ASPECTS OF RESEARCH AND DEVELOPMENT IN AMERICAN INDUSTRY: AN EXPLORATORY STUDY*

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Introduction

A considerable amount of effort has gone into empirical research to discover the determinants and effects of industrial research. Unlike other aspects of technological change, such as the diffusion of innovation, the spatial components of research and development (R&D) have not been assessed. This paper primarily extends economic study on the subject to examine the effect of locational variables on the research intensity of individual firms.

The paper is an exploratory one in that only certain relationships are examined. Emphasis is placed on the effects of firm and locational attributes on R&D, rather than on the broader, long-term effects of R&D on a firm's product mix or on city growth. The catalytic nature of technological change on urban and regional growth dynamics, therefore, falls largely outside the relationships examined here. Other related considerations, such as the location of R&D laboratories and long-term corporate technological behavior, are also beyond the scope of this paper.

The paper begins with a brief review of past research on industrial R&D and the small amount of related work on locational aspects of inventiveness. The following section describes a model employed to include both economic and spatial variables as determinants of the research intensity of individual firms. The statistical findings are presented and interpreted in terms of both sets of variables. Finally, a synthesis with previous research suggests future steps that would add to our understanding of technological change.

Economic Determinants of Research Effort

Research and development is the input stage of the first of three components of technological change and, as such, is often considered to be equivalent to

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the output or product of research, invention. The amount of research effort, whether measured by R&D spending, R&D employees, or scientists and engineers employed by the firm, is an indicator of the degree of the firm's commitment to innovation. The actual output of inventions resulting from research is difficult to measure accurately, and has generally been measured by the number of patents issued to the firm.[1] Although patents do indicate the real contribution to technological change, they are less accurate indicators of the actions of individual firms. Many inventions are discovered by small companies, but are licensed soon after to larger firms; in other cases, the larger company acquires the smaller one to provide the capital for the invention's development. More important, the propensity to patent inventions may vary considerably between firms and between industries. However, patent data have tended to be more comprehensive and more readily available than R&D data on the level of the individual firm, and dominate past research on industrial innovation and the inventive effort of firms [19, 20, 29].

Variations in inventive effort among firms are industry-specific, and several factors tend to be general determinants of differences in research intensity among industries [23]. First, industries differ in the value their customers place on technological advances. In some industries, then, Schmookler's demand-push hypothesis of inventive activity seems to be important. In other industries, scientific and technological innovation is necessary to maintain markets in the face of intense competition. Second, industries differ in the ease with which R&D can actually bring about significant inventions. Third, industries differ in market structure; a number of arguments have been put forward that posit higher research effort in industries with greater concentration but empirical results have been inconclusive [20]. However, recent empirical evidence as well as theoretical models indicate a nonlinear relationship where the greatest research intensity occurs at an intermediate level of competition [20].[2]

Within an industry, firm size is the critical varible determining overall research effort. The largest firms tend to spend more on R&D in absolute terms [23], but the question of whether large firms spend more on R&D relative to their size than smaller firms is less clear. Research intensity (that is, R&D expenditures as a percentage of sales) itself varies with firm size. In some industries, the largest firms spend more on research as a percentage of sales than smaller firms; in most industries, smaller companies are more research intensive, either because of organizational resistance to innovation in large firms [2, 24] or because of an explicit imitation strategy [1]. Again,

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[1]Correspondence between R&D and patents, or inventive input and output takes place with a lag of about four years, owing to normal delays between invention, patent application, and patent issue [29]. Employing the four-year lag, Branch [3] has found an additional two-year lag, on the average, before an invention contributes to the firm's profits.

[2]This conclusion is similar to that reached after a similar long-standing debate on the relationship between primacy and economic development.

the relationship is clearly nonlinear and has been best modeled by a function of the form:

$$(1) \quad R = a + b_1 \ln S + b_2(\ln S)^2 + b_3(\ln S)^3$$

where R is the research intensity of the firm (or total R&D effort), or R&D expenditures as a proportion of annual sales, and S is firm size. The logarithm of S is used because its distribution is less skewed, which has the effect of depressing the influence of larger firms [23, 29]. Recent research on the topic has built upon Equation (1), adding such factors as government incentive grants and foreign ownership [18].

Locational Influences on Inventive Activity

The question of city size and inventive activity has not yet been clarified by the limited research on the topic. Data constraints have limited intensive study to patents, rather than R&D, and the bulk of work has been of an historical nature. The most recent data were analyzed by Thompson [32] in the earliest such study. He determined that invention tends to take place disproportionately to population in metropolitan areas, but that much of this effect is attributable to differences in employment or industry mix. More sophisticated work [11, 21, 27] has presented evidence that inventive activity between 1860 and 1920 was disproportionately concentrated in the largest and most industrialized American cities. Higgs [16, 17], in a state level study for the same period, found urbanization and a regional dummy variable for uninventiveness in southern states to account for most of the variance in patents issued by state. Finally, Feller [12] found that industry specific employment influenced patents in some industries but not in others, which is not surprising in light of the overwhelming interindustry variations elaborated by work on current R&D patterns.

The increasing importance of corporate research in R&D and patenting renders it necessary to alter the principal question of interest with regard to invention and location. The fundamental change has been the institutionalization of R&D within large, multiplant firms [13]. As a result, the population or employment of a given city has little direct effect on the inventive effort of firms. Indeed, with decision-making about the allocation of effort to R&D largely centralized in the corporate headquarters, it can be argued that the headquarters location is the location with the most influence on firms' inventive behavior.

In this context, larger city size is likely to be more inhibiting than generative of research effort. Firms that have chosen large cities for central office locations or that have decided to remain there have tended to minimize risk and uncertainty with respect to location [35]. Large cities where many other firms are headquartered are known quantities as corporate location, providing the agglomeration economies and prestige associated with major cities [9, 28]. It is more risky or, at least, less conservative to operate a firm from a smaller metropolitan area. A conservative, risk minimizing attitude with respect to location may be assumed to be a negative attribute with respect to research and innovative activities by the firm as well. As a result, we can expect, ceteris paribus, more research intensive firms to be headquartered in smaller cities.[3] Since the choice of headquarters is related to the size of a firm and the extent of its market area [9], an interaction between these two variables is appropriate as a determinant of research intensity.

A Model of Economic and Locational Effects on Industrial Research

An appropriate model of spatial influences on industrial R&D should include basic economic determinants of research intensity. One such model is:

$$(2) \quad R = a + b_1 \ln S + b_2 (\ln S)^2 + b_3 (\ln S)^3 + b_4 S/A + b_5 \ln G + b_6 M + b_7 B$$

where A is the total assets of a firm, G is its age (since founding), and M and B are dummy variables indicating firm headquarters location in the Old Manufacturing Belt and the Boston-California areas, respectively. The ratio S/A indicates the degree of capitalization, such that a firm with above average assets can be expected to expend more on R&D than its annual sales would suggest. This could take place in growing industries, in which competition induces research activity among all firms but especially in those with the assets needed to fund R&D. In addition, assets are less subject to the yearly fluctuations to which sales (and profits) are subject. The sign of b_4, then, is expected to be negative. Similarly, for firms of a given size and capitalization, the age of a firm can exert an influence on research intensity, through either a long corporate history of research effort or the higher inventive activity of younger firms. The sign of b_5, then, could be either positive or negative.

Two different regional influences on research intensity have been included, and these will differ in their effects on firms in different industries. The Old Manufacturing Belt has been the core region for many industries and could have a positive effect on research intensity through agglomeration and competition. In high technology industries, in particular, the Boston area and much of California have frequently been cited as hotbeds of innovation [6, 7].

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[3]There is a wide range of reasons, including chance, for a particular city being the headquarters location of an individual firm. Whatever the reasons, differences in corporate attitudes and behavior are likely, reflecting local competition, bank behavior, and less tangible attributes [8]. The hypothesis examined here is that the effect of these factors varies primarily with city size. The role of these intangible factors is in agreement with the perception of Dr. C. H. Li, longtime director of corporate R&D for Honeywell (personal communication).

Firms headquartered in these areas could be expected to have higher research intensity. Although firms headquartered elsewhere often take advantage of such locations for their research activities, the effect of corporate headquarters location on R&D is the relationship explored here.

The interaction between firm size and the size of the headquarters city may be operationalized by an expansion of the parameter, b_1:

$$(3) \quad b_1 = c_o + c_1 \ln P + c_2(\ln P)^2 + c_3(\ln P)^3$$

where P is the population of the urban area where the firm is headquartered. Equation (3) expands b_1 rather than any other parameter to keep the firm size interaction at a relatively simple level, while at the same time the cubic functional form allows the effects of city size on inventiveness to be comparable to those of firm size, as expressed in Equations (1) and (2). The full model to be analyzed is:

$$(4) \quad R = a + c_o \ln S + b_2(\ln S)^2 + b_3(\ln S)^3 + b_4 S/A + b_5 G + b_6 M$$
$$+ b_7 B + c_1 \ln S \cdot \ln P + c_2 \ln S \cdot (\ln P)^2 + c_3 \ln S \cdot (\ln P)^3 + e$$

Data on the R&D expenditures of individual firms in the United States in 1975 compiled by Business Week from 10-K reports filed with the U. S. Securities and Exchange Commission were the basis for the empirical analysis [5]. Although annual fluctuations in R&D are common [10], such detailed data for a large set of firms have not been available before. Future research could incorporate examination of R&D cycles.

The data included 730 firms that together accounted for about 96 percent of all company funded R&D in that year. All firms that report R&D as a separate item, and that have 1975 sales of $50 million or R&D expenditures of more than $1 million, are included. Firms with less than $50 million in sales were eliminated to avoid their biasing the results in those industries where small firms spend large fractions of their sales on research. Generally, only smaller firms, firms for which R&D was not significant enough to report, or privately owned firms are excluded.[4]

Nonmanufacturing firms and industries with fewer than ten firms (e.g., oil, mining, services, and communication) were eliminated from the data for this study, leaving 550 firms in 16 industry categories.[5] (The remaining firms accounted for 86 percent of all R&D expenditures in the complete survey).

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[4]Market research, quality control costs, routine product improvement, and the legal expenses of patent applications, sales, and licenses are excluded from R&D costs, as is government funded contract research [5, pp. 62-65].

[5]Footnote on following page.

Assigning any multiproduct firm to a single SIC group involves some unavoidable loss of information, but the alternative is ruled out by the lack of data on R&D expenses on each product line. Data on firm sales and assets in 1975, firm age (years since the date the company was founded) and corporate headquarters location were obtained from the Fortune Directory of the 1,000 largest U. S. corporations [14, 15] and from Standard and Poor's Corporate Directory [30]. SMSA populations in 1970 were employed as the measure of city size for most cities; for smaller places, city size was used. For large urban complexes, SCSA's were used.[6]

The interindustry variation in research is evident when industries are compared according to average R&D expenditure as a percentage of sales, or research intensity (Table 1). In this ranking, two groups of industries (SIC categories) are apparent, each with two subgroups.[7] Seven industries are above average in research intensity (Group I), and all correspond to an image of high technology or innovation producing. The most research intensive industries, with R&D accounting for over four percent of sales, are Instruments, Office Machines, and Drugs (Group Ia). Four other industries also are above the mean research intensity of manufacturing (Group Ib): Aerospace, Transportation, Chemicals, and Electrical and Electronic Products. The nine industries that are below average in research intensity (Group II) also comprise two distinct subgroups. Five industries spent roughly between one and two percent of sales on R&D (Group IIa): Machinery, Rubber and Plastic Products, Stone, Clay, and Glass products, Miscellaneous Manufacturing, and Fabricated Metals. Finally, four industries allocated less than one percent of their sales to research (Group IIb): Primary Metals, Paper and Printing, Textiles and Apparel, and Food and Tobacco, all of which are recognized as low technology industries.

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[5]The original industry groups did not correspond to SIC categories, but rather somewhat more specialized groups of a few firms. To include some industry groups with very few firms, these were aggregated into two-digit or, in a few cases, three-digit industries. For example, seven appliance manufacturers were included in SIC 36 (Electrical Products) and four beverage firms were analyzed with food producers (SIC 20). Other industry groups in [5], such as General Machinery and Miscellaneous Manufacturing, included 51 and 72 firms, respectively, and were less specific than the SIC groups to which the firms were assigned (primarily 33, 34, 35, and 36). The SIC group used for each firm was either that corresponding to the group of firms in [5] or the SIC code of the firm's largest sales category found in [31].

[6]Standard Consolidated Statistical Areas (SCSA's) are comprised of groups of contiguous SMSA's. The 13 defined to date are: Boston-Lawrence-Lowell, Chicago-Gary, Cincinnati-Hamilton, Cleveland-Akron-Lorain, Detroit-Ann Arbor, Houston-Galveston, Los Angeles-Long Beach-Anaheim, Miami-Fort Lauderdale, Milwaukee-Racine, New York-Newark-Jersey City (including southwestern Connecticut), Philadelphia-Wilmington-Trenton, San Francisco-Oakland-San Jose, and Seattle-Tacoma. See [26] for definitions.

[7]Footnote on following page.

TABLE 1: R&D in U.S. Manufacturing Industries, 1975, Ranked by Research Intensity

Industry	Mean R&D (millions of dollars)	Mean Sales (millions of dollars)	Mean Research Intensity (R&D/Sales, percentage)		Number of Firms
Instruments (SIC 38)	21.0	387	5.43	Ia	32
Office Machines, Computers (SIC 357)	79.5	1560	5.10	Ia	26
Drugs (SIC 283)	37.3	879	4.24	Ia	31
Aerospace (SIC 372)	47.3	1534	3.08	Ib	19
Transportation Equipment (SIC 37 exc. 372)	63.2	2464	2.56	Ib	42
Chemicals (SIC 28 exc. 283)	25.7	1051	2.45	Ib	62
Electrical and Electronic Products (SIC 36)	22.5	923	2.44	Ib	65
Machinery, except Electrical (SIC 35 exc. 357)	11.5	568	2.02	IIa	56
Rubber and Plastic Products (SIC 30)	18.2	963	1.89	IIa	18
Stone, Clay, Glass, and Concrete Products (SIC 32)	10.6	608	1.74	IIa	17
Miscellaneous Manufacturing (SIC 39)	3.7	238	1.55	IIa	20
Fabricated Metal Products (SIC 34)	3.9	317	1.23	IIa	28
Primary Metals (SIC 33)	7.7	958	0.80	IIb	28
Paper and Printing (SIC 26 &27)	4.8	619	0.78	IIb	31
Textiles and Apparel (SIC 22 & 23)	1.4	296	0.47	IIb	32
Food, Beverages, and Tobacco (SIC 20 & 21)	6.3	1351	0.47	IIb	43
All Industries	22.8	954	2.39		550
Group Ia	43.8	901	4.86		89
Group Ib	35.1	1371	2.56		188
Group IIa	9.6	526	1.83		139
Group IIb	5.1	847	0.60		134

Empirical Results

The model of Equation 4 was analyzed by ordinary least squares for all 550 firms together and for the four broad groups of industries (Table 2). The results shown are for the step with the maximum number of significant coefficients (90 percent level or better). The estimated equations for all groups are significant at the 95 percent level, but the groups of industries show considerable differences in both the variables that are significant and the levels of explained variance. Except for the high technology group, the R^2 levels are quite low, generally reflecting the diversity of industries and firms considered. In Group Ia, high technology industries, California-Boston headquarters locations are associated with much higher research intensities (2.1 percent higher). Other than that, larger firms and relatively well capitalized firms are those with greater research efforts. In Groups Ib and IIa, medium technology industries, California or Boston headquartered firms also have higher research intensities. Location in large headquarters cities tends to inhibit research intensities, regardless of the location of R&D labs. Larger sales/assets ratios are again associated with higher relative research effort. In the lowest technology industries, Group IIb, Old Manufacturing Belt headquarters location has the larger regional effect on R&D. Research intensities tend to decrease with the size of city in which firms are located.

For all industries combined, a larger number of variables are significant, including both regional variables. Nonmonotonic influences from both firm size and the firm size-city size interaction variables result, both indicating higher research intensities among larger firms and those headquartered in the largest cities. Curiously, firm age is significant for all industries, but not for any subset. Overall, older firms tend to be less research intensive.

The more internally similar two-digit or three-digit SIC groups of industries also were analyzed, and the unique nature of R&D in each industry is evident (Table 3). Variance explained ranges from 13 to 88 percent, with the higher values generally, but not exclusively, associated with the most research intensive industries.

In most industries, the cubic specification of firm size employed in

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[7]This ranking, based on $\overline{(R\&D/S)}$ is somewhat different than one based on the average research intensity of a set of firms, or $\overline{R\&D}/\overline{S}$. In the latter calculation, an industry in which a few large firms do the bulk of the R&D has a lower average research intensity than if the total expenditures of those large firms are included in the calculation. Industries where this effect occurs are Instruments, Transportation Equipment, and Aerospace. By contrast, industries in which all firms engage in considerable R&D have lower research intensities when calculated by the first method.

TABLE 2: Determinants of Research Intensity by Industry Groupings*

Industry Group	Constant	lnS	$(\ln S)^2$	$(\ln S)^3$	S/A	lnS·lnP	$\ln S \cdot (\ln P)^2$
Ia	7.52	0.31** (2.20)			-4.525** (9.09)		
Ib	3.80			0.0011 (1.30)	-0.881** (3.12)		-0.0015* (1.66)
IIa	2.36			0.002** (2.19)	-0.910** (2.88)		-0.0010 (1.32)
IIb	0.68				-0.287** (3.75)		-0.0009** (2.61)
ALL	5.45	-0.30 (1.18)		0.0036* (1.87)	-1.248** (8.32)		-0.0006 (1.12)

*T-values are in parentheses. * = significant at the 90 percent level.
** = significant at the 95 percent level.

TABLE 2: (Continued)

$\ln S \cdot (\ln P)^3$	lnG	M	B	R^2	F-ratio	n
			2.15** (5.07)	.556	35.47** (3,85)	89
			1.12** (2.85)	.088	4.42** (4,183)	188
		0.33 (1.26)	0.83* (1.95)	.124	3.76** (5,133)	139
0.00002 (0.67)	0.12 (1.07)	0.30* (1.88)	0.37 (1.59)	.153	3.81** (6,127)	134
0.00010** (2.08)	-0.36 (2.56)	0.59** (2.58)	1.69** (5.54)	.181	14.95** (8,541)	550

TABLE 3: Research Intensity Determinants by Two-Digit S.I.C. Group*

Industry	Constant	ln S	$(\ln S)^2$	$(\ln S)^3$	S/A
Food and Tobacco (SIC 20 & 21)	-0.07				-0.108* (1.89)
Textiles and Apparel (SIC 22 & 23)	2.01				-0.578** (2.36)
Paper and Printing (SIC 26 & 27)	-23.88	13.04 (1.29)	-2.27 (1.31)	0.129 (1.32)	
Chemicals (SIC 28)	1.19				-0.997** (2.62)
Drugs (SIC 283)	2.82	1.76** (4.37)			-5.164** (6.85)
Rubber and Plastic Products (SIC 30)	-2.08	1.86 (1.53)	-0.13 (1.43)		-1.943** (2.67)
Stone, Clay and Glass Products (SIC 32)	95.34	-47.62** (3.76)	7.98** (3.70)	-0.424** (3.52)	0.606 (1.16)
Primary Metals (SIC 33)	5.37				-0.781** (2.56)
Fabricated Metal Products (SIC 34)	6.52				-2.062** (2.16)
Machinery (SIC 35)	35.76	-16.94* (1.69)	2.71 (1.58)	-0.138 (1.46)	-1.011** (2.27)
Office Machines and Computers (SIC 357)	11.93			0.003 (1.08)	-3.679** (3.34)
Electrical and Electronic Products (SIC 36)	9.50				-3.030** (3.76)
Transportation Equipment (SIC 37)	3.75	-0.84** (2.16)		0.006** (2.52)	-0.709* (1.74)
Aerospace Equipment (SIC 372)	5.90			0.012** (3.26)	
Instruments (SIC 38)	72.15	-31.68** (2.33)	5.57** (2.38)	-0.295** (2.29)	-4.006** (5.65)
Miscellaneous Manufacturing (SIC 39)	-6.79	2.58* (1.78)		-0.027 (1.63)	-1.202 (1.21)

*T-values are in parentheses. * = significant at the 90 percent level. ** = significant at the 95 percent level.

TABLE 3: (Continued)

lnS · ln P	lnS · $(\ln P)^2$	lnS · $(\ln P)^3$	ln G	M	B	R^2	F-ratio
			0.17 (1.23)			.132	3.05* (2,40)
	-0.0015* (1.90)					.224	4.19** (2,29)
-0.025* (1.83)		0.00020** (3.14)	-0.03 (0.17)	0.81** (2.38)	1.53** (3.38)	.475	2.49** (8,22)
	-0.0025** (2.46)		0.62** (2.41)	1.17** (2.52)	0.84 (1.24)	.244	3.61** (5,56)
	-0.0073** (3.49)					.665	17.83** (3,27)
		-0.00012 (1.38)	0.53 (1.52)	-1.69* (1.93)	-2.28* (2.03)	.685	3.11* (7,10)
-0.214** (2.94)	0.0121* (2.05)				0.82 (1.62)	.882	9.62** (7,9)
	-0.0030** (3.29)		-0.83** (2.20)	1.36** (3.02)		.379	3.51** (4,23)
			-0.48 (1.29)	-0.56 (1.01)		.276	3.05** (3, 24)
	-0.0024* (1.95)		0.33 (1.25)	0.67 (1.53)	2.05** (3.38)	.338	3.00* (8,47)
		0.00016 (0.67)	-1.31* (1.69)		0.88 (0.94)	.577	5.46** (5,20)
0.104 (1.27)	-0.0095 (1.36)	0.00003 (0.19)	1.22** (2.34)	1.16 (1.04)	2.73** (2.25)	.373	4.85** (7,57)
			0.64* (1.92)			.253	3.12** (4,37)
-0.116** (2.37)		-0.00036 (1.48)				.426	3.71** (3,15)
-0.438 (0.75)	0.0309 (0.85)	0.00010 (0.57)	-0.33 (1.04)		2.03** (3.59)	.858	14.78** (9,22)
				0.78* (2.05)		.402	2.52* (4,15)

most previous studies was not significant.[8] However, the majority of industries do exhibit a nonlinear pattern of research intensity with firm size. No clear pattern on this emerges with respect to level of technology across industries, and evidence of both increasing and decreasing research effort with firm size is apparent. Firm age has an ambiguous effect, being positive in three industries, negative in two, but insignificant in 11.

In the majority of industries, one or more locational variable was significant. Regional location influenced research intensity in eight of the 16 industries. Firms headquartered in the Old Manufacturing Belt expended more on R&D than other firms (by an average of about one percent of sales) in the Paper, Chemical, Primary Metals, and Miscellaneous Manufacturing industries. Boston and California based firms were more research intensive (by an average of over two percent of sales) in the Paper, Stone, Clay, and Glass, Machinery, Electrical, and Instruments industries - a group that includes industries with a wide range of research intensities. The Rubber and Plastic industry (SIC 30) is noteworthy because of greater research effort among firms outside either of the regions designated here.

A nonlinear variation in research intensity with city size is evident for most industries. In the Paper, Stone, Clay, Glass, Instruments, and Office Machines industries, the pattern is for increasing relative R&D effort among firms in larger cities. For Chemicals, Drugs, Metals, Machinery, and Aerospace, the effect of large city headquarters is to reduce research intensity. In general, the industry specific influences of headquarters city size make it difficult to generalize across industries. In many industries, however, large city size of headquarters definitely appears as a significant indicator of declining research intensities.

Conclusions

The industry specific nature of the determinants of R&D intensity examined in this study reaffirms that conclusion from previous research. Firm size related variables remained important in some industries when regional and city size variables were added, but annual sales were insignificant in several industries. The most universal variable appears to be the relative capitalization of firms in an industry.

Location of the corporate headquarters by region tends to be associated with greatly increased research intensities. This is especially true of California or Boston based firms in high technology industries. Firms in more basic industries, such as Chemicals, Paper, and Primary Metals, appear to have higher research intensities when located in the Old Manufacturing Belt.

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[8] Scherer [29] maintains that the conventional significance levels are not particularly relevant for a cubic function with its internal multi-collinearity. The results can be viewed, however, as best estimates of the underlying structural pattern in the relationship.

Size of headquarters city, specified as interacting with firm size, is quite a significant factor in the majority of two-digit industries. The direction of the relationship varies considerably by industry, and no clear relationship with the research orientation of the industry is apparent.

The increased research effort of firms in particular locations depends to some extent on government research expenditures at certain locations. The Boston-California regions are innovation areas largely because of the emergence of new firms that have spun off from universities and other research centers in those areas [7, 22]. It is unclear whether the distribution of federal research funds to new locations would increase the attraction of those places to private industry. That the regional effect is so pronounced even when headquarters, rather than research laboratory, location was employed, however, suggests that there are some attitudinal differences with location among corporate managers. The city size of headquarters variations found are less easily explained, and probably require inclusion of more detailed data on the research orientation of firms.

A more careful examination of the city size effects on R&D is needed. This could take the form of a location quotient analysis of firms in individual cities with respect to national and industry averages. The evidence presented in this paper, however, suggests that location (of headquarters) is, in fact, related to variations in firms' research efforts. Determining the causes of this relationship will require detailed study of individual urban areas as well as of the patterns in individual industries. The agglomeration of R&D facilities in certain locations and the attraction of federal and university activities for industry also need to be assessed. The role of federal R&D funds has received much recent interest, but few conclusions have been drawn [25, 33, 34].

Perhaps more useful would be a focus on the technological behavior of individual firms, tracing R&D through significant innovations to changes in production functions and the resultant effects on urban and regional growth. The beneficial effects of R&D on urban growth generally and agglomeration economies for research in certain sectors is a topic in need of empirical support.

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