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RESEARCH INTENSITY AND THE IDENTIFICATION OF HIGH TECHNOLOGY INDUSTRIES

by

John W. Medcof

Innovation Research Working Group
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John W. Medcof

The Michael G. DeGroote School of Business

McMaster University

Hamilton, ON, L8S 4M4

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Abstract

Research intensity (the ratio of R&D expenditures to total sales income) has a number of virtues as a metric for identifying high technology industries (those whose business activities are heavily dependent upon innovation in science and technology). Research intensity is unambiguous and quantifiable with data that are readily available from a variety of sources for a large number of firms and industries. It generates a list of high technology industries with high face validity that is quite stable over time. Industries with high research intensities are not necessarily those with the highest absolute expenditures on R&D and they have a much higher growth rate than the highest R&D spenders, and than the economy as a whole. Research intensity can be applied at the industry and firm level, and can be used by managers making strategic and other decisions. Research intensity, if judiciously used in light of its limitations, can be a useful tool for managers and policy makers and further research on it should prove useful.

The identification of high technology industries (HTI's) is a matter of growing interest to government agencies, business mangers, and researchers, primarily because some evidence indicates that HTI's have higher growth rates than most industries (Baruch, 1997; Dvir, Segev and Shenar, 1993; Harpaz and Meshoulam, 1997). Governments are anxious to attract HTI's to their jurisdictions hoping they will bring economic prosperity with them (Baruch, 1997; Dvir *et al*, 1993; Harpaz and Meshoulam, 1997; Lee and Shim, 1995). Business managers want to learn and adopt the management techniques of HTI's, hoping that they will enable success in their own firms. Researchers are studying HTI's for both theoretical reasons and in order to pass on useful knowledge to policy makers and managers.

Although the study of HTI's is generally acknowledged to be important, there is still some ambiguity about how to identify them. An unambiguous definition of HTI's would allow better research to be done on them, enable better communication among the various groups who are interested in them (policy makers, managers and researchers), and generally improve our ability to create economic prosperity through them, with better strategy and management. Closely related to attempts to identify HTI's have been attempts to identify high technology firms (eg. Hundley, Jacobson and Park, 1996). Studies of high technology industries and firms will be more likely to cross-fertilize each other if a single system for identifying both industries and firms is available. The purpose of this paper is to advance our ability to identify HTI's in an unambiguous and useful manner.

There have been various attempts to define "high technology", based upon various criteria and with varying levels of rigour (Baruch, 1997). For example, Reeble (1990) states that high technology industries engage in activities which involve high rates of technological change, high research and development expenditures, and innovative and technically advanced products. Shanklin and Ryans (1984) suggest three criteria that must be met to merit the label "high-tech," (1) the business has a strong scientific basis; (2) new technology can quickly make existing technology obsolete and, (3) as new technologies come on stream, their applications create or revolutionize markets and demand. These definitions are conceptually rich but operationalizing them in credible, concrete terms may prove difficult. Other writers have operationalized high technology without much conceptual elaboration, by merely stating that HTI's are those with high "research intensity", defined as a high ratio of R&D expenditures to total sales. The identification of HTI's should be based upon a definition of high technology that has both conceptual credibility and unambiguous, quantitative, operationalization

Baruch (1997) has recently attempted a definition of high technology that has both conceptual substance and operational rigour, through a literature review and by a survey of business people. He arrived at three conceptual dimensions for the definition of high technology: (1) Internal research and development constitutes a significant share of organizational operations; (2) A high proportion of employees have university degrees and/or are professional staff; and (3) The area of business activity is in advanced technology, on the cutting edge of technology developments. For two of these he did provide very credible operational definitions but for the third he was less successful. For the first, he proposed that the ratio of R&D expenditures to sales (research intensity) be calculated and that firms or industries with ratios greater than .05 are high technology because R&D would constitute a significant share of their operations. Second, he proposed that if 10% or more of employees have university degrees, the firm or industry is high technology. For the third dimension, he stated that it is inappropriate for precise measurement but he included it because it was so frequently mentioned as a criterion by those responding to his surveys. He pointed out that, although some areas of technology are widely regarded as leading edge, such as biotechnology and artificial intelligence, these could change over a decade or even a shorter period of time. Baruch's work is an excellent attempt to synthesize past work and to draw upon the perceptions of managers as well as academics. His first two criteria have a common conceptual basis, are quantifiable, and are applicable at both the firm and industry levels. The third, as he points out, is more problematic because it is not as readily quantifiable. It might be operationalized by polling knowledgable people (as defined by some rigorous method) about their opinions of what technologies are leading edge or "high". Fundamentally, though, this last criterion merely shifts the ambiguous question from "What is a high technology firm or industry?" to the equally as difficult question, "What is high technology?" Baruch's (1997) use or research intensity as a metric for high-tech is not unusual. It is probably the most frequently used index.

Research intensity has several advantages as a measure of high technology. It is easy to attach to a clear, credible conceptual definition. It is quantitative and so capable of unambiguous operationalization. The data used to calculate it are readily available from a variety of sources for a large number of firms and industries. It can be applied at both the industry and firm levels.

Another virtue of research intensity, which has not been pointed out in the literature, is that it is already in use as a managerial tool in some firms. This goes beyond merely being applicable at the firm level. Applicability at the firm level means that the data necessary to calculate research intensity are available for individual firms and that the research intensity ratio describes a meaningful characteristic of the firm. Use as a managerial tool means that, not only are the numbers available for calculating research intensity, but that managers in firms actually use research intensity as a tool in their decision making. For example, Scholefield (1994) describes the use of research intensity in decision making at ICI Chemicals and Polymers Ltd. He explains a method for integrating the technology strategy of the firm with the firm's overall strategy which assumes that different business strategies for the firm require different amounts of emphasis upon R&D. He uses research intensity to operationalize his recommendations about R&D emphasis. In a similar vein, Smith (1996) provides a system, based upon his experience as a director of engineering and technology in a commercial firm, for setting a level of R&D spending for the firm. That level of spending will depend upon the business strategy of the firm, and is operationalized as research intensity.

Thus, research intensity has much to recommend it as an operation measure of high technology. If we begin with a credible conceptual definition which states that, "A high technology firm or industry is one whose business activities are heavily dependent upon innovation in science and technology," it is a logical step to measure that heavy dependence with research intensity, the ratio of R&D spending to total sales. This operationalization is quantitative and unambiguous, can be calculated with readily available data, can be applied at both the industry and firm levels, and can be used by managers in decision-making. It has multiple utilities for governments, managers and researchers. Given this promise as a metric for operationalizing high technology, this paper will evaluate research intensity further, to explore its possible strengths and weaknesses, and its value relative to certain other metrics.

FACE VALIDITY

One obvious question about research intensity as a tool for identifying high technology industries is whether the list of high technology industries generated by it looks, intuitively, like a list of high technology industries. In the field of psychological testing, one procedure for evaluating the validity of items on a questionnaire is to determine if the items appear, on the face of it, to be appropriate for measuring the psychological characteristic they are supposed to measure. This is not the only criterion for validity, and certainly not always the most important one, but it is used. Psychologists call this Face Validity (Catano, Cronshaw, Wiesner, Hackett and Methot, 1997) and that terminology is adopted here to refer to the intuitive acceptance of a list of high technology industries.

The issue of face validity is not a trivial one since our intuitions are based upon years of experience and tacit understandings about which industries are high technology. Further, management and policy making are activities which depend heavily upon judgement. Managers and policy makers will not be able to make judgements about high technology unless they are intuitively comfortable with it. Supporting this view, Baruch (1997) found so much support for a definition of high technology based upon an intuitive understanding of what areas of science and technology are "high", that he felt forced to include it in his definition, even though it cannot be precisely operationalized. He adopted this position even though one of his primary goals was to have a definition of high technology that does allow precise operationalization. In a sense, with the question of face validity, we are asking whether Baruch's third dimension of high technology (Is the industry's business in an area of advanced technology, intuitively?) can be subsumed under his first dimension (Does the industry have high research intensity?). If we find that research intensity generates a list of high technology industries which has face validity, we can dispense with Baruch's third criterion as a separate dimension.

To check the face validity of research intensity as a tool for identifying high technology industries we need an explicit, conceptual definition of high technology. Here, high technology industries and firms are defined as those whose business activities are heavily dependent upon innovations in science and technology. Notice that this definition does not involve a distinction between "high" and "low" science and technology. The operative concept is heavy dependence upon innovation based on science and technology. It is not a long conceptual leap to say that a good way to measure the degree to which a firm or industry is dependent is to compare its annual expenditures on R&D to its annual sales. Research intensity is a good way to do this.

Now that we have a conceptual definition of high technology associated with research intensity, we can turn directly to the question of face validity. Fundamentally, the face validity question asks whether a list of industries with the highest research intensities appears intuitively to be a list of industries that are heavily dependent upon innovations in science and technology. This was investigated using the 1994 COMPUSTAT data base. Firms were aggregated into industries on the basis of their four digit SIC codes. For each industry, the sales (COMPUSTAT code "SALE") and R&D expenditures (COMPUSTAT code "XRD) of all its firms were summed. Then the sum of the R&D expenditures was divided by the sum of the sales, to yield the research intensity for the industry. Industries were rank-ordered by research intensity and the top 20 are shown in Table 1. Table 1, then, is a list of the 20 most high technology industries, according to the research intensity metric. The question is whether this list has face validity in the eyes of the reader. The research intensities are all above the .05 value specified by Baruch (1997) as his minimum criterion for acceptance as high technology. Most of the industries commonly thought of as high technology are there, including pharmaceuticals, software, electronics, instruments and telecommunications equipment. Conspicuous by their absence are aircraft manufacturing (SIC code 3721) and computer manufacturing (SIC code 3571). The industries listed in Table 1 account for 4.2% of the sales of all firms listed in the 1994 COMPUSTAT data base. They are a small, elite group of high technology industries. For this writer, the face validity of this list of high technology industries is good, but the two missing industries give cause for concern and should be explained. This concern will be discussed further, below.

Please insert Table 1 approximately here

INDUSTRY SIZE AND RESEARCH INTENSITY

Research intensity uses total sales as its measure of the size of an industry in calculating the importance of R&D expenditures to that industry. There is, however, the question of whether sales is the most appropriate measure of the overall size of the industry. Sales can fluctuate from year to year, more than, say, number of employees and total assets, and that could cause undesirable variation in the research intensity metric. Although sales is the most frequently used denominator in research intensity calculations, other measures of size can be, and are, used.

To explore how much might be gained by using other indices of size, Spearman correlation coefficients were calculated between sales (COMPUSTAT code SALES), number of employees (COMPUSTAT code EMP), and assets (COMPUSTAT code AT) using all firms in the COMPUSTAT data base. All firms were used (and not just high research intensity firms) to ensure that any relationships found among these variables would be a general one, and not just characteristic of some subset of industries. The Spearman correlation coefficients are shown in Table 2. All are above .97. This high intercorrelation indicates that the measures of size are more-or-less interchangeable and is consistent with past investigations of this question (Agarwal, 1979). Given that sales is the most frequently used measure of size, that it is used in the research intensity ratio used by managers in making their decisions, and that no conceptual reasons have been advanced for preferring the other measures, it seems that the continued use of sales in the denominator is warranted. However, the high correlations also indicate that, if necessary, other measures of size can be safely used as proxies for sales.

Please insert Table 2 approximately here

STABILITY

Another consideration is the stability of a list of high technology industries. Stability is important if research intensity is to be used in making decisions that have implications for significant periods of time. For example, one would question the wisdom of a government which established policies to attract targeted high technology industries if the list of such industries changed from year to year. Given the generally acknowledged dynamism in high technology industries, we would expect some turnover in their numbers, but a highly changeable list would have limited usefulness for most purposes.

To evaluate the stability of research intensity as a metric for identifying high technology industries, COMPUSTAT data were used to identify the 20 most research intense industries in each of the five years from 1990 through 1994, inclusive. Twenty-four different industries appeared in at least one of these lists. Of the 24, 16 appeared in all five years, two appeared in four, five appeared in two, and one appeared in only one year (Table 3).

Please insert Table 3 approximately here

Table 3 shows that over a five year period the list of high technology industries remained quite stable. Of the 24 industries which appeared at least once, 18, or 75% appeared in four or five years. However, six, or 25%, appeared in only one or two years. This is problematic because it is a significant amount of instability in the listing. This instability suggests that basing a list of high technology industries on research intensity data from only one year is not advisable.

We can investigate whether the two surprising omissions from Table 1 (aircraft and computer manufacture) are the result of instability in the research intensity metric. For each of these industries, their research intensities since 1986 were calculated and their presence in the top 20 determined. Aircraft manufacturing was not in the top 20 in any year between 1986 and 1994, inclusive. Despite the perceptions of many, aircraft manufacturers are consistently not among the largest proportionate spenders on R&D. Computer manufacturing was in the top 20 every year between 1986 and 1993, falling off only in 1994. Whether the 1994 result is a temporary aberration or indicative of a substantive trend is an issue deserving further investigation. It may reflect the recent commoditization and growth of the PC market, in which advertising and low price have become at least as important as technical edge in attracting customers.

ECONOMIC SIGNIFICANCE

Another issue of importance to policy makers and managers is the economic significance of high technology industries. For example, governments are interested in attracting high technology industries because of the economic growth they are believed to stimulate. But that growth may not have much effect upon the economy as a whole if the high technology industries involved are relatively small in size. Similarly, managers deciding whether or not to enter high technology businesses, as a strategic matter, may not be interested in those with little economic impact.

Economic significance is also important when considering the direct management of high technology. A small firm with high research intensity may be highly dependent upon scientific and technical innovation, but have a small R&D group, in absolute terms. That small group may focus on a narrow technology and do everything on a shoe-string budget. As a consequence of this and other factors, it may not manage its R&D in a very sophisticated way and may not be developing innovative management techniques. In contrast, a very large firm may have low research intensity but have high R&D expenditures, in absolute terms. As a consequence, its R&D group(s) may be large, may deal with a number of varied technologies, may use sophisticated management techniques, and may be constantly innovating in those techniques. As a consequence, their influence and sophistication in the field of technology management may be considerably higher than that of the small, research intense firm. At the very least, there is a good chance that their methods of technology management are different from those of the small research intense firm. So, the economic significance of R&D activity is important for at least these reasons. Here, we will approach economic significance through two paths, first by considering the total sales of high research intensity industries and, second, by considering the total R&D expenditures of industries.

Turning first to the total sales of high research intensive industries, Table 4 shows the industries listed in Table 1, rank ordered in terms of their total annual sales. Those at the top have the most economic significance. A government interested in attracting the most economically significant high technology industries might approach only the ten largest of these. Another approach might be to consider the synergies among related industries. The industries with SIC codes with the first three digits 283 all manufacture pharmaceuticals and related products. The sales of this grouping might be compared to that of the group with SIC codes beginning with 366 (communications equipment) to see which has the most potential economic impact.

Please insert Table 4 approximately here

The other approach to the question of economic importance is to consider the total expenditures on R&D, by industry. By focusing on just R&D expenditures, one gets a more precise picture of the economic impact of the R&D work itself, than is given by looking at annual sales.

Table 5 lists the 20 industries with the highest levels of R&D expenditures, based upon the COMPUSTAT 1994 data. These industries account for 41% of the sales of all industries in the COMPUSTAT data base, much larger than the 4.2 % of the sales accounted for by the top 20 research intensity industries. The two surprising omissions from the list of high research intensity firms in Table 1 (aircraft and computer manufacturing) both appear in the list of top 20 R&D spenders. Computers is number 15 and aircraft number 14. It seems that these two traditional "high-tech" industries are like the automobile industry. They all spend large amounts of money on R&D, but given the size of these industries, these expenditures are a relatively small part of their overall activities.

Please insert Table 5 approximately here

To tap both research intensity and economic importance, we can identify firms that appear in both the list of top research intensity firms (Table 1) and in the list of top R&D expenditure firms (Table 5). Six industries appear on both and they are listed in Table 6, ranked using a score which combines their rankings in the two tables. For each industry, its rankings in the two lists were summed. The industry with the lowest sum (i.e. closest to the top on the two rankings) is listed first. Table 6, then, lists high technology powerhouse firms, high in both research intensity and the economic significance of their R&D expenditures. Incidentally, this list is also relatively stable over time. All six appeared in the top 20 research intensity lists for the period 1990-1994.

Please insert Table 6 approximately here

Table 7 is a refinement of Table 6. It lists five high technology firms, par excellence. These are the top five industries from Table 6. They were all in the top 20 research intensity lists for all years from 1989 to 1994, and all but one were in the top 20 list for total research expenditures for every year during that same period. The only exception is the biological products industry (SIC 2836) which appeared on the top expenditures list in 1993 and stayed on in 1994. Also reported in 1994. Also reported in Table 7 are the top R&D spending firms in each of the industries and the research intensities and total expenditures on R&D of each industry. These are the cream of the crop of high technology industries.

Please insert Table 7 approximately here

INDUSTRY GROWTH

One reason high technology industries attract a great deal of interest is their above average rates of growth (Baruch, 1997; Dvir *et al*, 1993; Harpaz and Meshoulam, 1997; Lee and Shim, 1995). We can ask whether the research intensity metric really does identify industries with higher than average growth rates.

To investigate this, total sales were tracked over the five year period from 1990 through 1994, using COMPUSTAT data. Several industry groupings were tracked. One group consisted of the top 10 research intensity firms. The second consisted of the top 10 total R&D expenditure firms. The third, the top three firms in the combined rating (Table 6). The fourth included all industries in the COMPUSTAT data base. This last grouping was used to provide a baseline. As shown in Figure 1, the 1990 sales of each group was set at 100%, and the growth from there was tracked over four years. Figure 1 shows that the top 10 in R&D intensity and the top 3 from the combined scale had virtually identical growth, and that growth was considerably higher than that of the other two groups. The top 10 in total R&D expenditures did slightly worse than the baseline grouping of all industries in the COMPUSTAT data base, although these two may not be significantly different from each other.

These data support the use of research intensity as a metric for the identifying high technology industries. Research intensity does, indeed, identify a group of industries with well above average sales growth. Not much seems to be added by including the second criterion, high levels of R&D expenditure. Those firms identified solely on the basis of their high R&D spending had unremarkable performance.

Please insert Figure 1 approximately here

CONCLUSIONS

This paper has examined the usefulness of research intensity as a metric for identifying high technology industries and found it to have a number of virtues. First, high technology industries were defined as those whose business activities are heavily dependent upon innovation in science and technology. A logical way to operationalize "heavily dependent upon innovation in science and technology" is to measure the ratio of R&D expenditures to total sales. This yields a clear, simple conceptual definition and a single, clear, quantifiable operational definition. In addition, the data used to calculate it are readily available from a variety of sources for a large number of firms and industries

This simple, clear conceptual base and operationalization has other advantages. The definition does not distinguish between "high" and "low" science and technology and, therefore, avoids the necessity of settling the complicated issue of how to distinguish between these two, in a rigorous way which will find broad acceptance. This definition also relegates to secondary status certain other characteristics which some other authors have suggested should be included in the primary definition. For example, some authors have suggested that high economic growth be included as a fundamental dimension in the definition of high technology industries. But doing so complicates the basic definition unnecessarily. In the definition proposed here, high economic growth is a possible secondary characteristic of high technology industries, and the presence of that secondary characteristic is a matter for empirical verification.

The list of 20 high technology industries generated by the research intensity metric also has face validity. Most of the industries one would intuitively expect to be on the list were included, although there were two important omissions, aircraft and computer manufacturing. The absence of the latter is consistent with certain recent trends in the industry.

The list of 20 high technology industries is also quite stable, with a large proportion of those included remaining on the list over a five year period. However, 25% of those who were on the list in the 1990-1994 period were on for only one or two years. This degree of instability gives reason for caution and suggests that lists of high technology industries should be based upon data from several years.

The analysis here has shown that industries with high research intensity are not necessarily those with the highest absolute expenditures on R&D. Only six industries appeared on both the list for the top 20 most research intense, and the top 20 industries in terms of total R&D expenditures. This lack of overlap suggests that a conceptual distinction should be maintained between high research intensity and high R&D expenditures.

The usefulness of maintaining this distinction was reinforced by the data on sales growth. The ten most research intensive firms had a sales growth rate much higher than that for the top ten spenders on R&D in the 1990-1994 period. The growth rate for the research intensive industries was also higher than the average growth rate for all industries. This shows that the research intensive metric identifies a group of high technology firms whose growth rate is consistent with that predicted by economic theory, ie. above average.

IMPLICATIONS

One very important characteristic of the research intensity metric is that it can be applied at both the industry and firm levels and can be used by managers in making certain decisions. This universality of application opens the door for its use in integrating across levels of analysis. It opens the possibility that theorists may be able to conceptually connect theories in all three realms of ideas, using research intensity as the basis. It also provides policy makers and managers the conceptual opportunity to integrate their thinking across all three realms and to start linking different aspects of their decision-making activities.

Managers who have been using research intensity in making decisions, or who are considering doing so, can take heart from this analysis. It shows that research intensity has a number of good qualities recommending its use, as long as its limitations are judiciously accounted for. The metric has solid credentials and is well worth considering for more extensive use, and greater understanding of it through further research should be rewarding.

Cautions for those who would use research intensity for practical reasons are also suggested by the results of this analysis. Lists of high technology firms generated by the research intensity metric do evolve over time, although, for the most part, slowly. This suggests that time frame is an important consideration. Those using research intensity for making practical decisions should take time frame into account, for example, when setting specifications for research commissioned to help them make their decisions.

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TABLE 1

The 20 Most Research Intensive Industries

Rank	Industry Name	SIC Code	Research Intensity
1	MEDICINAL CHEMS, BOTANICAL PDS	2833	0.53
2	BIOLOGICAL PDS, EX DIAGNOSTICS	2836	0.42
3	PREPACKAGED SOFTWARE	7372	0.16
4	IN VITRO, IN VIVO DIAGNOSTICS	2835	0.15
5	TELE & TELEGRAPH APPARATUS	3661	0.13
6	PHARMACEUTICAL PREPARATIONS	2834	0.11
7	COML PHYSICAL, BIOLOGCL RESH	8731	0.11
8	ELECTROMEDICAL APPARATUS	3845	0.11
9	COMPUTER COMMUNICATION EQUIP	3576	0.11
10	LAB ANALYTICAL INSTRUMENTS	3826	0.11
11	ELEC MEAS & TEST INSTRUMENTS	3825	0.10
12	SPECIAL INDUSTRY MACHY, NEC	3559	0.10
13	LAB APPARATUS AND FURNITURE	3821	0.10
14	SEMICONDUCTOR, RELATED DEVICE	3674	0.09
15	X-RAY & RELATED APPARATUS	3844	0.09
16	RADIO, TV BROADCAST, COMM EQ	3663	0.07
17	OPTICAL INSTRUMENTS & LENSES	3827	0.07
18	TELEGRAPH & OTHER MESSAGE COMM	4822	0.07
19	COMPUTER STORAGE DEVICES	3572	0.07
20	MAGNETIC, OPTIC RECORDING MEDIA	3695	0.06

Based upon 1994 COMPUSTAT Data
Research intensity is total R&D expenditures divided by total sales.

TABLE 2

Spearman Correlation Coefficients
Between Various Measures of Industry Size

Sales			
Number of Employees	.977		
Assets	.979	.973	
	Sales	Number of Employees	Assets

Based upon 1994 COMPUSTAT DATA

TABLE 3
Stability of High Technology Industries Over a Five Year Period

Industries Appearing for Five Years

Medicinal Chems, Botanical Pds
Biological Pds, Ex Diagnostics
Prepackaged Software
Invitro, in Vivo Diagnostics
Tele & Telegraph Apparatus
Pharmaceutical Preparations
Coml Physical, Biologcl Resh
Electromedical Apparatus
Computer Communication Equip
Lab Analytical Instruments
Elec Meas & Test Instruments
Special Industry Machy, Nec
Semiconductor, Related Device
X-ray & Related Apparatus
Radio, Tv Broadcast, Comm Eq
Telegraph & Other Message Comm

Industries Appearing for Four Years

Optical Instruments & Lenses
Electronic Computers

Industries Appearing for Two Years

Lab Apparatus and Furniture
Magnetic, Optic Recording Media
Computer & Office Equipment
Securities and Commodity Brokers
Hotels and Other Lodging

Industries Appearing for One Year

Computer Storage Devices

Frequency of appearance in the list of 20 most research intensive industries, 1990-1994.

TABLE 4

The 20 Most Research Intensive Industries Rank Ordered by their Total Sales

Rank	Industry Name	SIC Code	Research Intensity	Sales
1	PHARMACEUTICAL PREPARATIONS	2834	0.11	137,766
2	SEMICONDUCTOR, RELATED DEVICE	3674	0.09	44,977
3	RADIO, TV BROADCAST, COMM EQ	3663	0.07	39,440
4	TELE & TELEGRAPH APPARATUS	3661	0.13	28,831
5	PREPACKAGED SOFTWARE	7372	0.16	25,209
6	COMPUTER STORAGE DEVICES	3572	0.07	16,104
7	COMPUTER COMMUNICATION EQUIP	3576	0.11	9,722
8	ELECTROMEDICAL APPARATUS	3845	0.11	6,352
9	SPECIAL INDUSTRY MACHY, NEC	3559	0.10	5,473
10	IN VITRO, IN VIVO DIAGNOSTICS	2835	0.15	4,161
11	ELEC MEAS & TEST INSTRUMENTS	3825	0.10	3,571
12	LAB ANALYTICAL INSTRUMENTS	3826	0.10	3,434
13	BIOLOGICAL PDS, EX DIAGNOSTICS	2836	0.42	3,126
14	COML PHYSICAL, BIOLOGCL RESH	8731	0.11	969
15	MAGNETIC, OPTIC RECORDING MEDIA	3695	0.06	703
16	OPTICAL INSTRUMENTS & LENSES	3827	0.07	622
17	X-RAY & RELATED APPARATUS	3844	0.09	486
18	LAB APPARATUS AND FURNITURE	3821	0.10	304
19	MEDICINAL CHEMS, BOTANICAL PDS	2833	0.53	45
20	TELEGRAPH & OTHER MESSAGE COMM	4822	0.06	31

Based upon 1994 COMPUSTAT Data

TABLE 5
The Top 20 Industries in Total R&D Expenditures

Rank	Industry Name	SIC Code	Total R&D Spending ($ millions)
1	MOTOR VEHICLES & CAR BODIES	3711	21101.60
2	PHARMACEUTICAL PREPARATIONS	2834	16216.54
3	COMPUTER & OFFICE EQUIPMENT	3570	12813.73
4	ELECTR, OTHER ELEC EQ, EX CMP	3600	7566.60
5	PHONE COMM EX RADIO, TELEPHONE	4813	5495.89
6	CHEMICALS & ALLIED PRODUCTS	2800	4594.90
7	PETROLEUM REFINING	2911	4553.63
8	PREPACKAGED SOFTWARE	7372	4107.06
9	PHOTOGRAPHIC EQUP & SUPPLY	3861	4046.06
10	SEMICONDUCTOR, RELATED DEVICE	3674	4020.28
11	TELE & TELEGRAPH APPARATUS	3661	3840.13
12	HOUSEHOLD AUDIO & VIDEO EQUIP	3651	3099.57
13	RADIO, TV BROADCAST, COMM EQ	3663	2906.03
14	AIRCRAFT	3721	2784.32
15	ELECTRONIC COMPUTERS	3571	2500.70
16	SCRH, DET,NAV,GUID,AERO SYS	3812	1998.12
17	FOOD AND KINDRED PRODUCTS	2000	1871.51
18	MOTOR VEHICLE PART, ACCESSORY	3714	1438.10
19	PLASTIC, SYNTH MATLS; EX GLASS	2820	1360.00
20	BIOLOGICAL PDS, EX DIAGNSTICS	2836	1336.48

Based upon 1994 COMPUSTAT Data

TABLE 6

Firms With High Research Intensity and High Total R&D Spending

	Industry Name	SIC Code	Combined Rank Score	Research Intensity Rank	Total R&D Spending Rank
1	Pharmaceutical Preparations	2834	8	6	2
2	Prepackaged Software	7372	11	3	8
3	Telephone & Telegraph Apparatus	3661	16	5	11
4	Biological Pds, Ex Diagnostics	2836	22	2	20
5	Semiconductors and Related Devices	3674	24	14	10
6	Radio, TV Broadcast, Comm Eq	3663	29	16	13

Based on 1994 COMPUSTAT data.
The combined Rank Score is the sum of the Research Intensity Rank and Total R&D spending Rank. Lower values on the combined rank score mean higher rankings of high technology.

TABLE 7

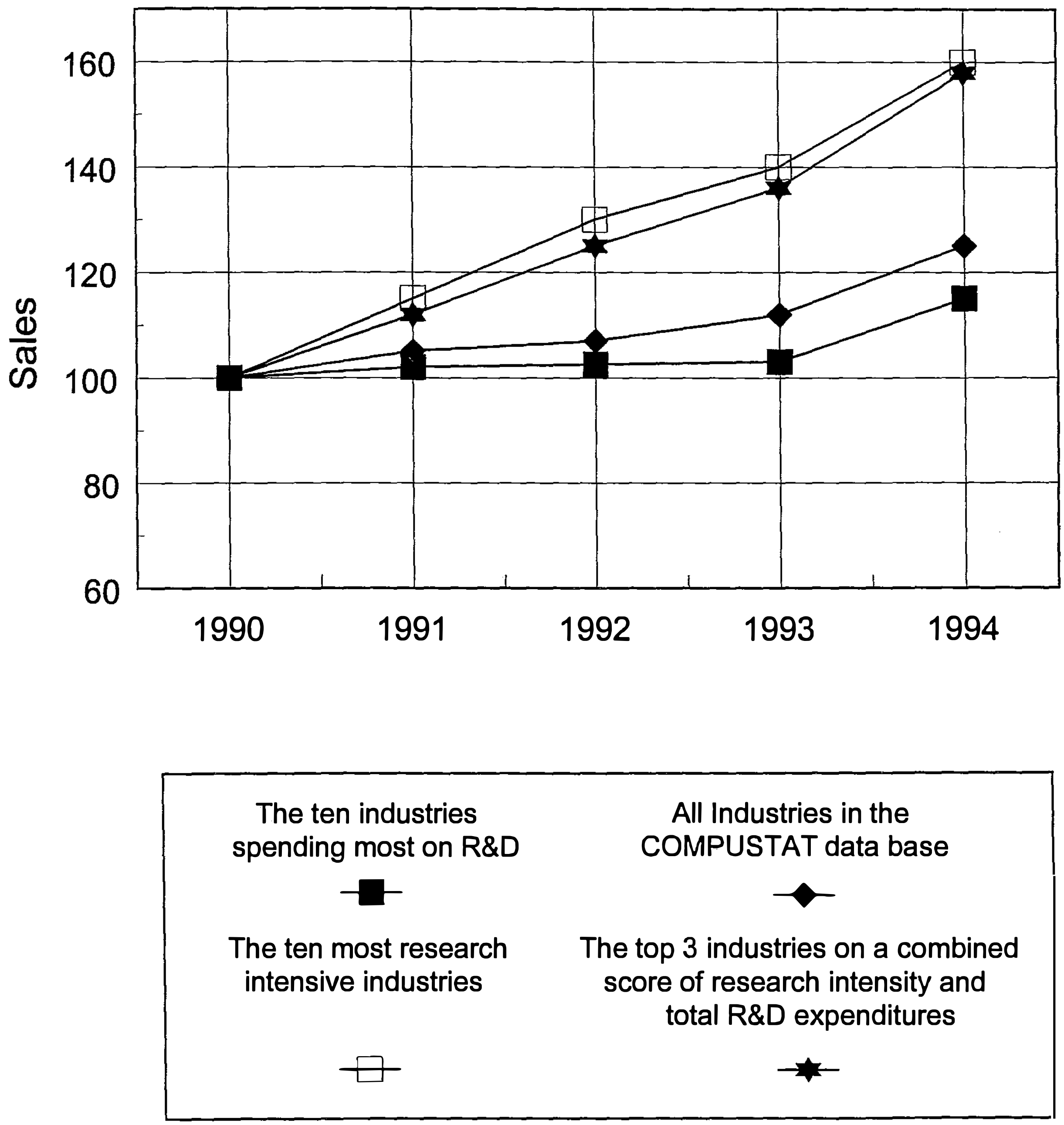
High Technology Industries, Par Excellence With Their Highest R&D Expenditure Firms

SIC Code	Industries and Firms	Research Intensity	Total R&D Spending ($ millions)
2834	Pharmaceutical Preparations	.18	16,216
	Glaxo Wellcome PLC		
	Johnson & Johnson		
	Merck & Company		
7372	Prepackaged Software	.16	4,017
	Microsoft Corp		
	Computer Associated Intl Inc.		
	Novelling		
3661	Telephone and Telegraph Apparatus	.13	3,840
	Ericsson (LM) Tel		
	Northern Telecom Ltd.		
	DSC Communications Corp		
2836	Biological Pds, Ex Diagnostics	.42	1,336
	Amgen Inc.		
	Genetics Institute Inc.		
	Biogen Inc.		
3674	Semi-conductors and Related Devices	.09	4,020
	Intel Corp		
	Texas Instruments Inc.		
	SGS-Thomson Microelectronics		

Based upon COMPUSTAT, 1994 data

Figure 1

Sales Growth in Various "High Technology" Groupings



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