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University–industry collaboration: Patterns of growth for low- and middle-level performers[1]

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Abstract. Following landmark legislation passed more than 20 years ago, university–industry relationships have now become central to understanding the changing role of research universities in American Society. The paper analyzes the development of university–industry partnerships during the 1990s. Past studies have used a broad array of measures of ties and a variety of research methodologies, but they have shared a focus on top collaborators or on samples of universities skewed toward the top. However, findings based on top collaborators may not be valid for other universities. Universities involved in mid- to low-levels of collaboration are qualitatively different in many ways from the more extensively studied set of top collaborators, suggesting that characteristics affecting university–industry ties may not be the same for these institutions. The paper shifts the focus away from top collaborators to this sizable and less studied majority. In general, we find that the same characteristics predicting high levels of involvement for the sample as a whole also predict high levels of involvement for the sub-sample of mid- and low-level collaborators. However, We find some particular characteristics of these institutions, such as land grant status, are also associated with stronger ties to industry, and that some characteristics of 25 top institutions do not predict the level of involvement of these lower-level collaborators. We will discuss whether the licensing of new technology is likely ever to become an important source of net revenues for current middle and low-level collaborators. Our findings raise doubts about whether many universities below the top 25 will earn substantial net revenues from licensing, though they do not dispute the potential service value of these ties. The study is based on examination of a wide range of potential influences on university–industry collaboration for institutions that are not currently among the most heavily involved in partnerships. These include status, other institutional characteristics (such as size and control), investment in science and engineering, and characteristics of offices or technology transfer.

Keywords: University–industry collaboration, licensing activity, industry expenditures.

More than 20 years have passed since landmark legislation in the United States ushered in a period of growth in university–industry partnerships. Since the introduction of these new laws, economic development has become an integrated part of the mission of America's leading research universities. Studying university–industry partnerships is therefore central to understanding the changing role of research universities in American society.

A major step in understanding the growth of university-industry ties is to identify which universities are most involved, and what it is about them that explains their involvement. Past studies have used a broad array of measures of ties and a variety of research methodologies, but they have shared a focus on top collaborators or on samples of universities skewed toward the top. These studies have provided valuable information about the organizational characteristics that influence university–industry ties for this population. However, findings based on top collaborators may not be valid for other universities. Universities involved in mid- to low-levels of collaboration are qualitatively different in many ways from the more extensively studied set of top collaborators, suggesting that characteristics affecting university–industry ties may not be the same for these institutions.

Our study shifts the focus away from top collaborators to this sizable and less studied majority. In general, we find that the same characteristics predicting high levels of involvement for the sample as a whole also predict high levels of involvement for the sub-sample of mid- and low-level collaborators. However, we find some particular characteristics of these institutions, such as land grant status, are also associated with stronger ties to industry, and that some characteristics of top 25 institutions do not predict the level of involvement of these lower-level collaborators. We will discuss whether the licensing of new technology is likely ever to become an important source of net revenues for current middle- and low-level collaborators. Our findings raise doubts about whether many universities below the top 25 will earn substantial net revenues from licensing, though they do not dispute the potential service value of these ties.

Using data from the Association of University Technology Managers (AUTM), we examine trends in university collaborations for the decade of the 1990s, and we conduct a more detailed investigation of the institutional attributes connected to higher and lower levels of collaboration for the year 2000. The study uses three measures of university–industry ties: (1) funds received from industry for research and development (R&D); (2) number of licenses generated by university research; (3) amount of licensing income received. The study is based on examination of a wide range of potential influences on university-industry collaboration for institutions that are not currently among the most heavily involved in partnerships. These include status, other institutional characteristics (such as size and control), investment in science and engineering, and characteristics of offices of technology transfer.

A changing mission

Beginning in the 1980s, a series of legislative and policy changes were enacted in the United States to promote university–industry partnerships.[2] Notable among these were the Bayh–Dole Act of 1980, which permitted universities to retain the property rights of innovations arising out of federally-funded projects and the Stevenson–Wydler Technology Innovation Act of 1980, which directed agencies with research budgets to allocate .5 percent of R&D funds to technology transfer. The Economic Recovery Tax Act of 1981 provided a tax credit for incremental increases in research and development (R&D) (Dustira 1992). These acts were intended to aid economic development, boost US economic competitiveness, and augment university R&D budgets.

The new legislation was enacted against the backdrop of important economic and political change. By the late 1970s, American business had lost the global advantage it gained in the aftermath of World War II, and the country faced both recession and inflation (Geiger 1993). The Reagan and Bush administrations were oriented toward privatization and deregulation as a stimulus to economic growth (Slaughter and Leslie 1997). Eliminating the "bottleneck" between university research and commercial application was identified by Republican policy makers as a potential source of renewed advantage in the marketplace (Feller 1997), at the same time that industry funding of research was seen as an alternative to federal funding (Slaughter and Leslie 1997).

Universities had their own reasons for interest in new partnerships with industry. They faced shrinking R&D budgets as funds from federal sources declined (Geiger 1993; Hackett 2001; Waugaman and Porter 1992). By establishing or expanding ties with industry, universities saw the opportunity to increase their resources for research and to enhance their reputations (Fairweather 1988; Geiger 1993). Changes in organized science further encouraged university interests in expanding technology transfer. Time from discovery to application had been shrinking, while the scale of research in the sciences and applied sciences continued to grow (Cooper and Novitch 1992; Geiger 1993; Waugaman and Porter 1992). Thus, the interest of leaders in government, industry, and universities converged just enough for the establishment of a more attractive environment for university-industry partnerships (Fairweather 1988; Geiger 1993; Hackett 2001; Louis and Anderson 1998; Powell and Owen-Smith 2002; Slaughter 1990; Slaughter 1993).

Of course, some universities had long been involved with industry (Cote and Cote 1993; Croissant and Restivo 2001; Feller 1997; Geiger

1993; Slaughter and Leslie 1997). From the time of their founding, the land grant universities were expected to contribute to the economic vitality of their states, and some private universities with strong engineering programs also encouraged collaborative relations with industry from the beginning (MIT and Stanford are noteworthy examples). Citing these historical examples, some researchers have argued that the new industry partnerships of the 1980s and 1990s did not substantially alter the priorities of research universities (Cote and Cote 1993).

Most researchers, however, have argued that the scale and nature of university–industry partnerships during the 1980s and 1990s set them apart from earlier, more limited collaborations. The increase in the number of ties, and especially in the magnitude of investments, has been sizeable, whether one measures patenting, licensing, or industry expenditures on university R&D (Duistra 1992; Feller 1997; Hackett 2001; Mansfield 1995; Owen-Smith 2001; Powell and Owen-Smith 2002). Perhaps equally important, the conditions under which grants are made have also changed dramatically. Unrestricted funding, which allowed universities to define how funds would be used, comprised a larger share of R&D funding from industry before the 1980s (Slaughter and Leslie 1997). Over the last quarter century, relationships have been increasingly based on restricted funds targeting specific research. This can have a significant impact on the way individuals and even units conduct research, skewing effort toward commercially attractive projects (ibid).

Trends in university–industry ties

Using annual data reported by AUTM, Figure 1 shows the level of industry funding received in 2000 for each of 113 research universities arranged from greatest to least. Levels of funding vary greatly for this set of 113 universities, industry expenditures for university R&D ranged from $63,000 to almost $110 million.

Figures 2–4 disaggregate universities into two groups: the top 25 universities in industry funding for R&D and the remaining 88 universities. These 88 universities are middle to low level collaborators and comprise our primary study population. We designate mid- to low- level collaborators as those receiving less than $20 million in R&D funding from industry in 2000. Figures 2–4 show the separate trend lines for the two groups across a ten-year period in R&D funding from industry, licensing, and licensing income. In these trend graphs, we report mean

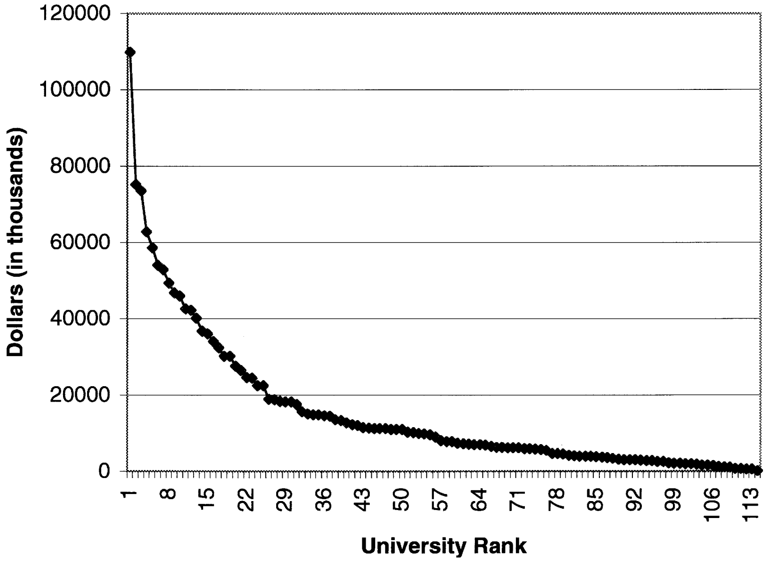

Figure 1. Industry expenditures on university R&D in 2000 (n = 113).

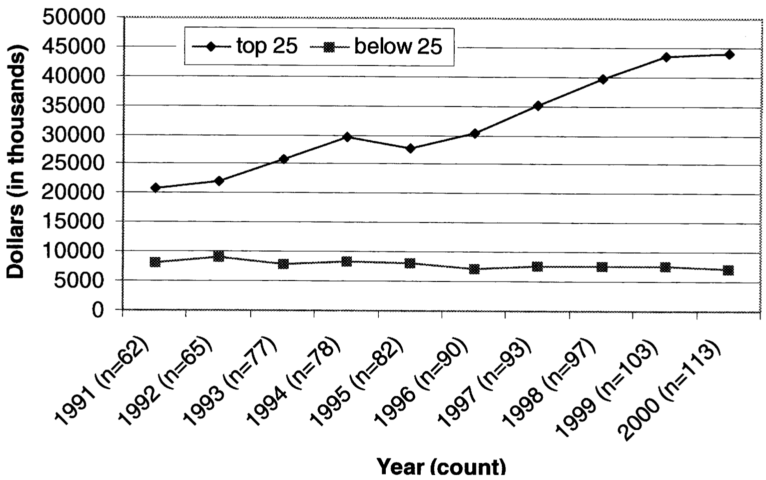

Figure 2. 10-Year trend of average industry expenditures on university R&D (adjusted to 2000 dollars).

figures for the two groups. The N for each year refers to the number of institutions reporting which meet our criteria for inclusion in the sample. The ten-year trend lines indicate that a division persists between these two groups of collaborators across time and across all three measures of collaborative ties.

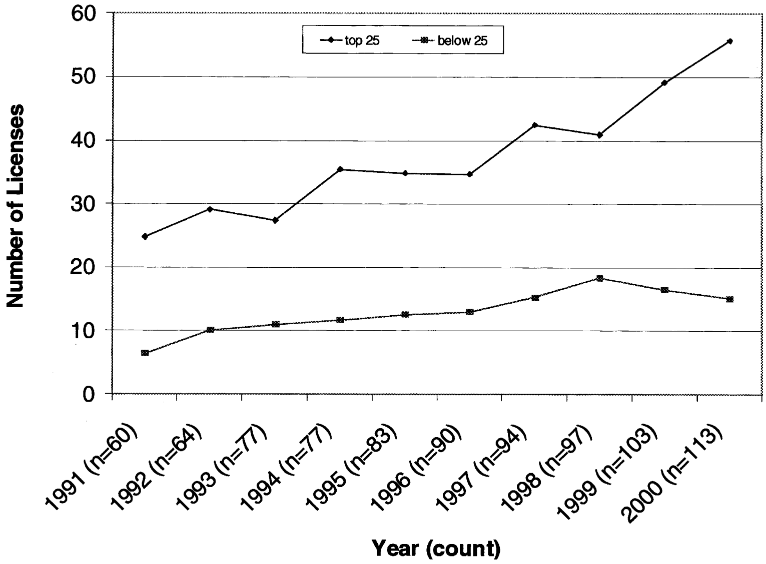

Figure 3. 10-Year trend of average number of university licenses granted to industry, comparison of top and mid to low level collaborators.

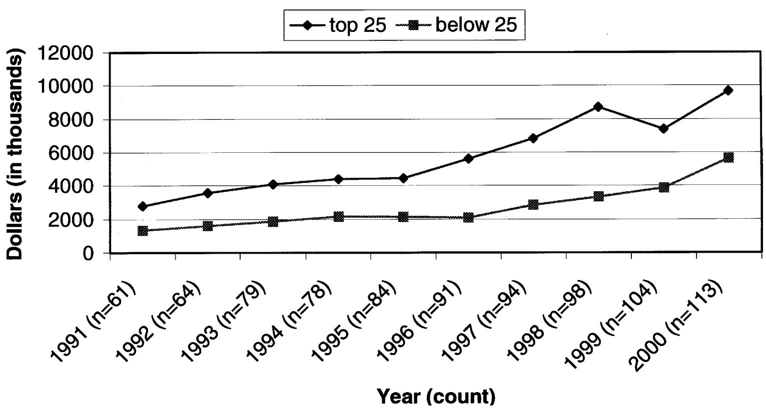

Figure 4. 10-Year trend of average university licensing income, comparing top and mid to low level collaborators (adjusted to 2000 dollars).

In 1991, average industry R&D funding for top collaborators was about two and one-half times that of other collaborators.[3] Figure 2 shows that over the ten-year period the division between the two groups grew wider. By 2000, the first group was receiving, on average, more than six times the amount of funding as the second group. Industry funding for the top 25 universities increased, on average, by 112 percent over the decade (from about $20.7 million to about $44.1 million), while industry funding for the 88 other universities fluctuated, on average, between $7 and $9 million during the period.[4]

Figure 3 shows that the average number of licenses granted to industry remained about four times greater for top collaborators than for other universities across ten years.[5] On average, top collaborators increased the number of licenses granted from 25 to 56 across the ten years, while the number of licenses granted in the second group grew from an average of 6.5 licenses in 1991 to 15 in 2000. The top group increased its licensing volume by 124% from 1991 to 2000, while the other set of universities again increased its volume at a higher rate, by 135%.[6] For this set of universities, both licensing income and volume increased at a faster pace among mid- to low- level collaborators compared to top collaborators, indicating that, as a group, they are rising in prominence in licensing activity.[7]

Figure 4 shows that average licensing income remained about two times greater for the top collaborators over other universities across the ten years.[8] Licensing income in the top group grew from an average of approximately $2.8 million to $9.7 million, while licensing income in the second group climbed from an average of approximately $1.4 million to $5.6 million. The top group increased its licensing income by 245% from 1991 to 2000, and, although a wide gap remained, the second group increased its licensing income at a somewhat higher rate, by 309%.[9]

These graphs of ten-year trends show that the top collaborators stayed well above other universities during the decade, and only the top collaborators experienced a dramatic increase across all measures. Mid- to low-level collaborators did not receive significantly more R&D funds from industry than in the past, but they licensed more of their research. The sharp differences in industry funding of research, in particular, hint at the desirability of separating universities according to their level of involvement with industry to fully appreciate the implications of the divergence among university groups based on industry ties.

Differences by tier

Past studies of university–industry collaborations have been oriented toward top tier institutions. Samples have been based on Carnegie Research I universities (Owen-Smith 2001), membership in the Business-Higher Education Forum, a prestigious gathering of influential industry and university leaders (Slaughter 1990), or presidents whose universities are members of the Association of American Universities (AAU)

(Slaughter 1993). Similarly, case studies and content analyses often focus on relationships involving top institutions or relationships involving high dollar investments (Powell and Owen-Smith 2002; Rhoades and Slaughter 1991).

Universities involved in middle- and low- level industry partnerships are highlighted in this study primarily because their characteristics also differ appreciably from those of top collaborators, suggesting that the characteristics explaining levels of involvement with industry may vary between the two groups, and that the value of industry collaboration may consequently also differ significantly between the two groups. Table 1 compares the top 25 collaborators with 88 other institutions on a number of institutional characteristics. These include: status, finances, size, control, and office of technology transfer (OTT) characteristics.

Table 1 indicates that the top 25 universities are much more likely to be Carnegie Research I universities, to be members of AAU, and to have higher ratings on scholarly quality of their programs according to the National Research Council (NRC)[10] compared to mid to low-level collaborators. In addition, they are less likely to be a public or land grant institution, and they are more likely to have a medical school. They tend to be much larger, as measured by number of faculty and by the number of graduate students enrolled in science and engineering programs. Their operating budgets per student are much higher, and they have substantially larger amounts of federal expenditures on R&D. Their offices of technology transfer are both older and better staffed. Data from Table 1 suggest that universities below the top 25 form a distinct population from top collaborators.

The differences between the two sets of institutions suggest the possibility that top collaborators operate within a different milieu and climate of expectations regarding industry collaborations and, consequently, that the forces bearing on levels of collaboration among mid- to low-level collaborators may be different from those bearing on top collaborators. An alternative possibility is that the same characteristics predicting high levels of involvement for top collaborators will also predict high levels of involvement for mid- to low-level collaborators. The first possibility implies inter-class heterogeneity in sources of industry involvement; the second implies inter-class continuities in these sources of involvement.

In general, we expect that the same characteristics associated with high levels of involvement with industry for top collaborators to be associated also with higher levels of involvement with industry for lower-level collaborators. It seems likely, for example, that compara-

Table 1. Comparison of top 25 in industrial expenditures on university R&D with other universities on organizational variables 2000

		Top 25	Below 25
Status			
Carnegie classification	Research I	24 (96%)	42 (48%)
	Research II	1 (4%)	25 (28%)
	Doctorate I & II	0	17 (19%)
	Bach. and Masters	0	4 (5%)
AAU membership	Member	20 (80%)	24 (27%)
NRC scholarly quality, 1995	Range 0–5,	3.01 (25)	2.34 (88)
	0 = Insufficient	sd* = .65	sd = .65
	5 = Distinguished		
Institutional characteristics			
Control	Public	16 (64%)	63 (72%)
Land grant institution	Land grant	7 (28%)	34 (39%)
Medical school	Medical school w/campus	19 (76%)	39 (44%)
Size of faculty, 1999	Number of FTE faculty, 1999	1204 (25) sd = 485	844 (88) sd = 414
Size of science and engineering (S&E) student population	Number of students in S&E**	2726 (25) sd = 1201	1324 (88) sd = 794
University finances			
Operating budget	Operating budget per student	64,354 (25) sd = 44,749	42,574 (88) sd = 96,589
Research expenditures	Fed. expenditures on R&D	254 mil (25) sd = 189 mil	67 mil (88) sd = 68 mil
Technology transfer offices			
Age of OTT office	Number of years since establishment	18.76 (25) sd = 12.21	11.4 (88) sd = 10.4
Size of OTT office	Professional FTE for technology transfer	5.6 (25) sd = 3.7	2.1 (88) sd = 1.9

*sd = standard deviation.
**S&E = engineering, physical science, geological science, math & computer science, life science.

tively high operating budgets per student will provide both the resources and the incentives for involvement with industry. Similarly, comparatively large numbers of science and engineering students on campus provide the manpower to increase industry ties. The existence of a medical school provides the context for expansion of industry ties, since medical schools are active locations of industry-related research.

At the same time, we expect that some relationships will differ between the two tiers. Our expectations are based on an assessment of the locations in which the strongest incentives and opportunities exist for involvement with industry, and, second, an assessment of what it takes to overcome initial disadvantages in the context of a system strongly influenced by resource inequalities and "first mover" advantages. Our underlying framework, then, is based on understanding the logic of opportunities and compensations within a highly stratified organizational structure.

Top collaborators include a mix of private and public research universities, because faculty quality and university motivations to collaborate span both forms of control. Among lower-level collaborators, we expect the historical mission of the universities to play a larger role. In particular, land grant universities were from the beginning expected to work with agriculture and industry to contribute to the economic development of their states (Nevins 1962). Many of these institutions took this charge seriously and created agricultural extension centers and industrial research centers. The long-standing commitment of land grant universities to state economic development may therefore be expected to carry over into the new technology transfer environment of the post-1980 period.

Opportunity structures can differ in other ways between the two tiers. In top tier universities, high levels of research support from the federal government have helped to support expanded industry ties. Institutions with high levels of federal support have equipment and expertise that is of value to industry (Geiger 2004: chap. 5). In addition, federal grants have been responsible for discoveries with commercial potential, and the federal government has strongly supported efforts to commercialize new discoveries. For these reasons, leaders in technology transfer are often also among the leaders in federal research support.[11] Institutions with lower levels of federal support typically have fewer research accomplishments to commercialize and they may also feel less pressure from the federal government to commercialize discoveries. Moreover, some institutions without strong traditions of federal support may look to industry sponsorship as an important alternative source of research funding, further weakening the relationship between federal research support and industrial ties for lower level collaborators.

One of the strongest indicators of whether a university has pursued economic development in earnest is its investment in an office of technology transfer. Professional staff members in these offices assist with patenting and licensing and collaborate with faculty members to aid in further development of their inventions (Etzkowitz and Stevens 1998). The establishment of these offices signal that university administrators are willing to devote resources to promoting patenting and licensing of discoveries. Because mid- to low-level collaborators are disadvantaged as compared to the larger and wealthier institutions with "first mover" advantages, we expect that they will have to compensate by making comparably greater investments in offices of technology transfer in order to move forward in this new area.

Data and methods

Our study is based on the AUTM surveys of technology transfer for the years 1991 through 2000.[12] We identified individual campuses as our units of analysis. Data reported on a system-wide basis only were therefore eliminated from the sample.[13] Independent medical and health science centers were also eliminated from the sample.

In each year, the AUTM survey received an increasing number of responses ranging from 98 in 1991 to 142 in 2000 (AUTM 2000). We conducted our analysis on data for the year 2000. Eliminating system-wide data, medical and health science centers, and cases lacking information about funds received from industry reduced the AUTM sample from 142 to 113 institutions. We split this group of 113 universities into two groups, according to the level of industry funding for university R&D. The top 25 universities received \$20 million or more from industry in 2000. The remaining 88 universities comprise the main population of interest for this study.

Dependent variables

In this analysis, we use three measures of university–industry ties: (1) industry R&D funding to universities, (2) number of licenses granted from universities to industry, and (3) income received from licenses granted to industry.[14] Although number of patents is a common measure employed in the study of university–industry ties (see, e.g., Owen-Smith 2001; Webster 1998; Webster and Packer 1997), we believe it is a less valid measure of collaboration. Patenting does not measure collaboration directly, but rather protection of a right. It is, moreover, relevant only for certain types of knowledge surrounding laboratory science. Patents are not typically sought in some areas of innovation of interest to industry, such as desktop publishing (Feller 1997; Leydesdorff and Etzkowitz 1997). In contrast, anything that a faculty member produces that is of interest to industry can be licensed (Feller, 1997). From a strictly economic perspective, licensing income is the most important of the three dependent variables, because it brings new discretionary income to campus. It can also be seen as the best indicator of the service role of universities in the area of technology transfer; only technologies that firms think will find a market are licensed.

These dependent variables were selected to represent the bi-directional relationship of university industry ties – money from industry going to universities, licenses granted from universities going to industries, and payment for licenses going to universities from industry. Industry R&D funding and licensing income comprise a large share of the total funds universities receive from industry, and they therefore represent good measures of the extent of industry-influenced research taking place at a university. For universities below the top 25, licensing income nearly equals industry sources of R&D funding, on average, making it an important partner in measuring financial ties with industry.[15]

The measures are important also for their potential impact on organizational change in universities. Though industry funding continues to represent a small portion of total research funding – less than 10 percent – its effect may be greater than size alone suggests (Slaughter and Leslie 1997). A modest change in funding source can have a multiplier effect and cause major alterations in how academics spend their time (Slaughter and Leslie 1997). Government block funds for R&D generally involve the transfer of unconditional money, sustaining university autonomy. However, funds from industry are often targeted toward a specific research agenda. An increased level of industry funding may affect undergraduate and graduate education by taking faculty time away from teaching and re-orienting faculty interest toward industry needs (Cote and Cote 1993; Croissant and Restivo 2001; Malone 1992; Powell and Owen-Smith 1998; Slaughter and Leslie 1997).

Independent variables

Previous empirical studies have examined a number of organizational characteristics hypothesized to be related to the number and magnitude of university–industry ties. These studies have sometimes addressed dependent variables outside the scope of our analysis, such as joint publications, faculty consulting, university–industry consortia, contract research, patenting, joint ventures in research parks or organized research units, and faculty start-up companies (Owen-Smith 2001).

These studies nevertheless provide what amount to hypotheses about the characteristics of universities that are associated with higher levels of industry involvement. The studies have included quality and status factors, such as faculty salaries and reputation (Geiger 1993; Fairweather 1988; Mansfield 1995; Tornquist and Kallsen 1994); graduate student quality (Owen-Smith, 2001); membership in AAU (Slaughter 1993). They have also examined institutional characteristics, such as land-grant status (Tornquist and Kallsen 1994); public control (Slaughter and Leslie 1997); size (Tolbert); historical relations with industry (Geiger 1993; Fairweather 1988); president's background (Cote and Cote 1993). Some studies have also included measures of commitment to science, such as size of faculty and post-doctoral student populations in science (Owen-Smith 2001); total research expenditures and federal funding in science (Mansfield 1995; Owen-Smith 2001; Tolbert 1985; Tornquist and Kallsen 1994); investment in research-related infrastructure (Geiger 1993; Fairweather 1988). Several studies have examined characteristics of offices of technology transfer, such as the size and age of these offices (Graff et al. 2002; Webster and Packer 1997). Finally, some studies have investigated location variables, including urban location (Tornquist and Kallsen 1994); proximity to research parks or industrial partners (Mansfield 1995; Tornquist and Kallsen 1994).

We have drawn from these previous studies to identify variables that may explain levels of involvement with industry among our sample of mid- to low-level collaborators. We have attempted to include as many variables showing positive net associations in previous studies as we could, consistent with the relatively small number of cases in our sample. We included one measure of institutional status: average program rating of quality of faculty scholarship.[16] (Models incorporating AAU membership as a second measure of status showed no improvements in explanation and no instances of statistical significance for AAU membership). We included three measures of other institutional characteristics: public or private control[17] land grant status,[18] and total operating budget/student.[19] We included three measures of science intensity: presence of a medical school,[20] size of S&E on campus as measured by number of graduate students in science and engineering programs),[21] and federal expenditures on university R&D. We included two measures related to offices of technology transfer: age of the office and number of full-time professional staff.[22] We also included one location variable: the density of high technology industry surrounding the institution. We used the Milken Institute's "Tech-Pole Index" to measure the technological intensity of areas surrounding universities.[23] This is a composite index of an area's national high-tech real output and concentration of high-tech industries.[24]

The variables used in our analyses are summarized in Table 2.

Results

We assessed six models, two for each of the dependent variables. The first model in each table shows effects for independent variables when the full sample of top and lower level contributors is considered. The second model in each table shows the effects for independent variables when only the bottom 88 contributors are considered. By comparing results for the two models, we can isolate variables that have a stronger effect on the sample as a whole (weighted by top collaborators) than on mid- and lower-level collaborators only, and those that have a stronger effect on mid- and lower-level collaborators than on the sample as a whole. In this way, we can identify whether patterns of industry involvement are similar or different for the mid- to low-level collaborators as compared to top 25 collaborators.

We used ordinary least squares (OLS) multiple regression for the models involving industry expenditures on university R&D and licensing income. Because the dependent variable is not normally distributed and is bounded, the model for licensing volume does not conform to the assumptions of OLS. Most universities below the top 25 collaborators grant a small number of licenses – 75 percent of the universities grant fewer than 15 licenses, yet up to 218 licenses were granted. We therefore used generalized linear modeling (GLZ) for the model of licensing volume.[25] The other two dependent variables, industry R&D support and licensing income, are also bounded, but their distributions are close to normal and can be assessed using OLS if the dependent variables are logged. Two independent variables, federal expenditures on university R&D and operating budget per student, were also logged before they were entered into the models.[26]

Results of the analyses are reported in Tables 3–5.

Table 3 presents data for the effect of university organizational characteristics on R&D expenditures received from industry. The pat-

Table 2. Variables in the analyses

Variable name	Description	Measurement	Total sample*	Mid/Low collab.*
Dependent variables				
INDEXP	Industry expenditures on university R&D (2000)**	Continuous	\$63–\$109,809	\$63–\$18,988
LICEXEC	Number of licenses executed by a University (2000)	Continuous	0–218	0–218
LICINC	Licensing income (2000)**	Continuous	\$0–\$148,938	\$0–\$148,938
Independent variables				
PUBLIC	Institution is public or private (2000)	Categorical,		
		1 = public	79	63
		0 = private	34	25
LAND GRANT	University designated as land grant institution (2000)	Categorical,	41	34
		1 = Yes	72	54
		0 = No		
OPBUD/STUD	Operating budget per student (2000)**	Continuous	\$7–\$900	\$7–\$900
FACQLTY	Mean rating of faculty scholarly quality for all programs rated at a university (1995)	Continuous	.91–4.68	.91–4.37
FEDEXP	Federal expenditures on university R&D (2000)**	Continuous	\$1,196–\$921,076	\$1,196–\$363,000
TOTGRD S&E	Total number of graduate students in science and engineering departments (2000)	Continuous	107–4,730	107–4,015

Table 2. Continued.

MED-SCHL	Medical school is associated with the campus (2000)	Categorical,		
		1 = Yes	58	39
		0 = No	55	49
OTTAGE	Number of years institution has had an office of technology transfer (2000)	Continuous	0–65	0–65
OTTFTE	Number of professional FTE staff devoted to technology transfer who are at least half-time (2000)	Continuous	0–17.5	0–13.1
TECHPOLE	Milken's Tech-Pole Index Ranking (1999)	Continuous, low score = more tech.	1–302	2–302

* For continuous variables, range is in parentheses. For categorical variables, count is given.
** Financial variables expressed in thousands.

Table 3. Results of OLS multiple regression for the influence of university organizational characteristics on industry expenditures, 2000

Variables	Model 1 (all universities) b (s.e.)	Model 2 (bottom 88) b (s.e.)
INTERCEPT	5.1***	9.8***
	(1.9)	(1.9)
PUBLIC (1 = public)	−.08	−.21
	(.23)	(.23)
LANDGRANT (1 = land grant)	.16	.46**
	(.19)	(.20)
OPBUD/STUD	.44**	.31*
	(.18)	(.18)
FACQLTY	−.23	−.20
	(.16)	(.16)
FEDEXPEND	.33**	.13
	(.13)	(.13)
TOTGRDS&E	.00***	.00***
	(.00)	(.00)
MEDSCHL (1 = med school)	.30*	.43**
	(.17)	(.17)
OTTAGE	−.00	.01
	(.01)	(.01)
OTTFTE	.01	.05
	(.04)	(.05)
TECHPOLE	.00	.00
	(.00)	(.00)
Adj. R^2:	.58	.42

$^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$.

tern of effects is generally similar between the total sample population and the bottom 88 institutions only. In both cases, the size of the science and engineering population (as measured by graduate students in S&E) and the wealth of the institution (as measured by operating budget/student) are positively associated with increased industry funding of research. These influences are somewhat larger for the total sample, reflecting the influence of the top 25 institutions. Having a medical school is also positively associated with industry funding in both cases, but medical schools are a more important factor for lower-tier institu-

Table 4. Results of generalized linear model for the influence of university organizational characteristics on licensing volume, 2000

Variables	Model 1 (all universities) b (s.e.)	Model 2 (bottom 88) b (s.e.)
INTERCEPT	−9.3 ***	−6.6***
	(1.10)	(2.6)
PUBLIC (1 = public)	−.17	−.27
	(.24)	(.28)
LANDGRANT (1 = land grant)	.27	.26
	(.20)	(.25)
OPBUD/STUD	.34*	.46**
	(.21)	(.23)
FACQLTY	−.06	−.06
	(.17)	(.21)
FEDEXPEND	.43***	.20
	(.15)	(.17)
TOTGRDS&E	.00**	.00***
	(.00)	(.00)
MEDSCHL (1 = med school)	−.13	−.16
	(.19)	(.22)
OTTAGE	.01	.01
	(.01)	(.01)
OTTFTE	.10**	.12*
	(.05)	(.07)
TECHPOLE	.00	.00
	(.00)	(.00)
Scaled Pearson Chi Square	97.95	66.21
Degrees of Freedom	101	76

*$p < .10$, **$p < .05$, ***$p < .01$.

tions. Federal expenditures are significant for the analysis of the total sample, but not for the bottom 88 only. Land grant status is significant for the lower-level collaborators, but not for the total sample population. These patterns are consistent with our expectation that federal funding has spillover effects among to collaborators, and that land grant status encourages interaction with industry for the majority of research universities.

Table 4 examines licensing volume. Again, the pattern of effects in the two sample populations is similar. As in the analysis of industry expenditures on research, size of the science and engineering effort on

Table 5. Results of OLS multiple regression for the influence of university organizational characteristics on licensing income, 2000

Variables	Model 1 (all universities) b (s.e.)	Model 2 (bottom 88) b (s.e.)
INTERCEPT	.01	2.4
	(3.9)	(4.8)
PUBLIC (1 = public)	−.94**	−1.26**
	(.47)	(.56)
LANDGRANT (1 = land grant)	.31	.43
	(.39)	(.49)
OPBUD/STUD	.81**	.82**
	(.38)	(.45)
FACQLTY	−.40	−.54
	(.32)	(.38)
FEDEXPEND	.28	.16
	(.27)	(.33)
TOTGRDS&E	.00	.00
	(.00)	(.00)
MEDSCHL (1 = med school)	.53	.50
	(.35)	(.42)
OTTAGE	.02	.02
	(.02)	(.02)
OTTFTE	.22**	.41***
	(.05)	(.07)
TECHPOLE	.00	−.00
	(.00)	(.00)
Adjusted R^2:	.54	.48

*$p < .10$, **$p < .05$, ***$p < .01$.

campus and campus budgetary strength both show significant effects. The number of OTT professional staff also shows a positive net association with licensing volume, indicating that organizational effort often does generate increased volume. The effect of this variable is not, however, stronger for the lower 88 than for the population sample as a whole. Indeed, the effect is somewhat weaker for the lower 88 institutions, a finding that runs counter to our expectation. Consistent with our expectation, federal expenditures on R&D continue to show a spillover effect in the sample as a whole, but not for the lower tier institutions considered separately.

Table 5 shows results for our analysis of licensing income. Again, the effects are very similar between the two populations. Private institutions have a large advantage in licensing volume over public institutions, as do the wealthier institutions over the poorer institutions (as measured by operating budget per student). Size of the OTT staff is the only other variable in the model that shows a significant net effect. The effect is somewhat larger for the bottom 88 institutions than for the total sample population, a finding that modestly supports our expectation that OTT investments are likely to play a larger role for lower-tier institutions, because these institutions have to make up ground in an area in which inequalities and "first mover" advantages are great.

Discussion

One of the more interesting findings of these analyses is how few of the variables often associated with industry ties are significant. Faculty quality (as measured by NRC rankings), location near high tech industry (as measured by the Milken Index), and age of the technology transfer office showed no significant net effects on any of the three dependent variables. Many of the other variables in the model show significant net effects on one or two of the dependent variables, but not on all three.

Different patterns of effect were found for each of the three dependent variables. Most analysts assume that the same factors causing a high volume of licensing activity also cause a high level of licensing income, but this was not true in our analysis. Science and engineering intensity (as measured by number of graduate students in science and engineering) and economic strength (as measured by operating budget per student) were strongly related both to industry funding and licensing volume. Only the latter was strongly related to licensing income. In addition, medical schools helped to generate industry sponsorship of research, while large technology transfer offices helped to generate both a high volume of licensing and higher licensing revenues.

One way to summarize these findings would be to say, if institutions want to generate industry research support, they should have a strong science and engineering infrastructure, including a medical school, and past success in obtaining federal grants. They should also be wealthy enough to have high operating budgets per student. If institutions want to generate a high volume of licensed technology, they should build not only science and engineering intensity and wealth, but also operate a well-staffed technology transfer office. If institutions want to improve their chances of gaining high licensing revenues, they should be wealthy and operate a well-staffed technology transfer office, and it is apparently also helpful to be located in the private sector (where incentives may be stronger to commercialize new discoveries and where hiring may support such efforts).

An explanation of these findings requires close consideration of the meanings and processes of industry funding and licensing in research universities. Industry support for R&D has been a routine, if relatively minor, element of university research for a long time. Industry funding for university R&D typically comes in relatively small amounts and is intended for a wide variety of purposes, including use of specialized equipment, technical training of industry scientists, highly applied research relevant to a company's product line, and clinical trials of new medications (Geiger 2004: chap. 5). In some cases, consortia of companies will pool resources to fund industry-relevant research on new materials or new processes. Our data show that scientific capacity is an important influence on industry support of research. Universities with medical schools have garnered more industry support, too. This is not surprising during a period of rapid growth in biotechnology. Among mid- to low-level collaborators, land-grant universities have taken their historical mission to work with industry seriously and therefore show higher levels both of industry funded research and licensing volume.

Large-scale licensing of discoveries to industry is a more recent and a higher stakes activity. Our data suggest that scientific and engineering capacity remains an important factor in generating licenses, and that campus wealth is more important in this area than in the more traditional area of industry sponsored research. In addition, the capacity of technology transfer staff becomes important for improving chances of success in this new domain. As one moves from licensing volume to licensing income, scientific and engineering capacity becomes relatively less important, while campus wealth and campus culture become more important. High dollar returns on licenses depend greatly on those rare discoveries that are highly marketable (Powell and Owen-Smith 2002). The strength of the private sector variable in our analysis of licensing income suggests that some characteristics of private universities contribute to the successful commercialization of these rare discoveries. These unmeasured characteristics may include the capacity to recruit highly entrepreneurial scientists and technology managers and closer ties to influential business networks.

We find strong support for the notion that the same factors explaining industry ties for top 25 collaborators also explain industry ties for lower-level collaborators. Of the eight variables that showed significant net effects in Table 3, six measured organizational characteristics that were significant for both populations. Of the seven variables that showed significant net effects in Table 4, six measured organizational characteristics that were significant for both populations. Of the six variables that showed significant net effects in Table 5, all six measured organizational characteristics that were significant for both populations.

We find weaker support for our expectations concerning significant differences between the two populations. Land grant status showed a significant net effect on industry expenditures for the lower-tier institutions, as expected, but it failed to show a significant net effect on either measure of licensing. This suggest that many land grant institutions may be more comfortable with the traditional role of producing research for industry than with the new role of producing discoveries that can be licensed. Federal expenditures for R&D showed a significant net effect on industry-sponsored research and licensing volume for the population as a whole, but not for the lower-tier institutions. This conforms to our expectations, but this variable is insignificant for licensing volume. Finally, our expectation that larger investments in technology transfer offices would be necessary for lower-tier institutions to overcome "first mover" advantages was supported only in a modest way. Higher numbers of professional staff were somewhat more strongly associated with increased licensing income for mid- to low-level collaborators than for all institutions in the sample population, but the effect was sizable for both populations.

Conclusion

Many observers of higher education have welcomed what they see as a new era of entrepreneurial institutions that have incorporated economic development as a core mission. Industry funding for research is a central element of this vision. However, the vision appears to fit top collaborators much better than it fits the majority of research universities. The majority of institutions are not receiving increasingly large sums of money from industry to support research. Industry funding for mid- to low-level collaborators remained stagnant over the decade of the 1990s, and has declined, for many of these institutions, since that time.[27] Most industry-sponsored research comes in comparatively small increments for very specified purposes. Relationships are mainly between individual professors and individual companies (Geiger 2004: chap. 5). Universities have sought to expand these funds through building research parks and similar joint funded research activities. However, during periods of recession or slow growth, these funds are difficult to obtain, and many of these efforts are now languishing.

Licensing, by contrast, does appear to represent a potential for significant growth in university budgets. For middle- to low-level collaborators, both licensing volume and licensing income grew significantly during the period of our study. At the same time, licenses are more costly to produce than research grants and contracts. They require high levels of formalization, well-paid professional staff, and new organizational structures. Without looking at the costs involved in developing and maintaining licensing capacity, reports of gains in this area can potentially be misleading.

We have collected some data relevant to the question whether licensing revenues exceed the costs of technology transfer offices. We received responses to inquiries about operating budgets from 33 institutions (of 113 contacted), 8 from top collaborators and 25 from mid- to low-level collaborators.[28] For the responding universities, operating costs for top collaborators averaged between $2 and $3 million; for mid- to low-level collaborators operating costs ranged from $25,000 to $800,000. Six of seven top collaborators responding to the question said that income had exceeded costs in 2000, and only one of six responding said that income had never exceeded costs between 1991 and 2000. By contrast, nine of 14 lower-level collaborators responding to the question said that income had exceeded costs in 2000, but five of 14 responding said that income had never exceeded costs between 1991 and 2000. These data, though fragmentary, suggest that licensing is more likely to produce net revenues for top collaborators than for lower-level collaborators. At the same time, it also suggests that many (and perhaps a majority) of middle- and low-level collaborators do meet costs and generate surpluses, at least in ‘‘good’’ years.

Over time, licensing income will rise faster than OTT costs for most institutions. Several of our respondents noted that licensing incomes do not materialize for many years after licensing agreements are signed. Many bio-medical products are tested for a decade or more before they are marketed. Given this long gestation period, respondents estimated that most institutions require five to ten years to generate income above operating costs. One respondent from a mid- to low-level collaborator observed, ‘‘I think, over time and with commitment and diligence, licensing fees will exceed operational costs. Licensing and intellectual property is a long term (activity)... We got started five years ago and some of the fruits of the early deals are coming to pass right now. We also feel that the more disclosures we get, the better chance of finding the big winner."

Unfortunately, not all institutions have the "the ingredients of success," defined by one of our respondents as good technologies, a well-developed regional "high-tech" infrastructure, national reach, and dedicated, skilled technology transfer staff. Technology transfer remains a risky venture for universities lacking these ingredients. A respondent from one struggling technology transfer office observed, "Our patenting costs have risen and are expected to rise due to significant increase in total research expenditures. We recently added some...staff and therefore our total operating costs continue to rise. The workload on both the university tech transfer side, as well as the research foundation, continues to rise. Our revenue is starting to rise... whether net revenue exceeds total operating costs remains to be seen." Based on this fragmentary evidence, and the written comments we received to our inquiries, it seems likely to us that between 15 and 30 percent of all universities involved in technology transfer will encounter difficulties generating strings of years in which revenues exceed costs. This estimate is obviously subject to correction when more complete data become available.

Generation of an operating surplus is not the major explicit justification for technology transfer activities. As one of our respondents said, speaking for most, "Our primary goal is to get as much good technology out in the hands of the public (as possible)." This is a good reason for any university to pursue technology transfer. Even so, few would deny that pecuniary interests have played a role in the rapid growth of technology transfer activities.[29] Many universities have been able to use technology transfer as a source of new revenue; indeed, in at least one case, Columbia University, net revenue now approaches or exceeds $100 million annually. For low-level collaborators, however, technology transfer should not be pursued as a certain future revenue center, because, for quite a few, this will be a prescription for disappointment.

Notes

1. We would like to thank Robert A. Hanneman for suggestions that improved the quality of this paper.
2. These changes are discussed in Etzkowitz and Stevens 1998; Fairweather 1988; Powell and Owen-Smith 2002; Slaughter 1990; Slaughter and Leslie 1997; Slaughter and Rhoades 1996; and Waugaman and Porter 1992.

3. The analysis of trends is complicated by changes in sample sizes over time. To reduce the difficulties created by this variation, the range in expenditures for each group at each time period was examined. A comparison of range of scores shows that even though range mostly increased for the mid- to low-collaborators over time, this group remained consistently and substantially below top collaborators on all measures. For industry expenditures, the range of funds for the mid- to low-level collaborators is smaller than that of the top 25 collaborators across ten years. The top group had higher highs and higher lows in expenditures compared to the second group, with the greatest deviation in range between the two groups occurring after 1997. In addition, the same graph was generated including only those universities that had data for all years. The conclusion using pairwise data is much the same – average industry expenditures in mid- to low-level collaborations remained well below that of top collaborators. Pairwise sample size in each off the ten years is 15 for the top group and 30 for the mid- to low-level group.
4. Generating the graph using pairwise data for only 1991 and 2000, the top group ($n = 23$) had a growth rate of 121% in industry expenditures on university R&D while the second group ($n = 38$) experienced an average decrease of funds of 1% from 1991 to 2000.
5. The range in the number of licenses granted is more variable over time compared to the ranges of financial measures. However, by mid-decade, the number of licenses granted by the top performers of the mid- to low-level collaborators often surpassed licenses granted by top collaborators. Even so, the average number of licenses granted by the mid- to low-level group remained far below the top group. Using pairwise data for 1991 and 2000, the top group ($n = 22$) had a growth rate of 143% in licensing volume while the second group ($n = 37$) had an increase of 181%.
6. The mid- to low-level group contains one university, Iowa State University, that granted 2.5 times more licenses in 2000 than the next highest school. Without this outlier, the deviation between the two groups of collaborators is greater. Without the outlier, the growth rate from 1991 to 2000 for the bottom group becomes 99%.
7. Looking at only those universities that are included in both the 1991 and 2000 datasets, the magnitude of change is greater and the variation between the two groups is more remarkable. Considering all three measures of collaboration, the top group far surpasses the other group in growth in industry R&D funds, while the lower level collaborators far exceed the top collaborators in growth of licensing activities.
8. Data for licensing income is also incomplete for universities across this time period. Examining the range of scores for each group of universities in each year indicate that even though some universities in the lower group received increasing amounts of licensing income, the group average remained well below the average licensing income received by the top collaborators. The range across the decade became greater in the mid- to low-level group with the highest earners receiving more licensing income than the highest earners of the top collaborators after 1997. The average licensing income received by the mid- to low-level group remained between 42% and 62% of that received by the top group. Using pairwise data for 1991 and 2000, the top group ($n = 23$) had a growth rate of 267% in licensing income while the second group ($n = 37$) showed an increase of 741% from 1991 to 2000.

9. The mid- to low-level group in Figure 3 includes one university, Columbia University, which earned slightly over twice as much licensing income as any other university in that group in 2000. If this school is left out, the deviation between the two groups in licensing income earned over time becomes more striking. Without the outlier, the second group increased its licensing income 293% from 1991 to 2000, still a greater percentage increase than the top collaborators.
10. Science and engineering programs include all programs in the biological sciences, engineering, physical sciences, and mathematics.
11. Research support became somewhat more widely distributed between the mid-1980s and mid-1990s, but has remained stable since that time, with the top 20 percent of institutions receiving 30 percent of all research funds (NSB 2002: 5–14).
12. The National Science Foundation also collects information about university-industry ties. We ran extensive analyses on the NSF data on industry expenditures for university R&D. The NSF data included 66 matches to AUTM data on this variable. The two data sets matched on dollar amounts only 9 times; in 40 cases, NSF was higher than AUTM, and in 17 cases NSF was lower. The AUTM mean was higher and its range smaller. When the data is logged, the two sources provide similar results. We report results only for AUTM data in this paper, because the pattern of effects was similar in the two data sets, and because NSF does not collect data on the other two dependent variables in our analysis, number of licenses and licensing income.
13. The following cases included system-wide data: University of California, Texas A&M, State University of New York, University of Missouri, University of Massachusetts, University of Oklahoma, and University of Illinois. (The latter included system-wide data in 2000 only).
14. Source: AUTM (2000).
15. By contrast, average industry R&D funding is about five times greater than average licensing income for the top 25 universities.
16. Source: Goldberger et al. (1995).
17. Source: NCES (2000).
18. Source: NCES (2000).
19. Source: NCES (2000).
20. Source: AUTM (2000).
21. Source: Computer-Aided Science Policy Analysis and Research (WebCASPAR).
22. Source: AUTM (2000).
23. Source: Milkin Institute (1999).
24. If city location was not listed in the index for a university, we used the nearest listed city or metropolitan area.
25. The defining feature of GLZ is that it allows a researcher to attend to the error distribution of the dependent variable separately from the way in which the dependent variable and independent variables are linked (Gill 2002; Hox 2002). With multiple regression, treatment of non-normal data is usually done by transforming a variable and then running the model using ordinary least squares. With GLZ, the transformation, as well as the distribution type, is incorporated into the model and estimated using maximum likelihood. In our data, the dependent variable, number of licenses issued, most closely resembled a negative binomial distribution, so a log link function was used.

26. Correlations between independent variables are .6 or below, except in one case: federal expenditures are correlated .69 with operating budget/student. It is possible that including federal expenditures reduces the explanatory power of operating budget/student. When federal expenditures are removed from the model for the bottom 88, for example, operating budget/student becomes significant. We have left both variables in the models, because both federal expenditures and operating budget/student show strong net effects for the sample population as a whole on two of the dependent variables.
27. The division among the universities would likely be even more apparent if system-wide data were included in the study. Several campuses included as part of system-wide data have strong ties to industry and would be among the top collaborators. These include: UC-Berkeley, UCLA, UCSF, and Texas A&M-College Station.
28. The data is intended for illustrative purpose only. Only one-third of the offices we contacted responded and several said that their operating budgets were confidential. In addition, the different conventions used by institutions in calculating operating costs require extreme caution in interpreting this data.
29. It is possible that some universities pursue technology transfer activities primarily because this has become an accepted part of what it means to be a research university, very much as institutional theory would suggest.

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