectiveness and R&D performance. For example, European firms are less involved with their customers in carrying out product development than are U.S. or Japanese companies. Timeliness of technical results and newness of the company's technology portfolio strongly affect overall R&D performance and more specifically new product revenues. Company sales growth is statistically related to overall R&D managerial capability as reflected in R&D meeting its multiple project-level objectives of schedule, technical performance and budgeted cost. These and other findings on strategic management of technology (many presented in Part 1 of this series in the January-February 1995 issue of *Research/Technology Management*) arise from our global benchmarking study of the 244 companies who account for approximately 80 percent of the R&D expenditures in Europe, Japan and the United States. (See sidebar on "Survey Methods" for complete details on the study.)

Acknowledgements

This research was sponsored jointly by the Industrial Liaison Program of the Massachusetts Institute of Technology and PA Consulting Group. The analyses presented here were performed by a team directed by the author, with principal contributions by Lauri Mitchell and Mark Bamford, both formerly of Pugh-Roberts Associates. We thank Drs. Paul Thornton and Stephen Payne of the PA Consulting Group for funding this study, and Thomas Moebus, MIT Director of Corporate Relations, for his overall support of the research program. Continuing analyses and expansion of the studies to other countries are now being supported by the MIT International Center for Research on the Management of Technology.

Enhancing R&D Performance

In initiating our research on technological effectiveness and R&D performance, we encountered the classical difficulties in R&D metrics. The Industrial Research Institute (IRI) has documented these same measurement problems in its first annual R&D survey: "Significantly ... the response was much lower for ... survey questions intended to measure R&D 'achievements' or outcomes. ... 'It appears that companies aren't keeping these kinds of records and don't know what to say when you ask them what outcomes are being realized from their R&D investments.'"[1] Our study ended up by determining 16 different measures of R&D performance and contributions to the firm, clustered into three categories, which we review in this article. First we examine a number of measures by which we attempt to assess competitive advantages in R&D efforts. Second we focus on the project level of performance and identify several evaluators of how R&D projects stack up against expectations. Third we seek strategic indicators that R&D performance matters to the firm and that R&D has had corporate impact.

Key Stakeholders

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 internal: (a) those senior officers of the firm who attempt to set direction and priority for the company; and (b) manufacturing/ operations, the customer for process change and improvement as well as cost reduction within the company. Figure 1 shows our results from asking each company to benchmark itself in order to identify how it is doing in satisfying

Insert Figure 1.

these different stakeholders relative to its own most serious competitor. Most companies primarily emphasize satisfying end-use customers, with about a third of the firms worldwide feeling that they surpass competition in meeting their external customers' needs.

In rank-ordering these three "customers" or objectives of R&D, the sample as a whole, and specifically the U.S. and European firms grouped separately, treated as least important the extent to which they surpass competition in satisfying manufacturing's technological requirements. However, as many might expect this slight does not pertain to Japanese companies. Only 1 out of 8 U.S. and European companies self-assess superiority in supporting manufacturing through R&D. Japanese firms overall, in contrast, perceive themselves as 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.[2]

Market Linkages

Next we examined linkages to the marketplace. Here Figure 2 indicates

Insert Figure 2.

that the poor performer is not the American company. I think U.S. firms have 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 believe that over the last four or five years United States companies have, 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.

Five R&D Performance Measures

We then looked at five different overall measures of R&D performance, listed in Figure 3. No significant regional differences exist among the sampled

Insert Figure 3.

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 somewhat surprised at this finding 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. Even the mix of industries is different for the three regions. Therefore, I had expected to see some statistical differences in overall R&D results that accrue these individual company differences of priority. But apparently these differences "cancel out" when aggregated to the regional level.

In examining data on portfolio composition of R&D spending, the U.S. senior technology officers who responded to our questionnaire are much more dissatisfied than their counterparts elsewhere in regard to several issues.

Americans are uncomfortable about their R&D 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 clearly recognized by R&D executives 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.[3,4] 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, as indicated in Figure 4, U.S. executives are concerned about

Insert Figure 4.

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.

Performance at the Project Level

We also looked at the several measures of project-level performance shown in Figure 5. 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

Insert Figure 5.

product breakeven time, meeting various project objectives, and recent 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.

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 survey 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 remarks that Robert Lutz, Chrysler's President and COO, made at our MIT conference 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 agree precisely with Lutz's observations about his own firm. As indicated in Figure 6, the use of multi-functional teams is seen as having

Insert Figure 6.

the highest statistical impact overall 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. This is consistent with recent reports in the literature of the successful use of so-called "heavyweight" project managers by leading Japanese auto makers. 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. These three major impact factors are not strongly differentiated among regions, suggesting that companies in all regions of the world are moving in similar ways to achieve accelerated time-to-market. 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 importantly 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.

Strategic Indicators of Performance

Our last cluster of measures are some strategic indicators of technological performance. What might indicate the strategic impact of technology management? We might look for changes in management support as possibly reflecting satisfaction with R&D impact. We might look outside the firm at a company's reputation for R&D excellence among its peers and competitors, the type of approach often used in benchmarking other aspects of management. Or we might seek changes in corporate sales and profitability that might relate to technology management. 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. This strongly reflects our earlier statement (see Figure 3) that no statistically significant differences were found among regions in regard to five broad aspects of R&D performance.

One area of interest is the level of overall support from top management. Japanese technology executives believe their top corporate managers are far more

Insert Figure 7.

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 in most of my discussions 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. Of course, this is not true of every firm. CTOs who think they are being uniquely harassed may feel somewhat 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 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 shall just indicate one overall result, shown in Figure 8. For the sample as a whole DuPont and IBM, despite all of its recent

Insert Figure 8.

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, 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 overall R&D excellence 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: (a) does one factor cause the other; or (b) do they both reflect other things that are taking place concurrently within the firm and/or industry; or indeed (c) is one variable merely a definition of the other? I display in Figure 9 a brief example 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. Figure 9 lists the primary variables that turn out to be strongly related statistically to each of those separate aspects of meeting stakeholder needs, and which to me indicate

Insert Figure 9.

causality. The survey 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, also contributes to satisfying end-use customers. But, in contrast, although revenues from new products does correlate significantly with end-use customers being satisfied, this is in reality *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 9. So revenues flow together with customer satisfaction. This is the kind of statistical puzzlement that often exists.

Similarly, let's examine the forces that help satisfy the internal manufacturing customer. Two factors are statistically significant correlates. From a causal point of view the survey results show that a more balanced R&D portfolio with respect to product and process emphasis is a key contributor to satisfying the internal manufacturing customer of R&D. Indeed, allocating more R&D attention and effort toward production needs ought to affect manufacturing positively. The survey data also generate the finding that satisfying manufacturing needs correlates strongly with reduction of production costs. Yet this is almost true by definition. Cost reduction is one of the most important features mentioned by companies that assert they are meeting strategic needs with respect to manufacturing. Therefore, I show this variable below the line in italics, as a mere correlate but not a cause of the manufacturing outcome.

Figure 10 displays the three forces that can now be seen as influencing, at a statistically significant level, revenues from new products and processes.

Insert Figure 10.

Timeliness of new products is most 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 also correlate significantly with new product revenues, but these are not causal forces of the results.)

Next are those R&D factors that influence overall corporate sales growth. The three statistically significant variables listed in Figure 11 broadly reveal an overall R&D managerial capability that shows up consistently in the multiple product and process development projects of the firm. In rank order of influence they are 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.

Insert Figure 11.

Overall Corporate Performance

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. Preliminary analysis of recent IRI survey data suggests there is not even a strong correlation between firm size and research intensity.[5]

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. The new IRI survey of business-unit R&D data should increasingly help to illuminate this belief.

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. Five of 16 R&D performance measures are strong correlates of the extent of electronics industry technology strategy development.

Finally, as argued in my previous Part 1 article,[6] the degree of linkage between technology strategy and overall corporate strategy does correlate with

several 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

Beyond the current analyses we are moving forward on a number of directions of data gathering and analysis. Master's theses prepared by participants in the MIT Management of Technology Program, our unique mid-career executive development program, have expanded the data and analyses of the chemicals and materials industry and the petroleum industry. The chemicals/materials sample has been further enlarged with comparative information gathered from Brazil.

Expansion into other regions is underway, with our first effort covering Singapore's top 200 R&D spenders, including companies based in Singapore as well as local divisions of multinational corporations. We plan to broaden the database to other countries. We also hope to find near-term 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 learned from the present activity, as well as new issues in the global strategic management of technology.

Conclusions and Implications

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 are relatively satisfied 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. 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 are 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 are 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 what I sense to be a surrogate for overall R&D managerial capability, i.e. 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* relate well to several measures of R&D performance. This as well as several other managerial influences 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 need to await much more in-depth analyses.

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"Sidebar": 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. Now 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, usable 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.

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. The three key stakeholders or "customers" for R&D efforts are the end-use customers of the firm, the senior officers of the company who define overall strategy and direction, and the internal manufacturing/operations organization that desires process change. The sampled companies regard themselves as surpassing their key competitor twice as frequently in regard to meeting end-user needs than in any other measure.

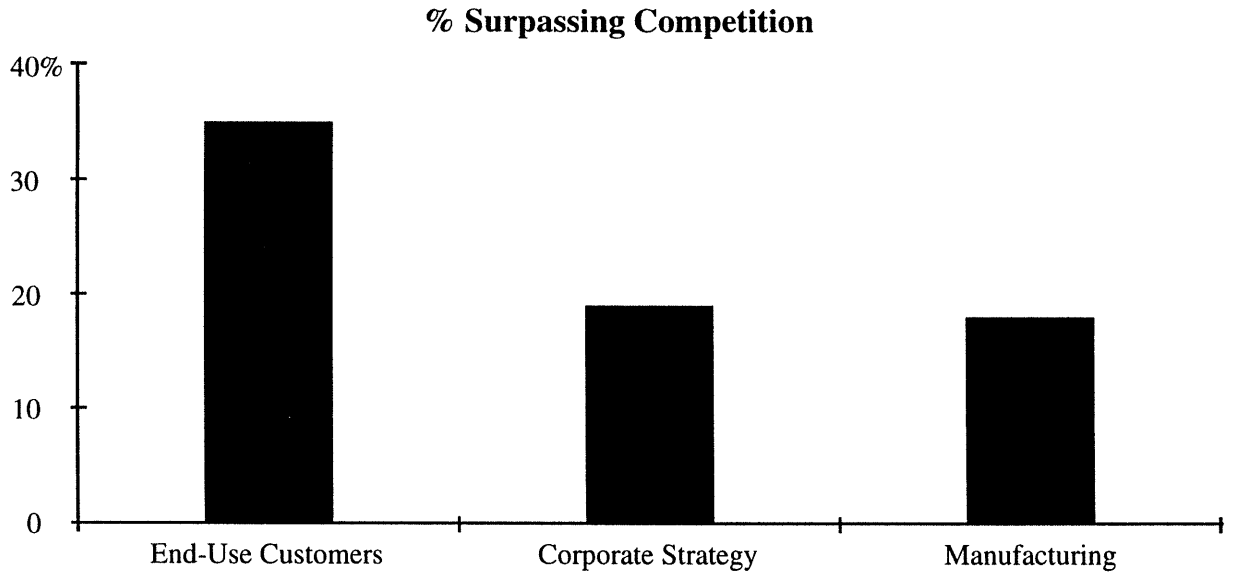

Figure 2. U.S. and Japanese firms have comparable market inputs from the "Voice of the Customer" throughout their product development cycles. European firms seem much further distant from possible customer influences.

	% Firms Claiming Extensive Market Inputs		
Used for:	**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	60

Figure 3. Overall R&D performance was measured in five different ways. Unfortunately, no statistically significant differences were found in any of them at the regional level of data aggregation.

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

No significant differences detected, at the regional level, in any of these 5 dimensions of performance

Figure 4. U.S. executives are concerned about imbalance in their R&D portfolios. They sense overemphasis upon the short-term and the "familiar", at the expense of longer-range and more novel undertakings. As shown in the chart American R&D portfolios are also perceived as more likely to overemphasize product development in contrast to process development

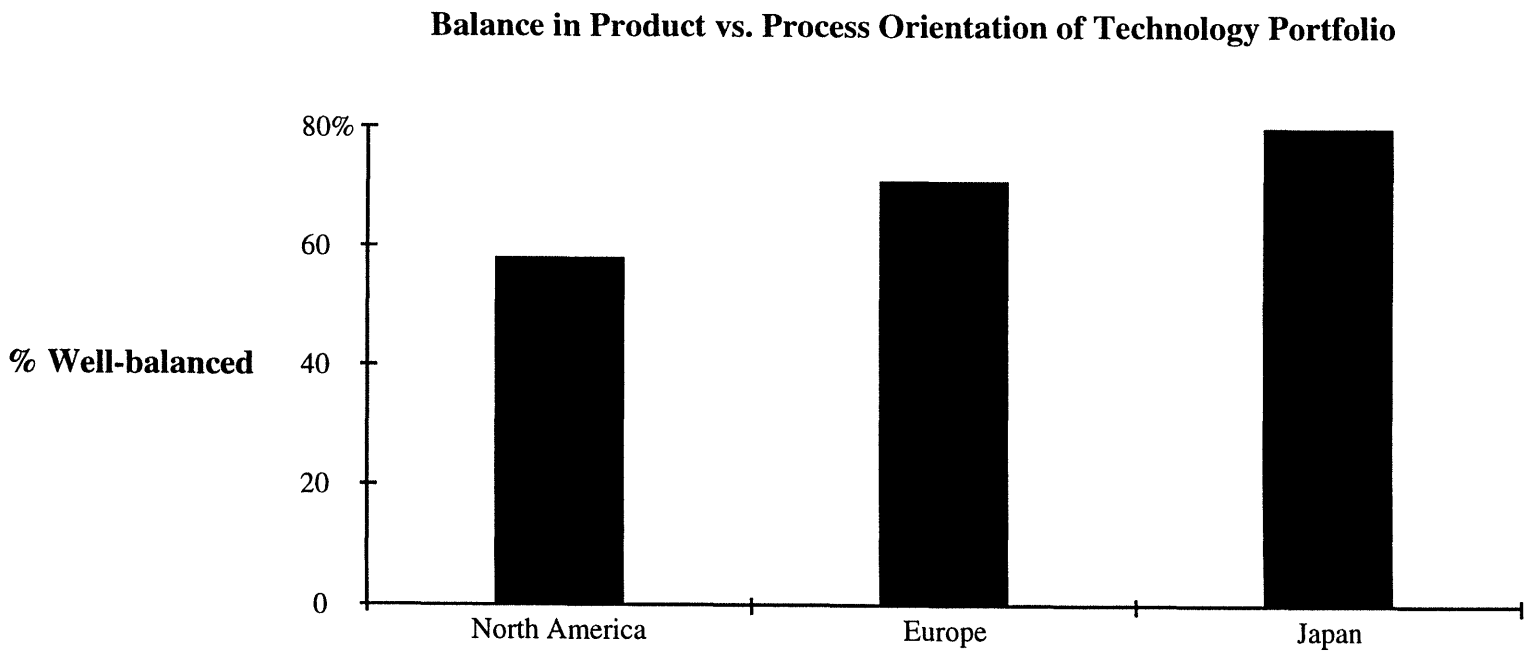

Figure 5. Data were collected on evaluations of project performance in regard to meeting internal objectives for the three traditional measures of technical specs, time to market, and budgeted development costs. European firms outperformed all others on all three evaluations, but these data are contradicted by other survey results.

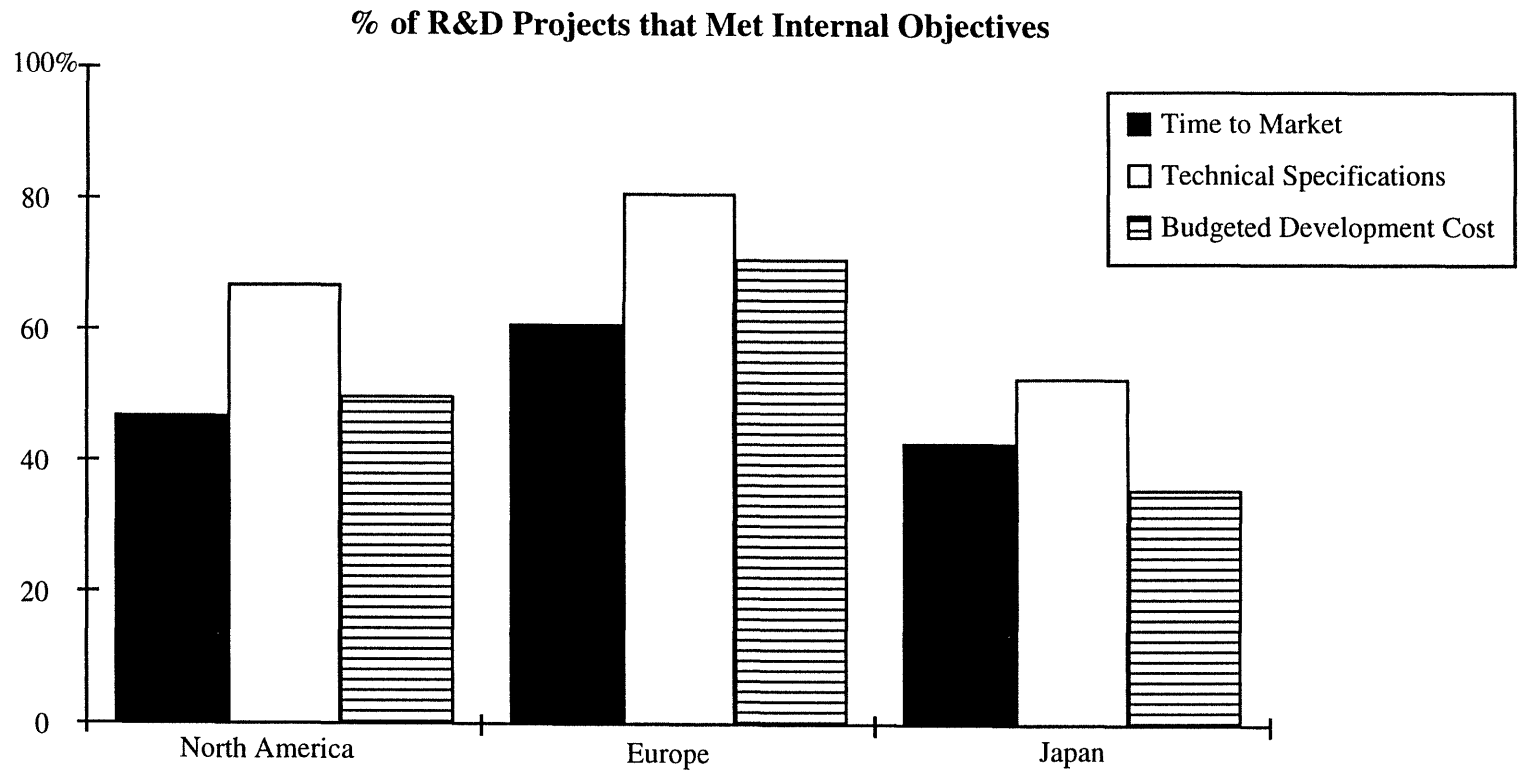

Figure 6. Twenty different factors were assessed as potentially important in affecting movement of new products to market. The top four influences are shown in the figure, with multi-functional teams and strong project managers having the highest overall statistical impact. No special regional practice patterns emerge from the survey results.

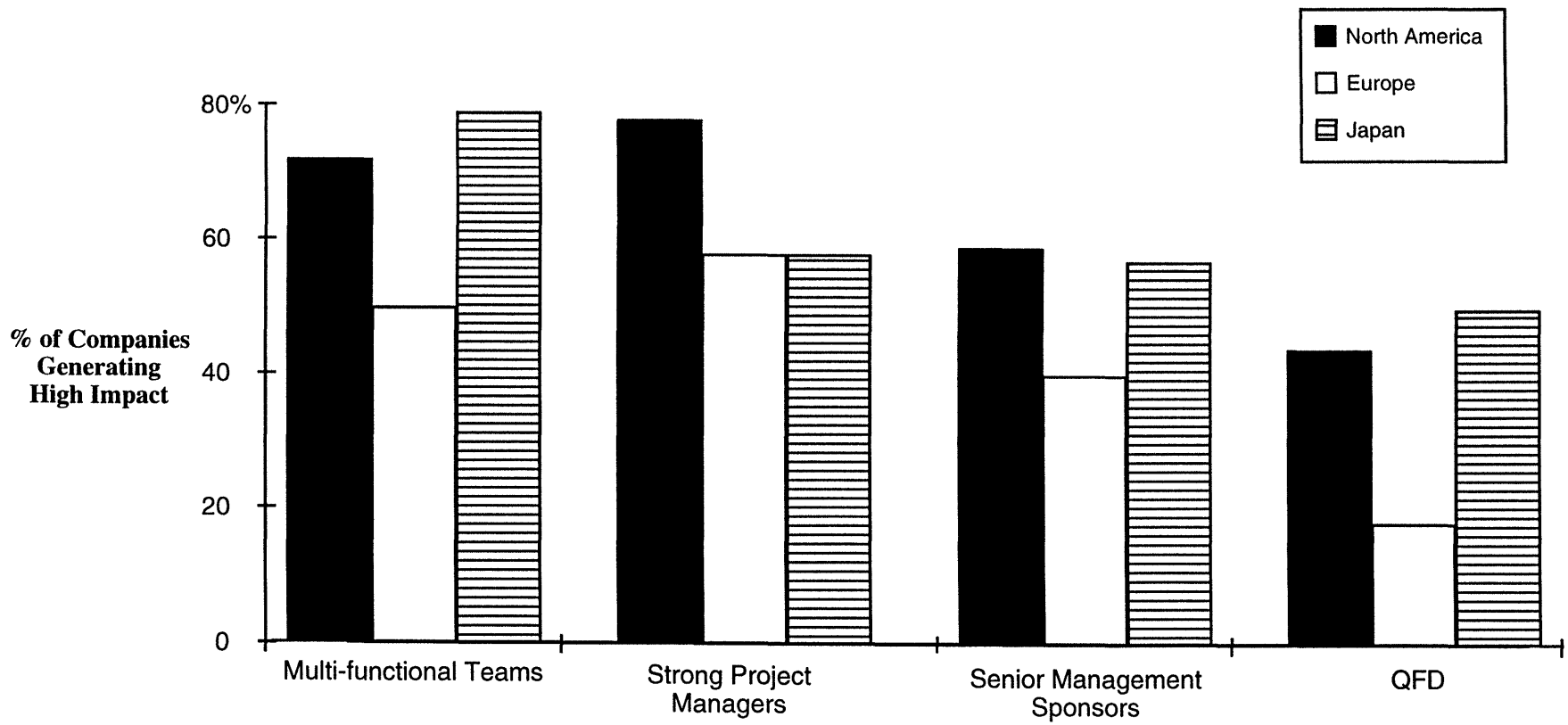

Figure 7. Japanese respondents more frequently regard their top management as highly supportive of R&D efforts. U.S. and European companies are comparable to each other.

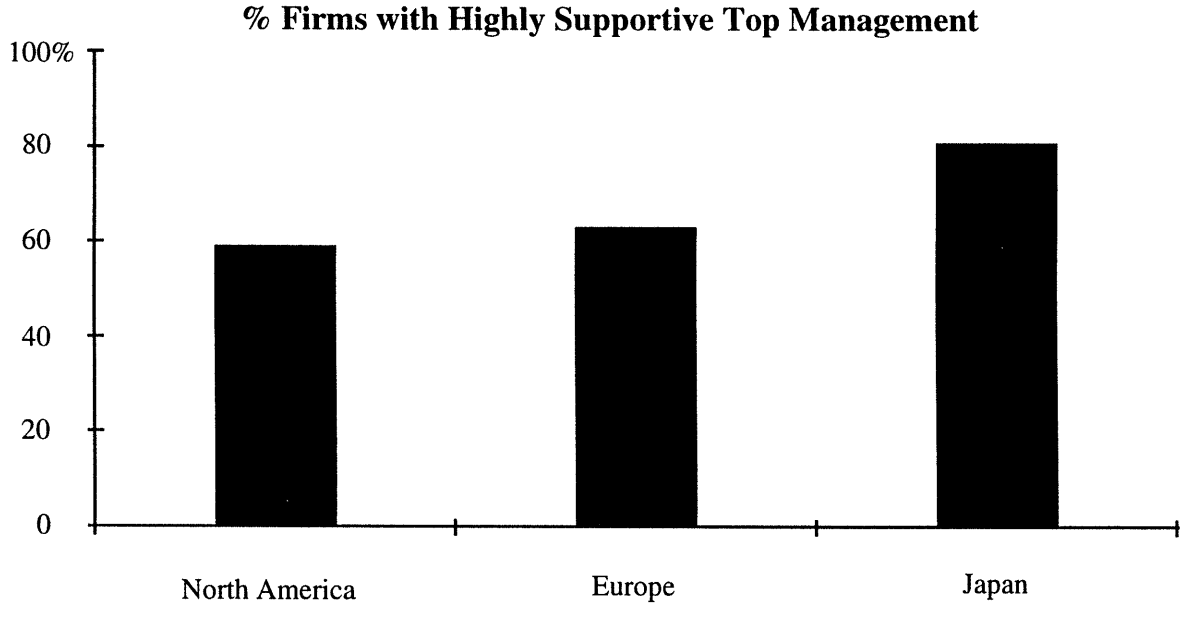

Figure 8. The most common approach to benchmarking is to identify companies with the highest reputation for excellence in the area of interest. Our survey data permit these comparisons for each industry and region studied. Shown in the figure are the ten companies most frequently cited in the overall global sample, with DuPont and IBM leading the pack in their reputation for R&D excellence.

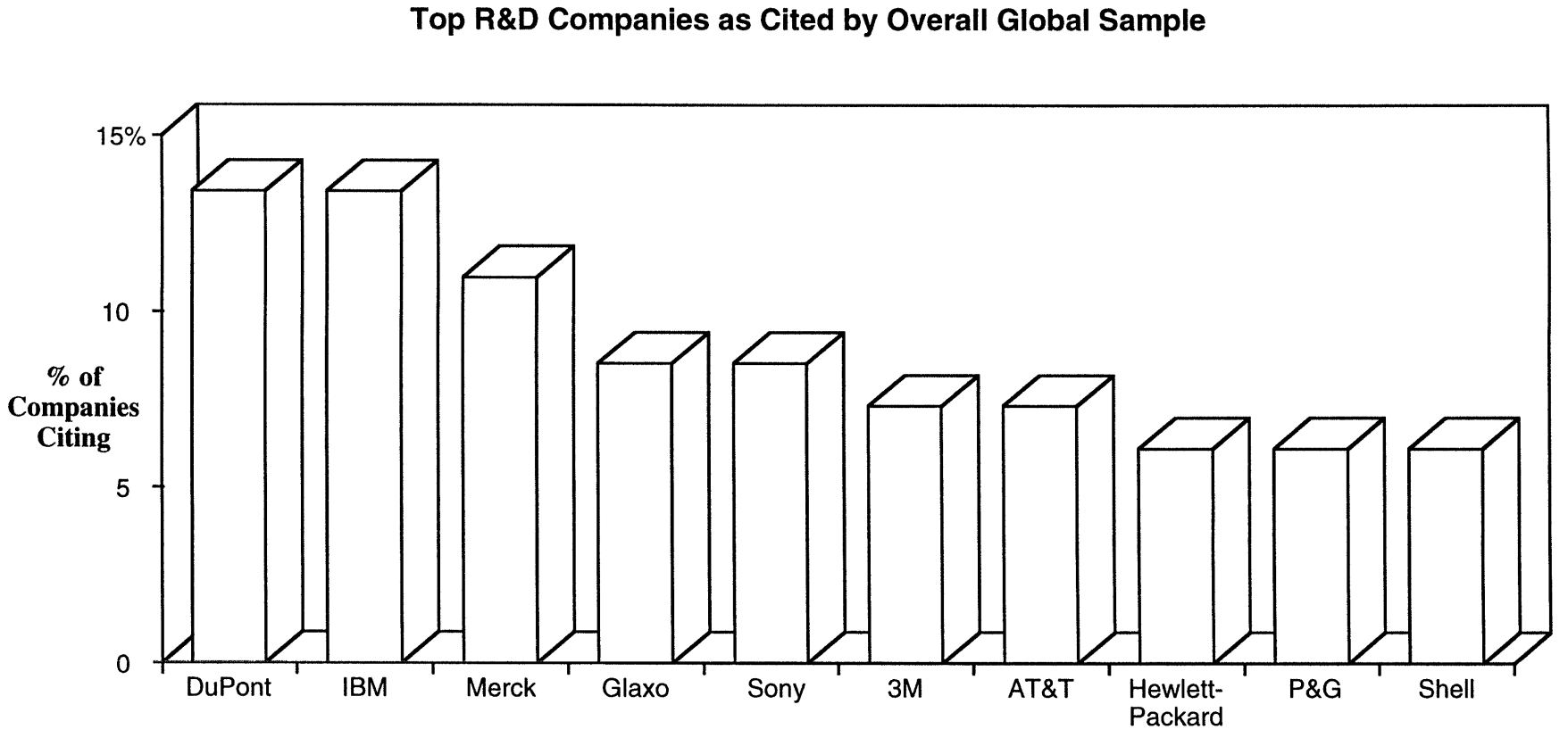

Figure 9. Different aspects of technology management show up as the key correlates of meeting the needs of the three different sets of company "stakeholders". Timeliness of new product offerings and competitive technology leadership significantly affect end-user satisfaction, for example, while a balanced product/process R&D portfolio most strongly correlates with a satified internal manufacturing customer.

Rank ordered by strength of impact on each targeted "stakeholder"

End-Use Customers	Corporate Strategy	Manufacturing
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 causality, of statistical relationship

Figure 10. The three key correlates of revenues from new products/processes across the entire sample, rank-ordered in importance, are timeliness and newness of the firm's technology, as well as indications of company abilities to adjust to external changes.

Timeliness

Newness of technology

Adjustment to external change

Figure 11. The global survey reveals three key aspects of R&D performance that contribute statistically significantly to sales growth. Taken together these factors reflect an overall R&D managerial capability that shows up consistently in the multiple product and process development projects of the firm.

Meeting project objectives in regard to:

- Time to market
- Technical specifications
- Budgeted development costs