17

PNL-4939
UC-13

R&D Intensities in U.S. Industries

J. M. Fang
L. A. Skumatz

January 1984

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

PNL-4939

DISCLAIMER

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

NTIS Price Codes
Microfiche A01

Printed Copy

Pages	Price Codes
001-025	A02
026-050	A03
051-075	A04
076-100	A05
101-125	A06
126-150	A07
151-175	A08
176-200	A09
201-225	A010
226-250	A011
251-275	A012
276-300	A013

PNL-4939
UC-13

R&D INTENSITIES IN U.S. INDUSTRIES

J. M. Fang
L. A. Skumatz

January 1984

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

SUMMARY

This report presents data on the R&D intensities in U.S. industries, defined to represent R&D expenditures as percentages of sales. Both company-funded and total (including federal funding) intensities are examined. The variations of the R&D intensities among industries and over time are also described. Qualitative discussions are provided on some probable causes underlying the inter-industry and temporal variations of the intensities. Limitations of the study and probable areas for further research are also noted.

At the industry level, the intensity information was used to categorize the individual industries into five groups: high, above-average, average, below-average, and low intensity. Data on individual firms were also examined for the aerospace, automotive, chemical, computer and office equipment, and electronics and semiconductor industries.

Although other data sources were also consulted, the study relies primarily upon two published data sources: National Science Foundation's Research and Development in Industry series and Business Week's "R&D Scoreboard." Although the two data series have some differences in coverage, definitions, and industry groupings, the relative intensities and trends are generally comparable, allowing for the inclusion of federal funding.

CONTENTS

TABLES

1.0 INTRODUCTION

This report presents data on the ratios of research and development (R&D) expenditures to sales in U.S. industries at different levels of aggregation and provides some qualitative assessment on the probable causes for the variations of such ratios among industries and over time. This information is intended to provide an understanding of industry practices on the level of R&D expenditures relative to sales, particularly for the industries and firms which are involved in the state-of-the-art technologies. The industries of particular interest are aerospace, automotive, chemical, computers, and electronics.

Since federal funds support a variety of R&D projects in the industrial sector, the information collected distinguishes between total R&D expenditures (including federal funds) and company-funded R&D expenditures (excluding federal funds). To simplify the discussion, the term "total R&D intensity" is used to represent total R&D expenditures as a percentage of net sales of an industry or a company. Similarly, the term "company R&D intensity" represents company-funded R&D expenditures as a percentage of net sales.

The two major data sources used in this report are the National Science Foundation's (NSF) Research and Development in Industry, 1980, supplemented by Science Resources Studies Highlights, dated August 8, 1983, and Business Week's (BW) "Industrial R&D Scoreboard."[1] The NSF data include industry summaries of both total and company R&D intensities but are without detail on individual firms. The BW source contains data for individual firms but reports only on company R&D intensities. Although there are some differences in coverage and industry grouping in the two data sources, there appears to be a high degree of comparability in terms of company R&D intensities.

Section 2.0 presents a summary of the major findings. Section 3.0 explains overall trends and variations across all industries and groups the

---

[1] Other data sources are also consulted in this study. However, to avoid confusion, we have concentrated on the NSF and BW data. See Appendix A for additional discussions on data sources.

industries into five categories in terms of R&D intensities. Section 4.0 details the data on aerospace, automotive, chemical, computers, and electronics industries. Section 5.0 provides some qualitative discussion on the probable causes for the variations in R&D intensities across industries and the variations over time of these intensities for individual industries or firms. Section 6.0 notes briefly the limitations of the study and the further research areas in terms of the data collected. Appendix A provides a more detailed discussion on data sources, and Appendix B explains the Standard Industrial Classifications (SIC) used in the NSF data.

2.0 SUMMARY OF FINDINGS

The major findings of this study are as follows:

1. Including federal funds, total R&D intensity in all industries combined were in the range of 2.6% to 3.2% during 1974-1981 (NSF data only). Company R&D intensity (without federal funds) ranged from 1.8% to 2.2% during the same period (NSF and BW data combined). BW data showed that company R&D intensity rose from 2.0% in 1981 to 2.4% in 1982.

2. According to BW data and using its industry groupings, the following are the high or above-average R&D-intensity industries:

Industry	Range of Company R&D Intensity During 1974-82 (%)
Semiconductors	5.7 - 7.8
Information processing: peripherals	5.9 - 7.2
Computers	5.9 - 6.8
Instruments	5.1 - 6.8
Drugs and Medicines	4.6 - 6.0
Office Equipment	4.0 - 5.1 [2]
Aerospace	3.0 - 5.1
Leisure Time Industries	1.7 - 4.8
Automotive: Cars & Trucks	3.0 - 4.0
Electronics	3.0 - 3.8
Machinery: Farm and Construction	2.4 - 3.3
(Industrial and Other) Chemicals	2.3 - 2.9
Electrical	2.5 - 3.1

When funding from federal sources is included, the total R&D intensities of some of these industries become significantly higher. The most conspicuous example is the aerospace industry. NSF data showed that, without federal

[2] Excluding 1974-76 because data for those years include computers.

funds, the intensity was in the range of 2.9% to 4.2% during 1974-81. Including federal funds, the range was 12.7% to 15.3%.

3. Some of the larger firms with sales over $1 billion in the high and above-average R&D-intensity industries are as follows:

Industry	Firm	Range of Company R&D Intensity During 1974-82 (%)
Semiconductors	National Semi-conductor	7.6 - 9.9
Electronics	Motorola	5.9 - 7.5
	Gould	2.6 - 6.8
Office Equipment	Wang Laboratories	3.3 - 7.5
Computers	Hewlett-Packard	8.0 - 10.0
	IBM	5.5 - 7.0
Drugs and Medicines	Eli Lilly	7.7 - 9.0
	Merck	7.8 - 10.0
	Upjohn	8.4 - 10.7
Industrial and Other Chemicals	American Cyanamid	3.3 - 5.3
	Rohm & Haas	3.4 - 5.0
	Dow Chemical	2.9 - 4.3
Aerospace	Boeing	4.8 - 8.6
	Northrop	2.0 - 12.7
	United Technologies	5.4 - 9.0
Automotive	Ford Motors	3.1 - 4.8
	General Motors	1.8 - 4.2
	Cummins Engine	1.9 - 4.3

Note again that if federal funds were included, the intensities would be higher.

4. The variations in company R&D intensities among industries appear to be related to the maturity and the technological character of the industries. In the relatively mature industries--such as food and beverages, textiles and apparel, lumber and wood products, paper, petroleum, steel and other primary metals, tobacco, leather and miscellaneous manufacturing--promises

of technological breakthrough are few and far between, and firms are less willing to invest heavily in R&D. In contrast, the "high-technology," relatively young industries--such as electronics and semiconductors, computers, office eqiupment, aerospace, drugs, chemicals, and automotive--are highly R&D intensive. Competition, both foreign and domestic, is another important factor in raising R&D intensity in industries. Other factors include the diversification of firms, tax incentives, regulations, federal support of R&D, and business conditions.

3.0 INDUSTRIES IN GENERAL

Table 1 presents data on all industries combined. Tables 2 through 4 provide the R&D intensities for the 2-digit SIC[3] industries. Tables 5 through 7 detail the available innformation at the 3- or 4-digit SIC levels. Some of the salient observations are discussed below:

1. The total and company R&D intensities in all industries combined tended to remain within a narrow range (Table 1):

   - Between 1974 and 1981, NSF data showed that total R&D intensity in all industries combined stayed relatively stable in the 2.6% to 3.2% range (col. 1). NSF data also showed that, excluding federal funds, company R&D intensities for all industries combined were lower than total R&D intensities by 0.7 to 1.1 percentage points (cols. 1 and 2).
   - BW data indicated that composite company R&D intensities for all industries rose gradually from 1.8% in 1974 to 2.0% in 1981 and then jumped to 2.4% in 1982 (col. 3).

2. The overall industry composite R&D intensities tended to obscure substantial variations among industries. Tables 2, 3, and 4 present data on total and company R&D intensities at the 2-digit standard industrial classification (SIC) levels from NSF and BW sources.

   - According to NSF data, in 1981 total R&D intensities for the 2-digit SIC industries ranged from 0.4% for food, textiles and other industries to 8.2% for instruments (Table 2).
   - Company R&D intensities computed from NSF data ranged from 0.4% to 6.8% in 1981. BW data showed a comparable range, from 0.5% to 4.6% in 1981 and from 0.6% to 5.2% in 1982. (Tables 3 and 4)
   - For discussion purposes, the observed R&D intensities can be used to group the industries into five categories.

---

[3] See Appendix B for a description of the SIC codes.

TABLE 1. R&D Expenditures as Percentage of Sales: All Industries

(%)

Year	NSF: Total (1)	NSF: Company (2)	BW: Company (3)
1974	3.1	2.0	1.8
1975	3.1	2.0	1.8
1976	3.1	2.0	1.9
1977	2.9	2.0	1.9
1978	2.9	2.0	1.9
1979	2.6	1.9	1.9
1980	3.0	2.1	2.0
1981	3.2	2.2	2.0
1982	--	--	2.4

Source and Notes:
NSF - National Science Foundation, Research and Development in Industry, 1981, in press, Table B-20 and B-21. Data contained in these two tables are revised from the NSF 82-317, Research and Development in Industry . Tables B-19 and B-20

BW - Business Week, "R&D Scoreboard," 1975-1982.

TABLE 2. Total R&D Intensities at the 2-Digit SIC Level: NSF Data (%)

Industry	SIC Code	1974	1975	1976	1977	1978	1979	1980	1981	1982
All Industries		3.1	3.1	3.1	2.9	2.9	2.6	3.0	3.2	--
Food & Beverages	20	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	--
Textiles & Apparel	22, 23	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	--
Lumber & Furniture	24, 25	0.8	0.7	0.7	0.8	0.7	0.7	0.9	0.9	--
Paper	26	0.8	0.9	1.0	0.9	0.9	1.0	1.0	--	--
Chemical	28	3.5	3.7	3.7	3.6	3.6	3.5	3.6	3.8	--
Petroleum	29	0.6	0.7	0.6	0.7	0.7	0.7	0.6	--	--
Rubber Products	30	2.5	2.5	2.4	2.1	1.9	1.9	2.2	--	--
Stone, Clay, and Glass	32	1.7	1.2	1.2	1.3	1.3	1.3	1.4	--	--
Primary Metals	33	0.6	0.8	0.8	0.7	0.7	0.6	0.7	0.8	--
Fabricated Metals	34	1.2	1.2	1.2	1.2	1.1	1.1	1.4	1.4	--
Machinery	35	4.6	4.8	4.9	4.9	4.6	4.5	5.0	5.2	--
Electrical Equipment	36	6.6	6.5	6.7	6.9	5.8	6.0	6.6	6.8	--
Transportation Equipment	37	7.1	6.8	6.3	6.2	6.1	7.7	--	7.7	--
Instruments	38	6.1	5.9	6.2	6.3	6.9	7.3	7.5	8.2	--
Other	21, 27, 31, 39	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	--

Source and Notes:
NSF - National Science Foundation, Research and Development in Industry, 1980, in press, Table B-20. Data contained in these two tables are revised from the NSF82-317, Research and Development in Industry. Tables B-19 and B-20.
BW - Business Week, "R&D Scoreboard," 1975-1982.

TABLE 3. Company R&D Intensities at the 2-Digit SIC Level: NSF Data (%)

Industry	SIC Code	1974	1975	1976	1977	1978	1979	1980	1981	1982
All Industries		2.0	2.0	2.0	2.0	2.0	1.9	2.1	2.2	--
Food & Beverages	20	0.4	--	--	--	--	--	--	0.4	--
Textiles & Apparel	22, 23	--	--	--	--	--	--	--	0.4	--
Lumber & Furniture	24, 25	--	0.7	0.7	0.8	0.7	0.7	0.8	0.9	--
Paper	26	--	--	--	--	--	--	1.0	1.0	--
Chemical	28	3.0	3.1	3.3	3.2	3.2	3.2	3.3	3.5	--
Petroleum	29	0.5	--	0.6	0.6	0.7	0.6	0.5	0.6	--
Rubber Products	30	--	--	--	--	--	--	--	1.9	--
Stone, Clay, and Glass	32	1.5	--	--	--	--	--	1.3	1.4	--
Primary Metals	33	0.5	0.7	0.8	0.7	0.6	0.5	0.5	0.6	--
Fabricated Metals	34	1.1	1.1	1.1	1.1	1.0	1.0	1.2	1.3	--
Machinery	35	3.8	4.0	4.2	4.3	4.2	4.2	4.5	4.6	--
Electrical Equipment	36	3.5	3.6	3.7	3.4	3.4	3.6	3.9	4.2	--
Transportation Equipment	37	3.1	2.8	2.6	2.6	2.7	3.1	3.7	--	--
Instruments	38	5.2	5.1	5.4	5.4	5.7	5.8	6.1	6.8	--
Other	21, 27, 31, 39	--	0.7	0.7	0.6	0.5	0.4	0.4	0.4	--

Source and Notes:
NSF - National Science Foundation, Research and Development in Industry, 1981, in press, Table B-21. Data contained in these two tables are revised from the NSF82-317, Research and Development in Industry. Tables B-19 and B-20.

BW - Business Week, "R&D Scoreboard," 1975-1982.

TABLE 4. Company R&D Intensities at 3-Digit SIC Level: BW Data (%)

Industry Group	SIC Code	1974	1975	1976	1977	1978	1979	1980	1981	1982
All Industries		1.8	1.8	1.9	1.9	1.9	1.9	2.0	2.0	2.4
Food and Beverages	20	.5	.5	.5	.5	.5	.5	.6	.7	.7
Textiles and Apparel	20, 23	.4	.4	.4	.5	.5	.6	.5	.4	.6
Lumber and Furniture	24, 25	--	--	--	--	--	--	--	--	--
Paper	26	0.7	0.8	.8	.9	.9	.8	.8	.9	1.0
Chemical	28	3.1	3.3	3.3	3.2	3.2	3.1	3.2	3.3	3.9
Petroleum	29	.4	.4	.4	.4	.4	.4	.4	.5	.5
Rubber Products	30	1.9	1.9	1.7	1.7	1.7	1.7	1.8	2.0	2.3
Stone Clay and Glass	32	--	--	--	--	--	--	--	--	--
Primary Metals	33	.7	1.0	.9	.8	.6	.5	.7	.8	.9
Fabricated Metals	34	1.6	1.1	1.2	1.1	.9	.8	.8	.8	.7
Machinery	35	2.6	2.4	2.4	2.3	2.0	2.1	2.1	2.4	3.0
Electrical Equipment	36	2.5	2.5	2.3	2.3	2.4	2.0	2.2	2.4	2.5
Transportation Equipment	37	3.0	2.8	2.7	2.6	2.8	3.2	4.0	3.9	4.1
Instruments	38	5.3	5.4	5.4	4.7	3.9	3.9	4.2	4.6	5.2

Source: BW - Business Week, "R&D Scoreboard," 1975-1982

Low intensity group:	Both total and company R&D intensity under 1%. Included are food and beverages (SIC 20); textiles and apparel (SIC 22 and 23); lumber, wood, and furniture (SIC 24 and 25); paper and allied products (SIC 26); petroleum and products (SIC 29); primary metals (SIC 33); and other industries including tobacco (SIC 21), printing and publishing (SIC 27), leather and leather products (SIC 31), and miscellaneous manufacturing (SIC 39).
Below-average intensity group:	Total R&D intensities in the range from 1% to 2.5%, or company R&D intensities approximately in the range between 1% to 1.9%. Included are rubber (SIC 30); stone, clay and glass (SIC 32); and fabricated metals (SIC 33).
Average intensity group:	Total R&D intensities in the range from 2.5% to 3.5%, or company R&D intensities in the range from 1.9% to 2.2%. Only the all-industries average fits in this category.[4]
Above-average intensity group:	Total R&D intensity in the range between 3.5% to 5%, or company R&D intensity between 2.2% and 4.5%. Included are chemical (SIC 28), machinery (SIC 35), and transportation equipment (SIC 37).
High intensity group:	Total R&D intensity above 5%, or company R&D intensity above 4.5%. Included are

[4] However, see the discussion in item 3 below.

electrical equipment (SIC 36) and instruments (SIC 37).

3. As shown in Tables 5, 6, and 7, the R&D intensities among industries at the 3- and 4-digit SIC levels were even more diverse than those at the 2-digit level.

   - o According to NSF data, total R&D intensity for office, computing, and accounting equipment (SIC 357, including computers) was 12% in 1980. Similarly, the aircraft and missiles (SIC 372 and 376, or aerospace) industry's total R&D intensity reached 13.7% in 1980 and 15.3% in 1981 (Table 5). Excluding federal funds, company R&D intensity in SIC 357 was 10.1% and intensity in aerospace was 4.2% in 1981 (Table 6). The big difference in the total and company R&D intensity for the aerospace industry reflected the high proportions of federal support in R&D in this industry. In 1981, federal funds accounted for 73% of the aerospace industry's total R&D expenditures.
   - o BW data at the 3- and 4-digit levels are grouped differently than the NSF data. Available data for 1981 ranged from 0.6% for steel (SIC 331 and 332) to 6.4% for computers (SIC 3573) and 7.1% for semiconductors (SIC 3674). The corresponding values for 1982 were 0.7% for steel, 6.8% for computers, and 7.8% for semiconductors. (Table 7)
   - o Applying the five R&D-intensity categories defined above in item 2 to the 3- or 4-digit SIC data in Table 7, we have the following:
     - The high R&D-intensity industries included drugs and medicine, office equipment, computers, semiconductors, aerospace, and information processing (peripheral).
     - The above-average intensity group included industrial and other chemicals, farm and construction machinery, electrical equipment, electronics (without semiconductors), automotive (cars and trucks), and leisure-time industries.
     - The average intensity group included personal and home care products, machine tools and equipment, appliances, automotive

TABLE 5. Total R&D Intensities at 3-Digit SIC Level: NSF Data (%)

Industry Group	SIC Code	1974	1975	1976	1977	1978	1979	1980	1981	1982
Industrial Chemicals	281-82, 286	3.3	3.6	3.7	3.5	3.5	3.2	3.3	3.5	--
Drugs and Medicines	283	6.3	6.4	6.3	6.4	6.2	6.1	6.2	--	--
Other Chemicals	286-85, 287-89	1.6	1.7	1.7	1.8	1.8	1.8	1.9	--	--
Ferrous Metals and Products	331-32, 3398-99	.5	.6	.6	.6	.6	.6	.6	--	--
Non-Ferrous Metals and Products	333-36	1.0	1.2	1.2	1.0	.8	.7	.7	--	--
Office, Computing & Accounting Mach.	357	12.6	12.0	11.6	11.5	11.1	11.0	12.0	--	--
Other Machinery Except Electrical	351-56, 358-59	--	--	--	2.2	2.1	2.1	2.3	--	--
Radio and TV receiving Equipment	365	1.7	1.4	1.4	1.8	1.8	2.5	4.3	--	--
Communication Equip.	366	7.6	7.6	7.6	7.7	7.7	8.8	9.1	9.6	--
Electronic Components	367	6.2	6.9	7.3	6.8	6.7	7.1	7.9	7.4	--
Other Elec. Equipment	363-64, 369	6.3	6.0	6.3	5.2	5.1	4.9	4.9	--	--
Motor Vehicles and Equipment	371	3.7	3.5	3.2	3.1	3.3	3.8	4.9	4.5	--
Other Transportation Equipment	373-75, 379	1.3	1.3	1.3	1.2	.8	.8	.6	--	--
Air Craft and Missiles	372, 376	14.1	12.7	12.7	13.3	13.3	12.9	13.7	15.3	--
Scientific Instruments	381-82	4.5	4.9	5.4	6.3	7.1	7.3	8.4	--	--
Opitcal and Surgical Instruments	383-87	6.7	6.3	6.4	6.4	6.8	7.2	6.9	--	--

Source and Notes:

NSF - National Science Foundation, Research and Development in Industry, 1981, in press, Table B-20. Data contained in these two tables are revised from the NSF82-317, Research and Development in Industry. Tables B-19 and B-20.

BW - Business Week, "R&D Scoreboard," 1975-1982.

TABLE 6. Company R&D Intensities at 3-Digit SIC Level: NSF Data (%)

Industry Group	SIC Code	1974	1975	1976	1977	1978	1979	1980	1981	1982
Industrial Chemicals	281-82, 286	2.8	3.1	3.1	3.0	2.9	2.6	2.8	3.0	--
Drugs and Medicines	283	--	--	--	--	--	--	6.1	6.3	--
Other Chemicals	286-85, 287-89	--	--	--	--	--	--	1.9	2.1	--
Ferrous Metals and Products	331-32, 3398-99	--	.6	.6	.6	.5	.5	.5	.6	--
Non-Ferrous Metals and Products	333-36	--	1.1	1.1	.9	.8	.6	.6	.7	--
Office, Computing & Accounting Mach.	357	--	9.4	9.1	9.6	9.8	10.1	10.4	10.1	--
Other Machinery Except Electrical	351-56, 358-59	--	--	--	2.1	2.0	2.0	2.2	2.3	--
Radio and TV receiving Equipment	365	--	1.4	1.4	1.6	1.4	1.7	2.7	2.7	--
Communication Equip.	366	3.9	4.2	4.3	4.4	4.5	5.0	5.4	6.0	--
Electronic Components	367	3.9	--	--	--	--	--	5.9	5.7	--
Other Elec. Equipment	363-64, 369	--	--	--	--	--	--	2.5	2.8	--
Motor Vehicles and Equipment	371	3.2	3.0	2.7	2.7	2.9	3.2	4.2	3.9	--
Other Transportation Equipment	373-75, 379	.6	.6	.6	.7	--	--	--	--	--
Air Craft and Missiles	372, 376	3.5	2.8	2.8	2.9	3.2	3.5	3.8	4.2	--
Scientific Instruments	381-82	4.4	4.7	5.3	5.7	5.9	5.8	6.2	7.0	--
Oitcal and Surgical Instruments	383-87	5.5	5.2	5.5	5.4	5.6	5.9	6.0	6.7	--

Source and Notes:
NSF - National Science Foundation, Research and Development in Industry, 1981, in press, Table B-21. Data contained in these two tables are revised from the NSF 82-317, Research and Development in Industry. Tables B-19 and B-20.

BW - Business Week, "R&D Scoreboard," 1975-1982.

TABLE 7. Company R&D Intensities at 3-Digit SIC Level: BW Data (%)

Industry Group	SIC Code	1974	1975	1976	1977	1978	1979	1980	1981	1982
Industrial and Other Chemicals	28 except 283 and 284	2.4	2.6	2.6	2.6	2.5	2.3	2.4	2.5	2.9
Drugs and Medicine	283	4.6	4.7	4.8	4.9	4.7	4.8	4.9	5.3	6.0
Personal and Home Care Products	284	1.7	1.6	1.6	1.1	1.6	1.7	1.8	2.0	2.3
Metals and Mining	33 except 331 and 332	1.0	1.2	1.2	1.0	.6	.5	.9	1.1	1.2
Steel	331 and 332	.5	.6	.7	.6	.6	.6	.6	.6	.7
Containers	341	1.6	1.1	1.2	1.1	0.9	0.8	0.8	0.8	0.7
Machinery: Farm and Construction	351-53	2.6	2.4	3.0	3.2	2.5	2.7	2.7	2.9	3.3
Machinery: Tools and Equipment	354-56, 358-59	--	--	1.9	1.7	1.6	1.6	1.6	1.9	2.6
Information Processing: Office Equip.	357 except 3573	5.8(b)	5.6(b)	5.4(b)	4.0	4.1	4.2	4.3	5.0	5.1
Information Processing: Computers	3573	--	--	--	5.9	6.0	6.1	6.4	6.4	6.8
Electrical	361-62, 364, 369	3.1	3.1	2.8	2.4	2.5	2.8	2.8	2.9	2.8
Appliances	363	1.2	1.2	1.1	1.4	1.2	1.5	1.8	2.0	2.0
Telecommunications	366									
Electronics	367 except 3573	--	--	--	3.0	2.6	2.5	2.9	3.1	3.8
Semiconductors	3674	--	--	--	5.8	5.8	5.7	6.0	7.1	7.8
Automative: Cars and Trucks	371 except 3714	3.0	2.7	2.5	2.6	2.8	3.2	4.0	3.7	4.0
Automative: Parts and Equipment	3714	--	--	--	1.5	1.4	1.5	1.5	2.0	2.3
Aerospace	372 and 376	3.0	3.2	3.5	3.5	3.7	4.2	4.5	4.8	5.1
Building materials	a	1.1	1.2	1.0	1.0	1.1	1.1	1.1	1.2	1.3
Conglomerates	a	1.3	1.5	1.7	1.5	1.7	1.6	1.8	2.0	2.8
Information Processing: peripheral	a	--	--	--	--	--	--	5.9	5.9	7.2

TABLE 7. (con't.)

Leisure Time Industries	a	1.7	1.7	2.4	4.3	4.1	4.2	4.2	4.2	4.8
Oil Services	a	1.3	1.2	1.0	1.1	0.9	1.7	1.6	1.8	2.1
Miscellaneous Marketing	a	1.7	1.8	2.0	1.9	1.8	1.7	2.1	2.0	2.4

Notes: a. Not easily classified.
b. Includes computers.

Source: Business Week, "R & D Scoreboard," 1975-1982.

parts and equipment, conglomerates, oil services and supply, and miscellaneous manufacturing.

- Building materials and metals and mining were in the below-average intensity group.
- Steel and containers were included in the low intensity group.

It should be noted, however, that the above grouping is not comprehensive. It covers only 3- or 4-digit industries whose R&D intensity data were available.

o With the exception of containers and electrical industries, there appears to be a definite upward trend ir the company R&D intensities in all other industries during the 1979-1982 period, especially in 1982. (Table 7)

4.0 SELECTED INDUSTRIES

In this section, detailed data on R&D intensities for the aerospace, automotive, chemicals and drugs, computers and office equipment, and electronics and semiconductors industries are presented and described.

Aerospace (SIC 372 and 376)

Tables 8 and 9 present detailed data on the aerospace industry:

1. The aerospace industry had the highest federal support in R&D. NSF data showed that total R&D intensity ranged from 12.9% to 15.3% during 1974-81 (Table 8, col. 1). Excluding federal funds, the company R&D intensity was only in the 2.8% to 4.2% range (Table 8, col. 2). Total R&D intensities were three or four times that of company R&D intensities.
2. Except for 1974, BW data on company R&D intensities were somewhat higher than the corresponding NSF data.[5] The BW data ranged from 3.0% in 1974 to 5.1% in 1982, exhibiting a definite upward trend. (Table 8, col. 3)
3. In 1982, the company R&D intensity of the 16 firms in the BW data averaged 5.1%. Those firms with sales in the $1 to $2.5 billion range had the highest average intensity at 6.7%. The second highest group averaged 4.9% for the 5 firms with sales over $5 billion. (Table 9)
4. Boeing, McDonell Douglas, Northrop, and United Technologies were the largest firms with relatively high company R&D intensity (Table 8, cols. 3 through 7). (Note: These data exclude federal support. If company-specific total R&D expenditure data were available, the R&D expenditure/sales proportions would be much higher.)

Automotive Industry

Tables 10 through 12 provide detailed data on the automotive industry:

---

[5] For this and subsequent comparisons of NSF and BW data, please see Appendix A for related qualifications.

TABLE 8. R&D Expenditures as Precentage of Sales: Aerospace

SIC 372 and 376

(%)

	Group Average			Selected Firms (BW: Company)			
Year	NSF: Total (1)	NSF: Company (2)	NSF: Company (3)	Boeing (4)	McDonnell Douglas (5)	Northrop (6)	United Technologies (7)
1974	14.1	3.5	3.0	4.8	4.5	2.4	9.0
1975	12.7	2.8	3.2	5.1	4.1	2.2	8.3
1976	12.7	2.8	3.5	4.9	3.0	2.0	6.9
1977	13.3	2.9	3.5	5.5	3.5	2.0	6.6
1978	13.3	3.2	3.7	5.1	4.1	3.0	7.0
1979	12.9	3.5	4.2	6.5	3.7	4.7	6.0
1980	13.7	3.5	4.5	8.1	3.3	5.6	5.4
1981	15.3	4.2	4.8	8.6	2.9	9.7	5.4
1982	--	--	5.1	7.6	3.5	12.7	6.1

Source:
NSF - National Science Foundation, Research and Development in Industry, 1981, in press, Table 20-B and B-21. Data contained in these two tables are revised from the NSF82-317, Research and Development Industry. Tables B-19 and B 20.

BW - Business Week, "R&D Scoreboard," 1975-1982.

TABLE 9. Distribution of Company R&D Industries in the Aerospace Industry, 1982

(SIC 372 and 376)

Sales Range ($ Billion)	No. of Firms	R&D expenditures as percentage of Sales (%)
	(1)	(2)
Under .5	5	3.9
.5 to 1.0	3	3.7
1.0 to 2.5	3	6.7
2.5 to 5.0	0	---
over 5.0	5	4.9
All firms	16	5.1

Source: "R&D Scoreboard, 1982" Business Week, June 20, 1983, pp. 122-153.

1. According to NSF data, the automotive industry's total R&D intensity ranged from 3.1% to 4.9% during 1974-81. Excluding federal support, company R&D intensities were in the range of 2.7% to 4.2%, approximately 0.4 to 0.7 percentage points lower than total R&D intensities. (Table 10, cols. 1 and 2)

2. BW data showed that company funded R&D intensities were in the range of 2.5% to 3.8%, some 0.2 to 0.5 percentage points lower than the corresponding NSF data (Table G, col. 3). The BW data also indicated that the cars and trucks group of the automotive industry tended to have higher company funded R&D intensities than the parts and equipment group. (Table 10, cols. 4 and 5)

3. In 1982, all 5 firms in the BW "cars and trucks" group had sales over $2.5 billion, and their combined company R&D intensity was 4.0%. In contrast, only one firm in the "parts and equipment" group had over $2.5 billion in sales. Its company R&D intensity was 2.2%, lower than the 2.6% of the 4 firms with sales between $1.0 and $2.5 billion. (Table 11)

4. Ford Motors, General Motors, and International Harvester are the three firms with the highest company R&D intensities in the cars and trucks group, ranging from 3.1% to 4.8% during the 1974-82 period. In the parts and equipment group, Cummins Engine had the highest company R&D intensities, ranging from 1.9% to 3.8%. Bendix and Eaton were two other larger firms in the group with average or above-average intensities. (Table 12)

Chemical Industry (SIC 28)

Tables 13 and 15 contain detailed data for the chemical industry:

1. At the 2-digit SIC level, the chemical industry's total R&D intensity stayed relatively stable in the 3.4 to 3.7% range, according to the NSF data (Table 13, col. 1). Similarly, the company R&D intensity ranged from 3% to 3.3% during 1974-1981, according to both the NSF and BW data. The BW data showed that this intensity rose from 3.3% in 1981 to 3.9% in 1982. (Table 13, cols. 2 and 3)

2. The total chemical industry (SIC 28) can be segregated into two major groups: drugs and medicines (SIC 283), and industrial and other chemicals

TABLE 10. R&D Intensities: Automotive Industry

SIC 371

(%)

Year	Total Automotive			Cars and Trucks	Parts and Equipment
	NSF: Total	NSF: Company	BW: Company	BW: Company	BW: Company
	(1)	(2)	(3)	(4)	(5)
1974	3.7	3.2	3.0	3.0	--
1975	3.5	3.0	2.7	2.7	--
1976	3.2	2.7	2.5	2.5	--
1977	3.1	2.7	2.5	2.6	1.5
1978	3.3	2.9	2.6	2.8	1.4
1979	3.8	3.2	3.0	3.2	1.5
1980	4.9	4.2	3.7	4.0	1.5
1981	4.5	3.9	3.5	3.7	2.0
1982	--	--	3.8	4.0	2.3

Source and Notes:
NSF - National Science Foundation, Research and Development in Industry, 1981, in press, Table 13-21 and B-21. Data contained in these two tables are revised from the NSF82-317, Research and Development in Industry. Tables B-19 and B-20.

BW - Business Week, "R&D Scoreboard," 1975-1982.

TABLE 11. Distribution of Company R&D Intensities in the Automotive Industry, 1982

SIC 371

Sales Range ($ Billion)	No. of Firms			R&D Expenditures As Percentage of Sales (%)		
	Total	Cars & Trucks	Parts & Equipment	Total	Cars & Trucks	Parts & Trucks
	(1)	(2)	(3)	(4)	(5)	(6)
Under .5	9	0	9	1.6	--	1.6
.5 to 1.0	2	0	2	2.5	--	2.5
1.0 to 2.5	4	0	4	2.6	--	2.6
2.5 to 5.0	3	2	1	3.2	3.9	2.2
Over 5.0	3	3	0	4.0	4.0	--
All Firms	21	5	16	3.2	4.0	2.3

Source: "R&D Scoreboard, 1982" Business Week , June 20, 1983, pp. 122-153.

TABLE 12. Company R&D Intensities for the Automotive Industry, Subgroup Average and Selected Firms, SIC 371

(%)

Year	Cars and Trucks				Parts and Equipment			
	Group Average	Selected Firms			Group Average	Selected Firms		
		Ford Motors	General Motors	International Harvester		Bendix	Cummins Engine	Eaton
1974	3.0	3.5	3.6	2.4	--	3.1	3.6	1.7
1975	2.7	3.1	3.1	2.5	--	3.2	3.8	1.7
1976	2.5	3.2	2.7	2.6	--	3.4	3.2	1.6
1977	2.6	3.1	2.6	1.9	1.5	1.4	3.3	1.5
1978	2.8	3.4	2.6	1.8	1.4	1.4	1.9	1.7
1979	3.2	4.0	2.9	2.6	1.5	1.6	2.3	2.0
1980	4.0	4.5	3.9	4.0	1.5	2.1	2.6	2.3
1981	3.7	4.5	3.6	3.5	2.0	2.0	3.0	3.0
1982	4.0	4.8	3.6	4.2	2.3	2.2	4.3	3.4

Source: Business Week, "R&D Scoreboard," 1975-1982.

TABLE 13. R&D Intensities: Chemical Industry, SIC 28

(%)

Year	Total Chemical SIC 28			Drugs and Medicine SIC 283			Industrial and Other Chemicals SIC 28 except 283		
	NSF: Total	NSF: Company	BW: Company	NSF: Total	NSF: Company	BW: Company	NSF: Total	NSF: Company	BW: Company
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1974	3.5	3.0	3.1	6.3	--	4.6	3.3	2.8	2.4
1975	3.7	3.1	3.3	6.4	--	4.7	3.6	3.1	2.6
1976	3.7	3.3	3.3	6.3	--	4.8	3.7	3.1	2.6
1977	3.7	3.3	3.2	6.4	--	4.9	3.5	3.0	2.5
1978	3.6	3.2	3.2	6.3	--	4.7	3.5	2.8	2.5
1979	3.4	3.1	3.1	6.1	--	4.8	3.2	2.6	2.3
1980	3.5	3.2	3.2	6.2	6.1	4.9	3.3	2.7	2.4
1981	3.5	--	3.3	--	6.3	5.3	--	2.1	2.5
1982	--	--	3.9	--	--	6.0	--	--	2.9

Source and Notes:

NSF - National Science Foundation, Research and Development in Industry, 1981, in press, Table B-20 and B-21. Data contained in these two tables are revised from the NSF 82-317, Research and Development in Industry. Tables B-19 and B20.

BW - Business Week, "R&D Scoreboard," 1975-1982.

(SIC 28 except SIC 283). Generally, the drugs and medicines group had much higher R&D intensities than the industrial and other chemicals group.

- o According to the NSF data, total R&D intensities in the drugs and medicine group ranged from 6.1% to 6.4%, compared to that of 3.2% to 3.7% for the industrial and other chemical group. (Table 13, cols. 4 and 7)

- o According to the BW data, company funded R&D intensities in the drugs and medicines group fluctuated between 4.6% and 4.9%, during 1974-1980. This intensity rose to 5.3% in 1981 and 6% in 1982 (Table 13, col. 6). The corresponding intensity in the industrial and other chemical group ranged from 2.3% to 2.5% during 1974-81 and rose to 2.9% in 1982. (Table 13, col. 9)

- o Comparison between the two separate estimates on company R&D intensities for the industrial and other chemicals group showed that the NSF data were generally higher than the BW data by 0.3 to 0.5 percentage points. (Table 13, cols. 8 and 9)

3. The average R&D intensities for the overall chemical industry and the two subgroups tend to smooth out the variations among firms. Using the company-specific BW data on company R&D intensities, several findings are useful:

   - o At the SIC 28 level, the 11 firms with 1982 sales ranging from $2.5 to $5 billion had the highest company R&D intensity, averaging 5.4%. The 17 firms with sales in the range of $1 to $2.5 billion had the second highest at 4.2%. For comparison, the industry average was 3.9% for 73 firms. (Table 14, cols. 1 and 4)

   - o For the drugs and medicine industry group (SIC 283), one firm with 1982 sales in the $0.5 to $1.0 billion range had the highest intensity at 10.3%. This is followed by the 7 firms in the $1.0 to $2.5 billion sale range, with 6.9%. The group average was 6%. (Table 14, cols. 2 and 5)

   - o Among the larger pharmaceutical firms with the highest company R&D intensities are Eli Lilly (1982 sales of $2.96 billion), Merck ($3.06 billion), and Upjohn ($1.83 billion). During the 1974-82 period, the

TABLE 14. Distribution of Company R&D Intensities in the Chemical Industry, 1982 (SIC 28)

Sales Range ($ Billion)	No. of Firms			R&D Expenditures as Percentage of Sales (%)		
	SIC 28	SIC 283	SIC 28 except 283	SIC 28	SIC 283	SIC 28 except 283
	(1)	(2)	(3)	(4)	(5)	(6)
Under 0.5	30	11	19	2.9	5.4	1.7
0.5 to 1.0	8	1	7	3.9	10.3	2.9
1.0 to 2.5	17	7	10	4.2	6.9	2.5
2.5 to 5.0	11	9	2	5.4	5.7	4.4
Over 5.0	7	1	6	3.2	6.3	2.9
All Firms	73	29	44	3.9	6.0	2.9

Source: "R&D Scoreboard, 1982." Business Week, June 20, 1983, pp. 122-153.

company R&D intensities of these firms fluctuated between 7.7% and 10.7% and were between 3 and 5 percentage points higher than the average intensities of SIC 283 as a group. (Table 15, cols. 1 through 4)

- o For the industrial and other chemical group (SIC 28 except 283), the two firms with 1982 sales between $2.5 and $5.0 billion had the highest R&D intensity at 4.4%. The group average of 2.9% for 44 firms. (Table 14, cols. 3 and 6)
- o American Cyanamid, Dow Chemical, and Rohm & Hass are three larger chemical firms (1982 sales of $3.45, $10.62, and $1.83 billion, respectively) with above-average R&D intensities. As shown in Table 15, their respective intensities ranged from 2.9% to 5.3% in the data period and were higher than the group average by 0.5 to 2.0 percentage points.

4. Since many firms have many different product lines involving different technologies, it would be useful to examine the product-specific R&D intensities. Unfortunately, such product-specific data are generally lacking. Among the chemical firms, Allied Chemical's data are instructive. The company's major product lines are chemicals, fibers and plastics, oil and gas, electrical and electronics, health and scientific products. Table 16 shows that the electrical and electronics product subgroup and the fibers and plastics group had higher intensities than the chemicals and unallocated groups. It can also be seen that Allied as a company had lower R&D intensities than the average for the industrial and other chemicals group.

Computers and Office Equipment (SIC 357)

Tables 16 through 19 present detailed data for the computers and office equipment industry:

1. According to the NSF data, total R&D intensities in the total computers and office equipment industry ranged from 11.0 to 12.6% of net sales between 1974 and 1981. There was an overall drop in the figures until 1980, when the intensity jumped a full percentage point. Excluding federal support,

TABLE 15. Company R&D Intensities for the Chemical Industry (SIC 28), Subgroup Average and Selected Firms

(%)

	Drugs and Medicines (SIC 283)				Industrial and Other Chemicals (SIC 28 except 283)			
		Selected Firms				Selected Firms		
Year	Group Average (1)	Eli Lilly (2)	Merck (3)	Upjohn (4)	Group Average (5)	American Cyanamid (6)	Dow Chemical (7)	Rohm & Haas (8)
1974	4.6	8.4	7.8	8.5	2.4	3.3	3.0	4.1
1975	4.7	8.5	8.4	8.8	2.6	3.5	3.4	4.6
1976	4.8	8.4	8.2	9.0	2.6	4.0	3.3	4.5
1977	4.9	8.2	8.4	9.0	2.5	4.0	3.3	4.0
1978	4.7	8.0	8.1	8.7	2.5	3.9	3.4	3.9
1979	4.8	7.7	7.9	8.6	2.3	3.9	2.9	3.4
1980	4.9	7.8	8.6	8.4	2.4	4.1	3.0	3.9
1981	5.3	8.5	9.4	9.0	2.5	4.5	3.4	4.1
1982	6.0	9.0	10.5	10.7	2.9	5.3	4.3	5.0

Source: Business Week, "R&D Scoreboard," 1975-1983.

TABLE 16. R&D Intensities of Allied Chemical Company, by Product Subgroup

(%)

Year	Total Company (1)	Chemicals (2)	Fibers & Plastics (3)	Electrical & Electronics (4)	Others[a] (5)
1978	1.9	0.7	2.3	--	2.6
1979	1.6	0.6	2.3	3.1	1.7
1980	1.9	1.4	2.2	3.9	1.5
1981	2.4	2.1	2.9	4.0	1.8
1982	3.0	2.9	3.8	4.5	2.2

(a) Includes oil and gas, health and scientific products, other operations and otherwise unallocated.

Source: Allied Chemical Company, 1982 Annual Report.

company R&D intensities based on NSF data ranged between 9.1 and 10.4% of net sales. The small differences between total and company R&D intensities indicate that most of total R&D expenditures in this industry are company funded and not federally supported. Company R&D intensities based on BW data ranged between 5.4 and 6.5% of sales. However, figures from both sources exhibit the same pattern over time - a drop in intensity over the period 1974-1976, with a gradual increase thereafter. (Table 17, columns 1-3)

2. BW data showed higher absolute levels of company R&D intensities for the computer as opposed to the office equipment category. Further, R&D in computers exhibited a steady rise in intensity, while the trend in office equipment included a decline from 1974-1978, and a rise in 1978-1982. However, as of 1982 the absolute intensity had not reached the levels of 1974. (Table 17, columns 4 and 5)

3. In 1982 the majority of firms in the computing and office equipment industry had sales of under one-half billion dollars. Generally, intensities in the computer industry fell as a function of firm size, while intensities in the office equipment industry were a positive function of firm size. (Table 18)

4. Burroughs, Control Data, IBM, Hewlett-Packard, Sperry, and Honeywell are the larger companies in the computer industry with high R&D intensities. Of these, the last four exhibited the highest company R&D intensities; but both the level and the pattern of these intensities over time differed among the firms. Hewlett-Packard consistently showed the highest intensity, which grew from 1974-1976, experienced a lull between 1976-1979, and then rose rapidly. R&D intensities at both Sperry and Honeywell fell between 1974-1976, and picked up again after that. IBM showed a similar pattern, except that the upturn in its company R&D intensity did not occur until 1982.

   On the other hand, in the office equipment industry, R&D intensity at Pitney-Bowes has remained relatively constant, while Wang rose steadily at a fast pace over the data period. (Table 19)

TABLE 17. R&D Intensities for the Computer and Office Equipment Industry

SIC 357

(%)

	Total C&OE (SIC 357)			Computers (SIC 3573)	Office Eqpt. (SIC 3574 & 3579
	NSF: Total	NSF:[a] Company	BW:[a] Company	BW: Company	BW: Company
Year	(1)	(2)	(3)	(4)	(5)
1974	12.6	--	5.8[b]	--	5.8
1975	12.0	9.4	5.6[b]	--	5.6
1976	11.6	9.1	5.4[b]	--	5.4
1977	11.5	9.6	5.5	5.9	4.0
1978	11.1	9.8	5.6	6.0	4.1
1979	11.0	10.1	5.6	6.1	4.2
1980	12.0	10.4	6.1	6.4	4.3
1981	--	10.1	6.1	6.4	5.0
1982	--	--	6.5	6.8	5.1

Source and Notes:

NSF - National Science Foundation, Research and Development in Industry, 1981, in press, Table B-21 and B-22. Data contained in these two tables are revised from the NSF82-317, Research and Development in Industry. Tables B-19 and B-20.

BW - Business Week, "R&D Scoreboard," 1975-1982.

(a) Note that definitions for columns differ slightly: NSF data includes all of SIC 357; BW does not.
(b) Office equipment figures only available.

TABLE 18. Distribution of Company R&D Intensities in the Computer and Office Equipment Industries, 1982

SIC 357

Sales Range ($ Billion)	No. of Firms			R&D Expenditures as Percentage of Sales (%)		
	Total	Computers	Office Equip.	Total	Computers	Office Equip.
	(1)	(2)	(3)	(4)	(5)	(6)
Under 0.5	23	15	8	6.6	9.2	2.3
0.5 to 1.0	5	2	3	4.9	8.8	1.9
1.0 to 2.5	2	0	2	(4.6)	--	4.6
2.5 to 5.0	5	5	0	(7.3)	7.3	--
Over 5.0	4	3	1	6.3	6.3	6.7
All Firms	39	25	14	6.5	6.8	5.1

Source: "R&D Scoreboard, 1982." Business Week, June 20, 1983, pp. 122-153.

TABLE 19. Company R&D Intensities for the Computer & Office Equipment Industry: Subgroup Average and Selected Firms, SIC 357

(%)

	Computers (SIC 3573)					Office Equipment (SIC 3574 & 3579)		
		Selected Firms					Selected Firms	
Year	Group Average (1)	IBM (2)	H-P (3)	Honeywell (4)	Sperry (5)	Group Average (6)	Pitney Bowes (7)	Wang Labs (8)
1974	--	7.0	8.0	6.5	6.0	5.8	2.1	3.3
1975	--	6.6	9.1	5.9	5.4	5.6	2.3	3.7
1976	--	6.2	9.7	5.0	5.0	5.4	2.1	4.4
1977	5.9	6.3	9.2	5.2	5.1	4.0	2.0	4.9
1978	6.0	6.0	8.9	5.3	5.3	4.1	2.2	4.9
1979	6.1	5.9	8.6	5.6	5.7	4.2	2.3	5.1
1980	6.4	5.8	8.8	6.0	6.2	4.3	2.4	6.7
1981	6.4	5.5	9.7	6.9	6.2	5.0	2.2	7.8
1982	6.8	6.0	10.0	7.2	7.1	5.1	2.3	7.5

Source: Business Week, "R&D Scoreboard," 1975-1982.

Electronics and Semiconductors (SIC 367)

Tables 20 through 22 provide detailed data on the electronics and semiconductors industry:

1. The NSF data showed total R&D intensities in the electronic components industry ranging between 6.2 and 7.9% of net sales between 1974 and 1981. Excluding federal R&D support, company R&D intensities ranged between 3.9 and 5.9% (for the few years figures are published). Company R&D intensities based on the BW data varied between 3.4% and 4.5% of sales. Both NSF and BW data displayed a basic upward trend over time. (Table 20, columns 1-3)

2. BW data allow an analysis of figures for the electronics and semiconductorindustries separately after 1977. The electronics group showed company R&D to range between 2.5 and 3.8% of sales, with a decline in the years 1977-1979 and a fairly rapid increase since that time. Company-funded R&D in the semiconductors industry varied between 5.8 and 7.8% of sales and declined slightly between 1977-1979 and rose rapidly thereafter. (Table 20, columns 4 and 5)

3. In 1982 the majority of firms in the electronics and semiconductor industries had sales of under one-half billion dollars. R&D expenditures in electronics ranged between 2.4 and 6.8% of sales, with no clear relation to firm size. In the semiconductor industry, R&D as a percent of sales for the smallest category of firms was 11.0% of sales (the only category represented by more than one firm). The overall industry average was 7.8%, indicating that R&D intensity in semiconductors fell as firm size increased. (Table 21)

4. Gould, Motorola, and Raytheon were the larger firms in the electronics industry with relatively high R&D intensity. R&D intensities at Gould exhibited a fairly steady upward trend, increasing from 2.6% in 1974 to 6.8% in 1982. Motorola showed the highest absolute intensities over the period (except in 1982), declining in the period 1974-1977 from 7.3% to 5.9%, and rising thereafter to a high of 7.3% again. Raytheon had fairly constant R&D intensities over the period 1974-1979, with fairly rapid increases since that time. (Table 22, columns 1-4)

TABLE 20. R&D Intensities: Electronic and Semiconductors

SIC 367

(%)

Year	Total Electronics Components SIC 367		Electronics & Semiconductors	Electronics	Semiconductors SIC 3674
	NSF: Total	NSF:(1) (Company Funds)	BW:(1) (Company Funds)	BW: (Company Funds)	BW: (Company Funds)
	(1)	(2)	(3)	(4)	(5)
1974	6.2	3.9	--	--	--
1975	6.9	--	--	--	--
1976	7.3	--	--	--	--
1977	6.8	--	4.0	3.0	5.8
1978	6.7	--	3.4	2.6	5.8
1979	7.1	--	3.4	2.5	5.7
1980	7.9	5.9	3.7	2.9	6.0
1981	7.4	5.7	4.2	3.1	7.1
1982	--	--	4.5	3.8	7.8

(1) Note: definitions of these two columns differ slightly. NSF figures include all of SIC 357; BW figures do not.

Source:
NSF - Table B-21, Table B-22, Research and Development in Industry, 1980, NSF 82-317. Detailed Statistical Tables.

BW - Business Week, "R&D Scoreboard," 1975-1982.

TABLE 21. Distribution of Company R&D Intensities in the Electronics and Semiconductor Industries, 1982

SIC 367

Sales Range ($ Billion)	No. of Firms			R&D Expenditures as Percentage of Sales (%)		
	Total	Electronics	Semi-Conductors	Total	Electronics	Semi-Conductors
	(1)	(2)	(3)	(4)	(5)	(6)
Under 0.5	65	58	7	5.0	4.4	11.0
0.5 to 1.0	6	5	1	5.5	3.3	14.5
1.0 to 2.5	2	1	1	8.0	6.8	9.9
2.5 to 5.0	4	3	1	4.6	4.2	5.5
Over 5.0	2	2	0	2.4(a)	2.4	--
All Firms	77	69	10	4.4	3.8	7.8

(a) Electronics industry figures only. No figures for semiconductors averaged in.

Source: "R&D Scoreboard, 1982." Business Week, June 20, 1983, pp. 122-153.

TABLE 22. Company R&D Intensities for the Electronics and Semiconductors Industries: Subgroup Average and Selected Firms, SIC 367.

(%)

	Electronics				Semiconductors		
		Selected Firms				Selected Firms	
Year	Group Average (1)	Gould (2)	Motorola (3)	Raytheon (4)	Group Average (5)	National Semic. (6)	Texas Instr. (7)
1974	--	2.6	7.3	2.2	--	8.8	4.1
1975	--	3.0	7.5	1.9	--	8.8	3.7
1976	--	3.5	6.8	1.9	--	7.6	4.4
1977	3.0	3.7	5.9	1.8	5.8	8.2	4.7
1978	2.6	3.9	6.0	2.0	5.8	8.7	4.4
1979	2.5	3.4	6.2	2.0	5.7	9.4	4.2
1980	2.8	3.9	6.5	2.6	6.0	8.2	4.6
1981	3.1	5.2	6.9	2.9	7.1	8.7	5.2
1982	3.8	6.8	7.3	3.6	7.8	9.9	5.5

Source: Business Week, "R&D Scoreboard," 1975-1982.

The largest semiconductor manufacturing firms are National Semiconductors and Texas Instruments. Company R&D intensities at National Semiconductors ranged from 7.6 to 9.9% of sales, while figures for Texas Instruments varied between 3.7 and 5.5%. Neither firm showed a steady trend in company R&D intensities, although both have exhibited fairly substantial increases over the last three years. The semiconductor firms as a group also had significant increases in its company R&D intensity. (Table 22, columns 5-7)

5.0 PROBABLE CAUSES FOR VARIATIONS IN R&D INTENSITIES

Sections 3.0 and 4.0 presented data on R&D intensities in U.S. industries and described how these intensities have varied among industries and across time. This section provides some qualitative discussions on the probable causes of such variations.

The major factors affecting the variations of R&D intensities include:

- o maturity of the industry
- o technological character of the industry
- o extent of competition
- o diversification of firms
- o tax incentives
- o regulation
- o federal funding
- o business conditions.

Each of these is briefly discussed below.

Maturity of the Industry

Differences in the relative maturities of industries can explain some of the variation in R&D intensities. In general, industries which are more mature exhibit lower R&D intensities. In these industries product lines are stable and there are relatively few opportunities for innovations leading to new products or new processes, as there might be in industries which are in the early stages of growth. Therefore, firms are less willing to invest heavily in R&D. R&D in mature industries is often carried out in response to government regulations, price pressures, or outside incentives such as consumer demand for fuel economy (Business Week 1976a). R&D in the mature industries tends to be reflected in increases in labor productivity in existing production processes (Mansfield 1981a). Examples of mature industries would include food and beverages, textiles and apparel, lumber and wood products, paper, petroleum, steel and other primary metals, tobacco, leather and miscellaneous products.

In contrast, industries which are in the early stages of growth tend to have many opportunities for new products and new processes which have

relatively high payoff. Hence, R&D expenditures in these industries tend to result in new products and expand the industries' product mixes. To keep up with the firms in the industry and maintain or gain market shares, heavy investment in R&D is a necessity. Electronics, semiconductors, computers, and office equipment are relatively young industries with high R&D intensities.

Technological Character of an Industry

Another source of variation in R&D intensities among industries is the technological character of the particular industries. Industries in 'high-tech' fields exhibit much greater levels of R&D expenditures than those in 'low-tech' areas because high-tech products tend to have a higher rate of technological obsolescence due to innovations which create new generations of products (Wolff 1982). To keep up with such development requires high levels of R&D expenditures.

Frequently, high-tech industries are also industries in the relatively early stages of growth. Hence, examples of high-tech industries with higher R&D intensities include electronics and semiconductors, and computers, as well as aerospace, drugs, and instruments. R&D in these industries tends to have high paybacks. Without investment in R&D, firms are likely to lose competitive position and market share.

Extent of Competition

The level of competition within an industry has a direct effect on R&D efforts and intensity of the industry. Staying in business in a competitive environment requires R&D aimed at improving the product, reducing costs, and introducing new products. Computers, electronics, and office equipment are recent examples of highly competitive industries with high R&D intensities.

Further, the increasing 'world market' character of industrial products can also impact R&D intensity in industries (McGraw-Hill Economics Department 1983, Gregory 1983). Foreign competition in recent years has precipitated significant increases in R&D in the U.S. automobile and aircraft industries, and this is reflected in the fluctuations over time of R&D intensity for these industries (Business Week 1979). Computers, electronics, and chemicals are

other examples of industries in which foreign competition also plays a role in raising the R&D intensities.

Diversification of the Firm

As firms in an industry expand their product lines and diversify their product mixes, R&D intensities will be affected, depending upon the manner in which such a move is achieved. If diversification is in the direction of high-technology and otherwise high R&D intensity products, then the firms' measured R&D intensity would be raised. If diversification is achieved through acquiring firms with low R&D intensities and "low technological content," then the firms' overall R&D intensity would be lowered (Link 1982, Business Week 1976a).

Tax Incentives

Changes in the structure of corporate tax requirements can cause the R&D intensities for an industry to change over time. The Economic Recovery Tax Act of 1981 is expected to have a positive impact on the volume and intensity of R&D expenditures by firms because it contained incentive tax credits to encourage business spending for R&D (National Science Foundation 1983a).

Variation of R&D intensity among industries can also be the result of differential incentives built into the tax structure. If some industries enjoy preferential incentives, decisions regarding R&D expenditures by firms in these industries would be favorably affected, leading to higher R&D intensities.

Regulation

Safety, health, pollution control, and energy efficiency regulations can affect the intensity of R&D among industries and the composition of the R&D undertaken, because different industries are impacted differently by such regulations. Firms and industries which are more directly impacted by the regulations would need to spend more on R&D in order to meet such regulatory requirements. For example, R&D in the auto industry had been affected significantly by the regulation on fuel economy, safety and emissions control (Business Week 1976a,b). Increasing FDA regulatory requirements have had a significant impact on the nature and amount of R&D undertaken in the

pharmaceutical industry. Much more extensive testing is required before any product can go to market, resulting in a shift in composition of the research toward testing and away from the development and introduction of more new products (Business Week 1979). Waste disposal regulations affect the chemical and nuclear power industries more than other industries.

Federal Funding

Decisions regarding federal R&D budgets affect intensities among industries, especially total R&D intensities. Traditionally, federal funds have largely been directed toward projects and industries related to national defense, space research and technology, health, and more recently, energy (Battelle Columbus Laboratories 1982). In 1981, the proportion of federal funding in total R&D expenditures was over 30% for all industries combined, 72.6% for aircraft and missiles, 42.5% for non-manufacturing industries, and 37.5% for electrical equipment (Table 23). Federal funding of industrial R&D usually includes areas which private industry could not or would not undertake. This would include areas which have a product which is not amenable to exclusive licensing to the firm funding the R&D (defense), areas with prohibitively high R&D costs (nuclear energy), or areas set as national priorities or goals (space program, energy).

Other things being equal, industries receiving more government funding for R&D will have higher total R&D intensities. In the data included in Tables 1 through 22 in Sections 3.0 and 4.0, the impacts of differential federal funding among industries would be reflected in the differences between the NSF data on total R&D intensities and NSF data on company R&D intensities. Note, however, that no attempt was made in this report to deal with the question of whether federal funding of R&D in an industry tends to discourage company funding of R&D in the same industry.

Business Conditions

Fluctuations in general business conditions over time can affect R&D intensities, measured by R&D expenditures as percentage of sales. During

TABLE 23. Sources of Total R&D Funds by Industry, 1981

NSF Data

Industry	SIC Code	Total R&D Funds ($ million)	Federal Funds ($ million)	Funds as Percentage of Total R&D Funds (%)
Total	--	52,007	16,465	31.7
Chemicals	28	5,326	383	7.2
Petroleum Refining	29	1,917	139	7.3
Machinery	35	6,762	689	10.2
Electrical Equipment	36	10,570	3,962	37.5
Motor Vehicles	371	4,929	634	12.9
Aircraft & Missiles	372, 376	11,702	8,501	72.6
Instruments	38	3,677	638	17.4
Non-Manufacturing	07-17, 41-67, 737, 739, 809 and 891	2,060	875	42.5
All Other Industry	--	5,064	644	12.7

Sources: National Science Foundation, Science Resources Highlights, NSF 83-313, August 8, 1983, p.3.

periods of recovery and prosperity, increases in R&D expenditures may keep pace with sales, resulting in the relative constancy of the R&D intensity. However, in times of recession, sales fall; R&D expenditures level may be kept constant or be reduced at a slower rate than the rate of decrease in sales, resulting in an increase in the R&D expenditures/sales ratio (Business Week 1981, Chemical Weekly 1983). This phenomenon seemed to be particularly evident in the 1981-82 recession. Following the recent public discourse on the productivity declines and loss of technological edge of U.S. industries, there has been a growing sense within industry that R&D is directly linked to productivity, international competitiveness, and profits (Mansfield 1981b, Battelle Columbus Laboratories 1982).

6.0 LIMITATIONS AND FURTHER RESEARCH

Given the time and resource constraints, this study has been undertaken with a very narrow focus, and several potentially useful areas of investigation were not pursued. Therefore, it is useful to briefly note the major limitations of the study reported above and the opportunities for further research.

Consistent with the objective of presenting data on, and describing industry practices in, R&D intensities, we have limited our attention to R&D intensity as measured by expenditures as a percentage of sales. Several alternative measures were not explored at all. These concepts include R&D expenditures as a percentage of capital investment, R&D expenditures as a percentage of profits, R&D expenditures per employee, and R&D expenditures per scientist or engineer. Although these measures are not as widely reported as the R&D expenditures/sales ratio, it would be useful to examine the conceptual relevance and the empirical results.

Another aspect of the narrow focus of this study is that only the R&D intensities are examined; the focus was not on the level of R&D spending. In terms of absolute research effort, a small proportion of a company with large annual sales would be much larger than a large proportion of a company with small annual sales. For example, a firm with a 0.5% intensity and $10 billion annual sales would be spending $500 million on R&D, while a firm with 10% intensity and $100 million sales spends only $10 million on R&D. In the results presented in this report, we have partially dealt with this problem by limiting our attention only to firms with annual sales of $1 billion or more, when looking at data for individual industries. It would still be useful to examine more closely the absolute level of R&D efforts by considering the R&D expenditures per se.

One other limitation in this report that was constrained by time allowed to undertake the study was the lack of graphics. Given the nature of the data being presented and discussed, judicious use of graphics can be most effective in demonstrating the points and depicting potential correlations.

Finally, given the data collected, certain relationships between relative R&D intensities and relative performance at both the industry level and at the firm level can be observed statistically. More detailed review of the literature might also identify additional economic hypotheses that the data can be used to test econometrically. This is particularly the case if the analysis has been expanded to include study of the absolute level of R&D efforts.

REFERENCES

Battelle Columbus Laboratories. 1982. Probable Levels of R&D Expenditures in 1983, Forecast and Analysis. December 1982. Columbus, Ohio.

Business Week. 1976a. "How GM Manages its Billion-Dollar R&D Program." June 28, 1976, pp. 54-58.

Business Week. 1976b. "Survey of Corporate Research and Development Spending, 1975: Where Private Industry Puts Its Research Money." June 28, 1976, pp. 62-84.

Business Week. 1977. "Survey of Corporate Research and Development Spending, 1976: What 600 Companies Spend for Research." June 27, 1977, pp. 62-84.

Business Week. 1978. "Business Week's R&D Scoreboard, 1977. R&D Spending Patterns for 600 Companies." July 3, 1978, pp. 58-77.

Business Week. 1979. "Business Week's R&D Scoreboard, 1978. R&D Spending at 683 Companies, Another Record Year." July 2, 1979, pp. 62-71.

Business Week. 1981. "R&D Scoreboard, 1980. Spending for Research Still Outpaces Inflation." July 6, 1981, pp. 60-75.

Business Week. 1982. "R&D Scoreboard, 1981. A Research Spending Surge Defies Recession." July 5, 1982, pp. 54-74.

Business Week. 1983. "R&D Scoreboard, 1982. The U.S. Still Leads the World in R&D Spending." July 20, 1983, pp. 122-154.

Chemical Weekly. 1983. "Between the Plans for R&D and Reality." June 1, 1983, pp. 22-24.

Gregory, Gene. 1983. "Meeting the Foreign Technical Challenge: Mega-Research Investment for Japanese Microelectronics." Research Management, 26(3):14-19.

Link, Albert N. 1982. "An Analysis of the Composition of R&D Spending." Southern Economic Journal, 49(2):342-349.

Mansfield, Edwin. 1981a. "Composition of R and D Expenditures: Relationship to Size of Firm, Concentration, and Innovative Output." Review of Economics and Statistics, November 1981, pp. 610-615.

Mansfield, Edwin. 1981b. "On Keeping America Competitive: Innovation, Investment, and Productivity." The Wharton Magazine, Summer 1981, pp. 36-41.

McGraw-Hill Economics Department. 1983. 28th Annual McGraw-Hill Survey of Business' Plans for Research and Development Expenditures, 1983-86. May 1983.

National Science Foundation. 1982. Research and Development in Industry, 1980. NSF-22-317. Washington, D.C.

National Science Foundation. 1983a. Science Resources Studies Highlights. NSF-83-313, August 8, 1983. Washington, D.C.

National Science Foundation. 1983b. Research and Development in Industry, 1981. In press. Washington, D.C.

Wolff, M.F. 1982. "News and Views of the Current Research Management Scene." Research Management, November 1982, pp. 2-3.

APPENDIX A

DATA SOURCES

This appendix presents a more detailed description of data sources used in this study, including some of the problems encountered. Supplemental data sources are also briefly noted.

MAJOR DATA SOURCES

Two major data sources are used in this report. The National Science Foundation (NSF) data are published in Research and Development in Industry, 1980, supplemented by Science Resources Studies Highlights, August 8, 1983. The Business Week (BW) information has been published annually since 1975 as "Industrial R&D Scoreboard." More complete references are shown in the list of references. Although these two sources have different coverage, definitions, and data collection methods, using both sources can provide a more complete picture of the R&D status of major industries in the U.S.

Coverage and Survey Method

The NSF information is collected as a survey and is conducted annually by the Department of Commerce, Bureau of the Census. Two survey instruments are used: RD-1, a long form, and RD-2, a shorter form, are systematically distributed to 11,500 firms. Firms selected represent all manufacturing industries and certain nonmanufacturing industries which are known to conduct R&D. Firms sampled must have at least 1000 employees, and sampling rates depend on the industry and employment size. The information by firm is kept strictly confidential so that fairly detailed questions can be asked; only industry-wide totals are published. This allows the NSF industry-wide data to include information which is not available in the Business Week publication.

The information published in Business Week is collected by assembling the Form 10K financial reports which are required annually by the Securities and Exchange Commission. The sample size has increased steadily since 1975 to include data on 776 firms in 1982, representing over 90% of the national

industrial R&D expenditures. Only firms which have sales of over $25 million (or $35 million in certain years) and for which R&D expenditures represent over 1 percent of sales or $1 million dollars in volume are included in the survey. Further, only firms which file with the SEC in time for BW's June/July publication date can be included.

Comparability

Several major differences exist between data published by BW and NSF.

- o NSF publishes only industry-wide information classified by two- and three-digit Standard Industrial Classification (SIC) categories. BW groups individual firm responses by 'industry titles' which do not necessarily relate directly to SIC categories. (See Appendix B for a description of SICs.)
- o The definition of R&D differs somewhat between the two sources. NSF considers a greater degree of engineering follow-on as part of total R&D expenses than does BW. This does not appear to be a large difference in fact.
- o The R&D expenses published by BW include only company-funded R&D by firm. NSF reports both company-funded and federally funded R&D expenses by industry.
- o The definition of 'net sales' by NSF differs from the definition of 'sales' used in BW. By far the largest part of the difference derives from the sales by foreign subsidiaries which are included by BW, but systematically excluded by NSF. This difference causes BW's sales figures to be larger than those used by NSF, and explains the systematic difference in the R&D intensity figures (R&D expenditures/sales) computed using the two sources; BW intensities are consistently lower.
- o Data published by NSF report total R&D expenditures and, in addition, report the breakdown between 'basic' research and 'applied' research for each industry. BW does not obtain this information.

For practical reasons, BW did not group its "R&D Scoreboard" firms according to strictly SIC codes. Very often, data provided by individual firms cannot be clearly placed into any one SIC category. Rather, firms manufacture

a wide variety of products (sometimes closely related, sometimes unrelated conglomerates) which often cross the boundaries between SIC classifications, even at the two-digit level.

An indication of the problem is provided when examining the NSF figures for the Rubber industry (SIC 30). The Battelle report indicates that roughly 35% of the R&D funding for the rubber industry is derived from federal sources. Clearly, the government was not funding 35% of rubber-product R&D, but instead, several major rubber-producing firms had divisions which also conducted research related to the aerospace industry. These crossovers are common, and represent a serious problem when conducting this type of analysis.

NSF labels the industry data it publishes using two- and three-digit SIC codes. In the course of this study, we made an effort to match the BW 'industry' categories with those detailed by NSF. Complicated by the differences in definitions and coverage noted above, it proved impossible to derive a satisfactory match up. Instead, since major trends seemed very comparable between the sources, data from the two sources were kept separate. BW information was used when individual firm-level data was needed, and NSF was used when industry-level analysis or analysis of funding by source was needed.

SUPPLEMENTARY SOURCES

Several other useful sources of information on industrial R&D expenditures were identified and used to a limited extent in this study. McGraw-Hill Economics publishes an annual Survey of Business' Plans for Research and Development Expenditures, which includes information on roughly 300 firms reported in major industry groups correlating closely with the categories reported by NSF. The twenty-eighth of these surveys was published in May 1983 and includes information not only on current and past R&D expenditures and a variety of intensity measures, but also asks firms to forecast R&D expenditures and sales for new products and processes four years ahead.

Battelle Columbus Laboratories annually publishes a report on expenditures for R&D. The latest volume, published in December 1982 was titled Probable

Levels of R&D Expenditures in 1983 - Forecast and Analysis. Using data from NSF, the McGraw-Hill survey, and other sources, this report analyzes R&D expenditures by major industrial sectors, by major funding sources, and forecasts the sources and volume of R&D funds by broad industrial classes (comparable with categories published by NSF). Federal funding is detailed by major agencies (DOD, EPA, etc.), and expenditures by colleges and universities and other nonprofit institutions are also examined.

APPENDIX B

STANDARD INDUSTRIAL CLASSIFICATIONS (SIC)

Most of the information published on R&D expenditures is reported by major industrial categories. A consistent method of organizing and classifying industry data was established by the government and is called the "Standard Industrial Classification" (SIC). This system uses a tree or outline format for breaking down industries into finer and finer components, with each succeeding level noted by an additional digit. This is the system to which NSF data refers in its "SIC code" column. This system and the industry titles were used to associate the NSF data with similar categories obtained from the BW source.

The most commonly used level of the breakdown is the two-digit SICs. Major manufacturing industries are included as SICs 19 through 39, and a list of these "major groups" follows.

19	Ordnance and accessories
20	Food and kindred products
21	Tobacco manufactures
22	Textile mill products
23	Apparel and other finished products made from fabrics and similar materials
24	Lumber and wood products, except furniture
25	Furniture and fixtures
26	Paper and allied products
27	Printing, publishing, and allied industries
28	Chemicals and allied products
29	Petroleum refining and related industries
30	Rubber and miscellaneous plastic products
31	Leather and leather products
32	Stone, clay, glass, and concrete products
33	Primary metal industries
34	Fabricated metal products, except ordnance; machinery; and transportation equipment

35 Machinery, except electrical
36 Electrical machinery, equipment, and supplies
37 Transportation equipment
38 Professional, scientific, and controlling instruments; photographic and optical goods; watches and clocks
39 Miscellaneous manufacturing industries

Each two-digit SIC industry is further disaggregated into several three-digit SIC industries. Each three-digit industry consists of a set of four-digit SIC industries which are further disaggregated into five-digit SIC components. This system continues to finer and finer levels, with the seven-digit level being the most disagggregated level.

For example, the chemical industry, SIC 28, is disggregated into the following three-digit industries:

281 Industrial inorganic chemicals
282 Plastics materials, synthetic rubber, and manmade fibers
283 Drugs
284 Soap, cleaners, and toilet goods
285 Paints and allied products
286 Industrial organic chemicals
287 Agricultural chemicals
289 Miscellaneous chemical products

Drugs, SIC 283, is further divided into several four-digit groupings, including the four-digit industry, 2831, which is further broken down into its component categories, as shown below:

2831 Biological products
28311 Blood and blood derivatives, for human use
28312 Vaccines, toxoids, and antigens, for human use
28313 Antitoxins, antivenins, and similar derivatives, for human use
28314 Diagnostic substances, and other biologics, except for industrial use
28315 Biological products for veterinary use
28316 Biological products for industrial and other uses
2833 Medicinals and botanicals
2834 Pharmaceutical preparations

PNL-4939
UC-13

DISTRIBUTION

No. of Copies

OFFSITE

2 J.P. Thereault
Director
Division of Plans
and Evaluation
Office of Nuclear Energy
U.S. Department of Energy
Washington, D.C. 20585

27 DOE Technical Information
Center

No. of Copies

ONSITE

DOE Richland
Operations Office

H.E. Ransom

28 Pacific Northwest Laboratory

R.C. Adams
J.W. Currie
L.R. Dodd (3)
J.M. Fang (10)
L.A. Skumatz (5)
M.K. White
Publishing
Coordination (2)
Technical Information (5)