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ABSTRACT

This study examined the characteristics of those universities from which scientists, working in private industry, procure research information. It assessed these characteristics with respect to institutional size, quality, institutional type, geographic location, and the presence of cooperative research structures. The study involved a citation analysis of articles written by firm-based scientists within the computer equipment and aircraft industries, and associated these findings with the ascriptive characteristics of the universities that were cited. Citations were found for 117 institutions of higher education. The results indicated that several institutional characteristics, including land grant status, average faculty salaries, and scientific research expenditures, were significantly associated with university research production that was of interest to firms active in these industries. Findings also indicated that the region surrounding a university may be a factor in how often the institution's research is employed by industry, urban and suburban universities being cited most often. The results suggest that high quality, well paid faculty with ample resources are most likely to produce scientific research that is later utilized by private firms. It is suggested that these findings have policy implications for industry, federal and state resource providers, and institutional planners. (Contains 42 references.) (GLR)

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OUT OF THE IVORY TOWER:

AN ANALYSIS OF THE INSTITUTIONAL CHARACTERISTICS OF UNIVERSITIES FROM WHICH FIRMS ACQUIRE SCIENTIFIC RESULTS

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This paper was presented at the annual meeting of the Association for the Study of Higher Education held at the Marriott City Center, Minneapolis, Minnesota, October 29 - November 1, 1992. This paper was reviewed by ASHE and was judged to be of high quality and of interest to others concerned with the research of higher education. It has therefore been selected to be included in the ERIC collection of ASHE conference papers.

Abstract

This study examines the characteristics of the universities from which scientists who work in private industry procure research information. In contrast with other investigations of university and industry interaction, this paper considers not what universities have to offer to firms, but rather, assesses the characteristics of the institutions that firms turn to for scientific research knowledge. The methodology employs a citation analysis of articles written by firm-based scientists within the computer equipment and aircraft industries, and associates these findings with the ascriptive characteristics of universities.

The results indicate that several institutional characteristics, including land grant status, average faculty salaries, and scientific research expenditures, are significantly associated with university research production of interest to firms active in these industries. Findings on the effects of program quality in the model are also significant, but need to be treated with caution. The study findings have policy implications for industry, federal and state resource providers, and institutional planners. Most importantly, these results suggest that high quality, well paid faculty with ample resources are most likely to produce scientific research that is later utilized by private firms.

OUT OF THE IVORY TOWER:

AN ANALYSIS OF THE INSTITUTIONAL CHARACTERISTICS OF UNIVERSITIES FROM WHICH FIRMS ACQUIRE SCIENTIFIC RESULTS

Funding for university research has commonly been bestowed upon only a select few of the 3500 post-secondary institutions in this country (National Science Foundation [NSF], 1989). While knowledge produced by universities is used by industry (Small & Greenlee, 1979), it is not clear that the institutions receiving the bulk of research funding are also the ones that industry looks to for external research. Indeed, few studies to date have examined firm utilization of university-generated knowledge on a large scale, and little scholarly attention has been given to research activity in post-secondary institutions other than large research universities.

On the other hand, numerous studies and reviews, as well as increased public attention, have been directed toward the relationship between the research enterprises of universities and firms. Much of this interest appears to arise out of an enhanced concern over U.S. economic well-being and tightening budgets within academe (Matkin, 1990; Rogers, 1988). The literature reporting on the interactions between sectors has predominantly been composed of descriptions of past or current cooperative endeavors (Geiger, 1992; Matkin, 1990), cautionary tales (Low, 1983; Varrin & Kukich, 1985) or suggestions for change (Abu-

Laban, 1989; Powers, Powers, Betz, & Aslanian, 1988). Most collaboration literature has emphasized what universities have to offer to or gain from industry.

Institutional characteristics have been used in the investigation of a variety of aspects of higher education. For example, characteristics of academic organizations have been analyzed extensively in attempts to predict student outcomes of college (e.g., Pascarella & Terenzini, 1991), and higher education's effects on earnings (e.g., Solmon & Wachtel, 1975), as well as for college and university planning purposes. To date, little has been done to analyze the characteristics of the universities assisting firms in scientific research endeavors, in part, because of the difficulty in identifying these linkages. Most studies that have examined institutional characteristics of universities that collaborate with private industry have been only descriptive in nature.

Fairweather's (1988) review of the literature on industrial and academic partnerships suggests that attributes of firms and universities can be useful in understanding the implementation of alliances and the subsequent use of academic research by private firms. Past research has indicated that particular characteristics of universities that may influence relationships between the two sectors include size, available resources, quality, prestige, institutional type, location, and organization (Prager & Omenn, 1980; NSF, 1982; Public Policy Center, 1986; Stankiewicz, 1986). However, there has been little empirical

work reported that tests these concepts in a comprehensive way.

Institutional Attributes and Research Utilization

Resource or size characteristics are often linked with possible research utilization (Fairweather, 1988; NSF, 1982). If an institution has more of the resources considered necessary to support a research enterprise available (such as numerous qualified faculty and graduate students, large libraries and well-equipped laboratories, and an abundance of research dollars), the institution could be expected to generate more research. One qualification to this statement is that not all university research is useful to industry (i.e, research taking place in psychology may be of little value to an electrical engineer attempting to solve a problem in the private sector). It would seem that research conducted in only a limited number of departments is pertinent to scientific endeavors, and hence resources attributed to these designated departments may be of primary interest (Fairweather, 1988, p. 43).

A second constraint on resource measures as a predictor of research utilization is quality or prestige of the faculty (Fairweather, 1988, p. 51; Solmon, 1981). Even if a department has an abundance of resources (e.g., faculty, students, laboratories), it does not necessarily follow that the faculty are producing research of use to industry. Indeed, if faculty are not highly trained or well qualified, have other non-research interests, or have not kept abreast of current developments in

their field, they may not have the time or background to produce the research industry needs or is able to utilize. In addition, it may well be that faculty of high quality are more likely to produce research that has broad applicability, including use by private industry.

Variation by type of institution may also be associated with firm utilization of research (Fairweather, 1988; Prager & Omenn, 1980). In particular, land grant status, Carnegie classifications, and public/private designations are worthy of consideration. Land grant institutions were developed to be an agent of economic development (Schuh, 1986) and, based on their original mission of serving state and public needs, may be expected to have closer ties to the businesses in their vicinity (Wahlquist & Thornton, 1964). Carnegie classifications may be relevant because the are based on amount of federal support, number of doctorates awarded, and level of institutional research priority (Carnegie, 1987). The public/private institution split may be another distinction of interest, due to differences in funding sources.

The location of a higher education institution may also impact the extent of research utilization by the private sector (Calzonetti & Walker, 1991, pp. 228-232; Jaffe, 1989; Lund, 1986; Premus, 1982). If a university is geographically close to many firms interested in its research, it may have more chances to share and interact. This reasoning suggests that cooperation of any magnitude is more apt to take place in urban rather than

rural areas. Other characteristics of urban universities enhance the chances of industrial utilization of research as well. Frequently, as part of their unwritten mission, urban universities engage in public service to their immediate metropolitan and suburban areas. Further, some have argued that the research conducted in urban institutions is more likely to be applied rather than basic (Public Policy Center, 1986), which may have more appeal to firms given that the ultimate goal of industry is applied development.

Much time and energy has been invested in the past two decades in the establishment of research parks or cooperative university/industry endeavors. These parks were devised to promote the exchange of information between the two sectors (Epstein & Blumenthal, 1986). If indeed these experiments are successful, an increase in knowledge transfer is expected for institutions involved in research park enterprises. However, the success record of research parks nationwide has been uneven, with one estimate putting 50% of all research parks in the less successful category (Powers, et al., 1988).

Design and Methodology

This study is designed to examine the similarities and differences in the universities that firms draw research knowledge from, as well as investigate which, if any, of the characteristics of the institutions have predictive power in terms of firm utilization of university research. With this

study, we take a preliminary step, based on the examination of two industries, at answering the following questions:

- Which post-secondary institutions do firms use as sources for their research information?

- Are there similarities in the academic institutions from which firms draw scientific information?

- Which characteristics of universities can be linked to the frequency of citation by firms?

Our research contributes to the literature by examining the knowledge transfer component of the firm/university relationship. As such, this is an empirical study of the institutions which produce research that firm scientists subsequently use in their own work. Specifically, we examine institutional characteristics associated with the colleges and universities that are producing the utilized research. We then draw inferences on the strength of these variables in predicting the types of academic institutions from which firms acquire research results.

The study makes use of citation analysis as a mode of inquiry in an initial attempt at linking firm activity with the higher education institutions from which industry draws knowledge. While citations have been used in the past to study journals, disciplines, and specialties (Borgman, 1990; Chubin,

1987), citations to articles written by university-based scientists have been selected in this study as a proxy for firm utilization of academic research. Previous studies that have employed citation analysis in the examination of firm and university interactions were not directed at characteristics of the academic institutions (Small & Greenlee, 1979; Tornquist, 1992). The selection of citations as a measure allows for the analysis to be conducted on a large scale and yet takes into account variation across individual institutions.

Citation analysis is not without limitations. Citations serve only as a proxy for knowledge transfer and not as a direct measure. Just because a publication written by a university-associated scholar is cited, this does not necessarily mean that university resources in any way contributed to the work, that the research cited was actually read or used in any substantial manner, or that all authors contributed to the same degree. In addition, only select groups of firm scientists publish their results, limiting this study to a very specific type of knowledge transfer which may or may not be generalizable to informal communication taking place or to knowledge transfer in other sectors or industries.

In this study we have chosen to examine research transfer activity in the aircraft and electronic equipment industries. These industries were identified on the basis of their substantial R&D activity (Powers, et al., 1988) and publication rates. A stratified random sample of 92 papers listing citations

was taken from the 136 firms publishing within these two industries during 1986 and 1987 (two papers from each firm if they were available). The list of citations given in each paper was examined and the authorship of the referenced works was determined (only 62 of 136 firms had sampled papers with citations to university-affiliated publications). A list of the colleges and universities to which cited authors were associated was compiled along with the number of times each institution was acknowledged. The universities on this list were examined with respect to institutional characteristics including measures of size, quality, institutional type, geographic location, and the presence of cooperative research structures.

Descriptive Results

One hundred seventeen institutions of higher education were cited in the sample of papers (See Appendix A). The compiled list of universities that firms in this study referenced includes more than just those commonly associated with large research enterprises. Indeed, some of the cites were to what are typically considered non-research institutions. Specifically, over one-third of the institutions were not Research I or Research II universities as designated by their Carnegie classification (See Table 1).

While a surprising variety of higher education institutions appeared in the citation sample, it is clear that most of the research being utilized by private firms in these two industries

is authored by faculty residing at Research I universities. This can be observed by examining the sum of fractional citation counts on Table 1. The breadth of institutions is present, but the sum of fractional citation counts indicates that most of the total authorship is located in the major research universities.

Insert Table 1 about here

The colleges and universities identified in this study vary by other measures as well (See Table 2). Most of the institutions are quite large, with enrollments in 1987 averaging over 18,000 students. Yet, sixteen institutions that were cited had less than 5,000 students, and five of them had less than 1,000 students. Three of the institutions in the sample awarded no graduate degrees in 1987, and another 13 awarded less than 200 graduate degrees in the same year. These institutions are indicative of the wide variety of institutional types that are contributing to research used by industry.

Insert Table 2 about here

One other descriptive result of interest relates to university location. The data indicate that the population of the region surrounding a university may be a factor in how often the institution's research is employed by industry. Eleven percent of the institutions in our sample are located in rural

areas, while 42 percent of the institutions were classified as being in an urban area (College Handbook, 1987). The remaining 47 percent of institutions were in suburban areas (which, by definition, are located near cities). An examination of fractional citation counts broken out by urban/rural location shows that over 56% of the cited authorships came from institutions located in urban areas, and 5.6% came from institutions in rural areas. Rural institutions are producing industry-cited research at about half the rate one would expect from the proportion of institutions in the sample. This may be due to the remote locations of these schools, lack of collaborative opportunities, or other factors that inhibit the transfer of knowledge between rural institutions and industry.

Model

Based on the analysis of institutional characteristics associated with research output, our general model appears as follows with appropriate variations in explanatory variables based on the level of aggregation:

$C_i = f\{ R_{ij}, Q_{ij}, T_i, L_i, S_i \}$ where

C_i = Number of citations made by firms to university i

R_{ij} = Resource characteristics of department j in university i

Q_{ij} = Quality rankings of department j in university i

T_i = Institutional classification type of university i

L_i = Location of university i

S_i = Presence of cooperative research structures at university i

Two primary choices exist for determining how to attribute credit in collaborative papers: whole and fractional counting (Anderson, et al., 1988). A fractional counting scheme was selected for this study because the relative contribution of authors was believed to be of more importance than the actual numbers of authors. Thus, the number of citations (C_i) was calculated as the sum of the fractionally counted authorships for each institution. For example, a cited article with one author employed by University A increased University A's citation count (C_i) by one. If the cited article had more than one author, any one coauthor would increase his or her institution's count by only a fraction (e.g., by 1/4 if there were four authors listed). Although certainly not perfect, since the relative contribution of each author is impossible to determine, it was more appropriate to this study than a whole counting scheme which would more drastically misrepresent the contribution of the institutions involved (Lindsey, 1980). Sampling information and citation data were compiled from the Current Contents Address Directory (1986-1987), Million Dollar Directory (1986), Science Citation Index and various DIALOG databases.

A variety of resource characteristics were considered for

the equation, including number of students (both completions and enrollment, from IPED's Completions data tape and Torregrosa, 1988), number of faculty (Moore, 1987; Guidance Information System, 1989), and research expenditures (NSF, 1989). Because all of these indicators were highly correlated, research expenditures in the scientific fields of interest (physics, math, engineering, and computer science) were selected as the resource characteristic most closely related to the needs of this study. (This indicator is referred to as "Technology Research Dollars" in the results tables.)

The determination of a quality variable (Q_{ij}) was more problematic. Since most rankings of "quality" or "prestige" are at least partly subjective in nature and vary by evaluator, there was no one good source. We selected rankings from the Assessment of Research - Doctorate Programs in the United States from both the engineering, and physical and mathematical sciences volumes (Jones, Lindzey, & Coggeshall, 1982a, 1982b), regarded as the most comprehensive quality rankings yet produced (Webster, 1987). It has been noted, however, that while this study of graduate programs had many measures that reflect quality, there was no attempt to consolidate them. Webster (1987) suggests that one of the reputational measures, either the faculty's "scnolarly quality" or the program's "effectiveness," might be used for comparisons across programs. We chose the scholarly quality measure as a proxy for program excellence.

There are several concerns in employing this measure as a

proxy for quality. First, as with all reputational surveys, these results merely reflect a consensus of faculty opinions. These opinions may be based on many factors that might cloud the assessment of the present day quality of the program's faculty (e.g. past performance of the institution, lack of knowledge about the program, and the like). In addition, quality measures are usually highly correlated with institutional resource indicators (Hagstrom, 1971).

Second, data were available for only 92 of 117 institutions in our sample. The <u>Assessment of Research - Doctorate Programs in the United States -- Engineering</u> considered only those programs that awarded a set number of doctorates. This meant that many of the smaller institutions necessarily would be dropped when testing our models, and we felt that these institutions were of great interest to our study.

Finally, there were no provisions for comparing or combining the quality rankings of our program areas (engineering, physics, math, and computer science) within each institution. We chose to take the average of all the standardized scores that were available within the program areas for each institution.[1] Due to our apprehensions over this methodology, and the skepticism of reputational quality indicators in general, the equations containing the quality variable were considered separately from

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[1] Several methods of integrating the quality figures were attempted, with no appreciable change in any of the results listed below.

the rest of the model, and should be approached with caution.

A third variable that is, in some respects, both a resource and a quality variable was also selected: average faculty salaries per institution (Average Salaries, 1987). Two arguments support the choice of this variable. First, if salaries accurately reflect relative productivity, we would expect institutions that employ more productive, higher quality scholars would have higher average salaries. We would further expect that these scholars would produce research that has broad applicability, including relevance to real world problems.

Moreover, institutions that commit more money to faculty salaries are not only making a judgement as to what their faculty are worth as a part of their overall budget and market conditions, but these institutions in all likelihood have more total resources as well. This variable serves as a proxy for faculty quality and institutional resources, both of which we theorize will impact knowledge transfer to industry.

Several institutional type variables (T_i) were considered for inclusion: Carnegie ranking (Carnegie, 1987), land grant status (Wahlquist & Thornton, 1964), and public/private designation (The College Handbook, 1987). The Carnegie ranking was discarded because of its high correlation with the resource variables considered, and in particular, research expenditures. The public/private designation was also dropped because of its inter-correlation with the land grant variable. The land grant variable was judged more likely, on theoretical grounds, to

influence the model than the public/private dichotomy, and thus was included.

The location variable (L_i) considered was urban or rural status (The College Handbook, 1987). The literature has consistently pointed towards location as an important consideration, and as indicated above, urban institutions may have qualities that encourage industry utilization of their research.

The presence of cooperative research structures (S_i) was determined from a list of all research/industrial parks currently operating or under active development as of 1985 (Powers, et al., 1988). Due to the success of a few parks such as the Stanford Industrial Park and the Research Triangle Park in North Carolina, many believe that these types of structures have the ability to increase the level of research transfer between universities and private industry.

Results and Discussion

Table 3 presents the results of multivariate modeling, using ordinary least squares-based multiple regressions, employed in an attempt to understand which institutional characteristics can be linked to the frequency of citations by firms. In each equation, the dependent variable was the sum of fractionally counted university-based authorships.

Five of the six variables were included in the first estimation; the quality variable was excluded because it limited

the sample size and because of the aforementioned problems with deriving a suitable set of quality scores. The availability of faculty salary data slightly limited the sample size as well (from N=117 to N=111). The resource, land grant status, and faculty salary variables were all positive and significant at the .05 level. Neither the location variable nor the research park dummy variable were significant.

Insert Table 3 about here

It is not surprising that the amount of research monies expended by mathematics, physics, computer science and engineering departments would have a significant association with utilization of research in the two industries selected for this study. The amount of research dollars is apt to be correlated with the number of grants and contracts and with the total amount of research produced, both of which increase the likelihood that university research will be utilized by industry.

The significance of the land grant variable is of more interest. One of the original purposes for developing land grant institutions (i.e. that they would "generate new knowledge and apply that new knowledge to the problems of society" (Schuh, 1986)) is apparently still evident today. Land grant institutions seemingly continue to follow this part of their mission, and are more likely than other institutions to produce knowledge that is used by industry. Though we cannot directly

infer from our results that the mission of these institutions, with their sense of service to the public, is the cause of the significant outcome, it does distinguish land grant institutions in comparison to other large, well endowed universities.

The significance of the average faculty salary variable is more difficult to interpret. If higher quality, more productive scholars are indeed being compensated for their abilities, then one conclusion is that these scholars, in addition to being generally productive in their field, also are more likely to produce research that is of use to industry. If, however, average faculty salaries at an institution are more a function of available resources, then a different conclusion might be drawn. This would indicate that a generally higher level of institutional resources, of which faculty salaries are a significant component, increases the chances of producing research that industry is able to utilize. Both explanations are probably playing important roles.

The lack of significance of the research park variable confirms critical suspicions towards this vehicle for industry - university interaction. While certainly there have been some success stories, the overall track record of research parks throughout the nation is too uneven for this type of structure to significantly affect the model. One problem may be that many research parks are still in their infancy, and may not have had adequate time to develop. It has been said that a minimum of ten years and as many as twenty years are needed to fully establish a

research park (Powers, et al., 1988). It may be interesting to revisit this question in the future when these cooperative ventures have had more time to develop.

A final comment on the results in Table 3 has to do with the r-square of this equation. Given the many diverse reasons that industry may be led to utilize a particular university's research, including personal contacts, proximity, and the hiring of graduates, an equation that accounts for one-third of the variance is impressive. Clearly, there are institutional factors that do account for the production of research that is of interest to private firms.

The Quality Question

Table 4 presents the results of the model using the quality score described above. Conclusions from these results should be drawn with caution due to the problems discussed. However, the inclusion of the variable does lead to two findings which have policy implications.

Insert Table 4 about here

Both equations in Table 4 include the quality score variable. Due to the high correlation of quality with average faculty salaries ($r = .64$), the salary variable was not entered. Equation 1 in Table 4 shows the material influence that the quality score has on the model and its results. All other

variables become not significant at the .05 level, while the explained variance of the equation increases to .42. If indeed the quality variable employed here measures programmatic quality in departments likely to contribute to the industries under investigation, then one conclusion might be that high quality academic programs also are the most likely to produce research that is useful to private industry. The policy implication is that there is a positive social and economic benefit to society from raising the quality of certain academic programs that may not be currently taken into account when making institutional or state funding decisions.

The second equation in Table 4 employs an interaction term between the quality score and the technological research dollars variable. The explained variance of the equation is very high (r-square of .57), and the interaction term is positive and significant. The equation implies that it is not just the presence of research dollars or high quality faculty alone that make the difference in producing research that is utilized by private industry, but rather, it is the combination of high quality faculty and available resources that matters. If this is true, the most cost-effective policy in this arena for assisting private industry would be to direct a disproportionate share of the research dollars towards the highest quality programs. It is likely, however, that high quality programs already receive a large share of the research dollars, and that these results only tell us what the academic and political marketplace already

knows.

Conclusions

Our results suggest that research expenditures, land grant status, and faculty salaries are associated with university production of research of interest to firms in the aircraft and computer equipment industries. This would appear to indicate that universities with many resources available for research, a history of applied research or outreach, and well paid faculty (which may also reflect a market induced measure of quality) are best suited to produce the research needed in the industrial sector. Urban locations and the presence of a research park are not significantly related to producing such research in the context of our study.

Drawing conclusions for the equations limited to those institutions for which quality indicators are available should be approached with care. The quality variable is highly correlated with the resource variables and there are problems deciphering what the quality indicators are truly measuring. Still, for the colleges and universities remaining in our sample we see that "quality" institutions are more apt to produce research of use to industry, that there is an interaction between quality and research dollars, and that institutions with quality faculty are more likely to make use of research dollars in a manner most compatible with firm needs.

The ability to distinguish the characteristics of

universities that firms turn to for information may assist state and federal agencies, industry, institutional planning offices, and other resource providers in new determinations of funding allocations for post-secondary research. This study suggests that increasing research expenditures and faculty salaries would promote information transfer between the sectors (although we cannot draw any conclusions as to how large an increase is enough), especially if the money is directed toward institutions with an outreach or service emphasis (land grant status). Fostering these environments in other schools might then be a first step. The list of cited institutions suggests that industry is garnering information from a broad range of colleges and universities and so a wider distribution of funding may be advantageous.

Targeting a narrower range of institutions may have a more immediate benefit. Our results suggest that an increase of resources to high quality faculty located in established research departments is likely to produce the type of research industry is looking for. If this is true, then there are efficiencies to be gained by supporting the research of higher quality faculty members, at the expense of broad support for all researchers.

By means of citation analysis we have been able to identify characteristics of universities that help predict where industry looks for research knowledge. This methodology has exciting possibilities for further investigation of university/firm cooperation. For example, an examination of the citation

practices of firms in other industries (particularly those based on the biological and medical sciences) is warranted, along with a series of comparisons over time. Areas of non-scientific university-practitioner collaboration, such as in the fields of psychology or counseling, could also be explored, albeit with more difficulty since the transfer of knowledge may not be as well represented in the publication and citation patterns for these fields. Given the lack of scholarly investigations of this nature, further examination of the characteristics of the higher education institutions that the private sector turns to for research knowledge is called for.

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Appendix A

Institutions of higher education cited in the sample of papers:

Appalachian State, NC
Arizona State University, AZ
Athens University, AL
Boston University, MA
California State University, Northridge, CA
California Institute of Technology, CA
Carnegie-Mellon University, PA
Case Western Reserve University, OH
Catholic University of America, DC
Central University of Iowa, IA
Central Washington University, WA
Clarkson University, NY
Colorado State University, CO
Columbia Union College, MD
Columbia University, NY
Cornell University, NY
City University of New York, Mt. Sinai School of Medicine, NY
Dartmouth College, NH
Drexel University, PA
Fisk University, TN
Florida State University, FL
George Washington University, DC
Georgia Institute of Technology, GA
Harvard University, MA
Harvey Mudd University, CA
Illinois Institute of Technology, IL
Indiana University at Bloomington, IN
Iowa State University of Science/Technology, IA
Johns Hopkins University, MD
Kansas State University, KS
Lehigh University, PA
Louisiana State University, LA
Massachusetts Institute of Technology, MA
Michigan State University, MI
New York Institute of Technology, NY
New York University, NY
North Carolina State University, NC
Northwestern University, IL
Oakland University, MI
Ohio State University, OH
Ohio University at Athens, OH
Oregon Graduate Center, OR
Oregon State University, OR
Pennsylvania State University, PA
Polytechnic University, NY

Princeton University, NJ
Purdue University, IN
Queens College, NC
Rensselaer Polytechnic Institute, NY
Rice University, TX
Rutgers, State University of New Jersey, NJ
Salisbury State University, MD
Seaton Hall, NJ
Southeastern Mass University, MA
Southern Methodist University, TX
Stanford University, CA
State University of New York at Albany, NY
State University of New York at Buffalo, NY
State University of New York at Stony Brook, NY
Syracuse University, NY
Tennessee Technical University, TN
Texas A&M University, TX
Texas Tech University, TX
Thiel College, PA
Tulane University, LA
University of Arizona, AZ
University of Arkansas, Fayetteville, AR
University of California at Berkeley, CA
University of California at Davis, CA
University of California at Irvine, CA
University of California at Los Angeles, CA
University of California at San Diego, CA
University of California at Santa Barbara, CA
University of California at Santa Cruz, CA
University of Chicago, IL
University of Cincinnati, OH
University of Colorado at Boulder, CO
University of Connecticut, CT
University of Dayton, OH
University of Denver, CO
University of Florida, FL
University of Houston, TX
University of Illinois at Chicago, IL
University of Illinois at Urbana, IL
University of Iowa, IA
University of Kansas, KS
University of Massachusetts at Amherst, MA
University of Maryland at College Park, MD
University of Miami, FL
University of Michigan, Ann Arbor, MI
University of Minnesota, Duluth, MN
University of Minnesota, Twin Cities, MN
University of Missouri, Columbia, MO
University of Missouri, Rolla, MO
University of Nebraska, Lincoln, NE
University of Nevada at Reno, NV
University of New Mexico, NM

University of Oklahoma, Norman, OK
University of Oregon, OR
University of Pennsylvania, PA
University of Pittsburgh, PA
University of Rochester, NY
University of South Florida, FL
University of Southern California, CA
University of Tennessee at Knoxville, TN
University of Texas at Austin, TX
University of Utah, UT
University of Virginia, VA
University of Washington, WA
University of Wisconsin at Madison, WI
University of Wisconsin at Milwaukee, WI
Vanderbilt University, TN
Virginia Polytechnic Institute, VA
Wesleyan University of Connecticut, CT
Widener University, PA
Wilkes College, PA
Yale University, CT

TABLE 1

INSTITUTIONS AND FRACTIONAL CITATIONS BY CARNEGIE CLASSIFICATION

CARNEGIE CLASSIFICATION	NUMBER OF INSTITUTIONS	FRACTIONAL CITATIONS			
		MEAN	MIN	MAX	SUM
RESEARCH I	59	5.87	0.25	37.59	346.40
RESEARCH II	16	1.96	0.20	6.00	31.40
DOCTORATE-GRANTING I	11	2.28	0.50	4.50	25.08
DOCTORATE-GRANTING II	8	1.46	0.50	3.00	11.67
OTHER	23	0.96	0.03	6.50	22.08
TOTAL	117	3.73	0.03	37.57	436.63

TABLE 2

DESCRIPTIVE STATISTICS FOR INSTITUTIONS
(N = 117)

VARIABLE	NOTES	MEAN	SD	MIN	MAX
TOTAL TECHNOLOGY RESEARCH DOLLARS ($1000'S)	a	21478.2	37749.5	0	315584
LANDGRANT INSTITUTION	b	0.23	0.42	0	1
URBAN INSTITUTION	c	0.42	0.49	0	1
RESEARCH PARK PRESENT	d	0.23	0.42	0	1
PRIVATE INSTITUTION	e	0.41	0.49	0	1
NUMBER OF GRADUATE DEGREES AWARDED 1987		1326.3	1076.7	0	4937
INSTITUTION ENROLLMENT 1987		18141.2	12314.5	150	53115
AVG FACULTY SALARY ($1000'S)	f	38.87	5.05	22.53	50.83
STANDARDIZED QUALITY RATING	g	50.80	8.93	32.00	73.00

NOTES.

a) Technology research dollars was defined as the amount of externally funded or separately budgeted research dollars expended by the departments of Physics, Math, Computer Science, and all Engineering units within the institution for 1987.

b) 1 = Institution is a land grant institution.

c) 1 = Institution is located in an urban area.

d) 1 = A research park is affiliated with the institution.

e) 1 = Institution has private affiliation.

f) n = 111.

g) n = 92.

TABLE 3

REGRESSION MODEL AND RESULTS

Dependent Variable:	Fractional Citations
N:	111
R-Square:	0.34
Sig of F for equation:	< 0.001

VARIABLE	B	T-STAT	T SIG
Research Park	-0.45	-0.39	0.694
Urban Area	1.22	1.24	0.218
Land Grant Institution	2.72	2.34	0.021
Technology Research ($1000's)	3.63 E-05	2.55	0.012
Avg Faculty Salary ($1000's)	0.44	4.3	< 0.001
Constant	-15.2		

TABLE 4

REGRESSION MODEL AND RESULTS WITH QUALITY VARIABLE

Equation Number	1			2		
Dependent Variable:	Fractional Citations			Fractional Citations		
N:	92			92		
R-Square:	0.42			0.57		
Sig of F for equation:	< 0.001			< 0.001		
VARIABLE	B	T-STAT	T SIG	B	T-STAT	T SIG
Research Park	-0.68	-0.56	0.578	-0.91	-0.87	0.388
Urban Area	0.63	0.58	0.562	0.5	0.54	0.593
Land Grant Institution	1.78	1.47	0.145	1.42	1.36	0.179
Technology Research ($1000's)	2.13 E-05	1.44	0.155	-4.01 E-04	-5.08	< 0.001
Quality Score	0.39	5.89	< 0.001	0.21	3.05	0.003
Quality - Research Dollars Interaction				7.40 E-06	5.42	< 0.001
Constant	-16.61			-6.85		