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WHO BEARS THE GROWING COST OF SCIENCE AT UNIVERSITIES?

by

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I. Introduction

Scientific research has come to dominate many American university campuses. The growing importance of science has been accompanied by a growing flow of funds to universities to support research from federal and state government, corporate and foundation sources. What is not well known, however, is that an increasing share of the costs of the research at universities is being funded out of internal university funds. So it is natural for us to ask who bears the growing cost of the internal funds spent on research at universities?

We begin in the next section by sketching the reason for the growing cost of scientific research at universities and the reasons for the growing share of universities' research costs that are funded out of internal university resources. The latter include changes in federal indirect reimbursement cost policies and the growing cost of start-up funds for new faculty. We present evidence on the magnitude of start-up costs that universities face for new researchers in science and engineering fields from a survey that we undertook during the summer of 2002 of department chairs, deans and vice presidents of research at over 200 public and private universities.

Our paper then turns to an estimation of who bears the costs of internal research expenditures. Using panel data for 22 years for 228 universities, we estimate in the next section the impact of growing internal university expenditures on research on student/faculty ratios and the substitution of lecturers for tenure track faculty, on average faculty salaries and on tuition levels. Perhaps our most important findings are that universities whose research expenditures per faculty member have been growing the most rapidly in absolute terms, other factors held constant, exhibit the greatest increase in student/faculty ratios and, in the private sector, the largest increases in tuition levels. So while undergraduate students may benefit from being in close proximity to great researchers, they also bear part of the growing costs of research in the form of larger class sizes, fewer full-time professorial rank faculty members and higher tuition levels.

Finally, in the brief concluding section, we speculate on future directions that research on the impact of the growing cost of science on academic institutions might take and also about whether the growing efforts by universities to commercialize their faculty members' research may yield sufficient revenues to begin to offset the universities' increasing costs of scientific research.

II. The Growing Importance and Costs of Science

Scientific research has come to dominate many American university campuses and this is reflected in the way universities are ranked. *U.S News & World Report's* annual ranking of national universities as undergraduate institutions places heavy weight on the institutions' expenditures per student and research expenditures are included in this total.[1]

The 1994 Carnegie Foundation classification of PhD granting institutions into Research I, Research II, Doctoral I and Doctoral II institutions was heavily based on the institutions' volumes of external research funding and institutions strove mightily to increase their funding to receive a higher classification in the next Carnegie classification revision.[2] Concerned that universities were placing too much weight on the volume of their faculty members' external research funding and not enough on the quality of their graduate programs, Carnegie collapsed its four PhD institution categories into two in

[1] *U.S. News & World Report* (2001)
[2] Carnegie Foundation for the Advancement of Teaching (1994)

2000 and based a university's classification solely on the number of PhDs that the institution produced each year.[3] Over 150 institutions are now included in the category doctoral extensive, which includes those institutions the produce the greatest number of doctoral degrees per year. This total is up from the 87 institutions that were classified as Research I in Carnegie's 1994 classification.

As a result of this change, the 2000 classification "watered down" the prestige that universities received from being included among the institutions in Carnegie's "top" university category. Not surprisingly, major research universities increasingly turned to their membership in the prestigious Association of American Universities (AAU), an association of 63 major research universities, to stress their prestige and research universities that were not currently members of the AAU increasingly sought to be admitted.[4] While the specific criteria for being considered for membership in the AAU are not public, an institution's volume of external research funding is clearly important.

Viewed in terms of 1998 dollars, the weighted (by faculty size) average volume of total research and development expenditures per faculty member across 228 American research and doctoral universities increased from about $70,000 per faculty member in 1970-1971 to about $140,000 per faculty member in 1997-1998.[5] This growth in scientific research, which was fueled by the availability of funding from government, corporate and foundation sources, did not derive primarily from the various ranking and

[3] Carnegie Foundation for the Advancement of Teaching (2001).
[4] For example, on the page of its World Wide Web Site titled "Claims to Fame", Stony Brook University declares, "As one of the only two universities invited this year to join the Association of American Universities (AAU), Stony Brook becomes one of 63 members that includes such institutions as Harvard, Yale, Johns Hopkins, Princeton and Stanford." (http://www.stonybrook.edu/sb/claims)
[5] The figures that follow are all computed from the NSF WEBCASPAR system (http://caspar.nsf.gov).

classification schemes, but rather from the major advances being made in science and the importance of these advances to our society.

To take but one example, recent advances in decoding the human genome, in advanced materials and in information sciences promise major advances in health care treatment in the years ahead. Any university worth its salt wants to be a leader in these fields so that it can attract top faculty, undergraduate and graduate students, increase its research funding for its programs and potentially achieve financial returns by commercializing its faculty members research (a point we return to below). To illustrate the attention that institutions are paying to promoting the value of their faculty members' research to society, table 1 summarizes the titles of some of the press releases issued by our own university during the first 9 months of 2002 that deal with faculty research in the health and nutrition area.

What is not well recognized, however, is that in spite of generous external support for research, increasingly the costs of research are being borne by the universities themselves. During the 1970-1971 to 1997-1998 period, the weighted average institutional expenditure on research per faculty member at the 228 universities more than tripled. As a result, as figure 1 shows, the weighted average percentage of total research expenditures per faculty member being financed out of institutional funds rose from about 11 to 20 percent during the period. Increasingly the academic institutions themselves are bearing a greater share of the ever-increasing costs of scientific research.

There are a number of forces that have led to the costs of research borne by universities to soar over the past three decades.[6] Theoretical scientists, who in a previous generation required only desks and pencils and paper, now often require supercomputers.

[6] These forces are discussed in more detail in Ehrenberg (2000, chapter 6) and Ehrenberg (forthcoming).

Experimental scientists increasingly rely on sophisticated laboratory facilities that are increasingly expensive to build and operate. Research administration now includes strict monitoring of financial records and environmental safety, as well as the detailed review and monitoring of experiments involving human subjects.

Historically the federal government and other external funders through the provision of indirect cost recoveries have funded much of the research infrastructure that universities operate, as well as their research administration costs. Each institution was allowed to mark-up the direct costs that its faculty members requested from external funders for research support by a multiple called the indirect cost rate and the indirect cost revenues received on successful grant applications went to support the institution's research administration and infrastructure costs. However, after a well-publicized case involving Stanford University in the early 1990s, government auditors began to take a much harder look at universities' requests for indirect cost recoveries and put caps on the expenses that universities could claim for expenses in a number of areas. As a result, the average indirect cost rate at private research and doctoral universities, which was over 60 percent in 1983, fell to about 55% in 1997 and has remained near that level ever since then.[7] On average, for any given level of direct cost research funding which their faculty members received, these private universities received 8.3% less funds from the federal government to support their research infrastructure and administrative costs in 1997 and thereafter than they did in 1983.

[7] Indirect cost rates at the public research and doctoral universities were lower at the start of the period and actually rose slightly during the period. The lower initial rates were due to many publics not having to return funds to their state that the state had spent constructing new research facilities. The increase came about because declining state support for operating budgets of public higher education made it more important for the public universities to try to tap all available potential sources of revenue (Ehrenberg (2000, forthcoming).

What is the likely response of an institution faced with such a reduction in external support for research infrastructure and administration? On the one hand, it might try to reduce its expenditures in these areas to match the decline in the external support for research that it was receiving. But such a strategy would alienate its faculty who would view the institution's commitment to research as declining. In addition, if the reductions were made in areas in which the institution was not spending more than the maximum that the federal auditors would allow it to recover, the auditors would further respond by lowering its indirect cost rate in the following year. So invariably private university administrators made up for the reduction in external funding for research administration and infrastructure by increasing their own institutional commitments.

In recent years the federal government has also placed increasing pressure on all universities to provide "matching" institutional funds for any research proposals that they submit. While universities try to provide matching funds out of funds that they would have spent for research even in the absence of a new external grant, they can not always get away with doing this, especially for large center grant proposals. Put another way, to compete for external funding, increasingly institutions have had to bear an increasing share of the direct costs of their faculty members' research out of their own pockets.

Finally, as scientists' equipment became more expensive and the competition for top-quality scientists intensified, the start-up funding that universities needed to provide to attract young scientists increased. Universities typically cannot recover these expenses in their indirect cost revenues billings, because the new scientists rarely have external funding when they first arrive at the university. During the late 1990s, it was often alleged, although no systematic data existed to support this claim, that universities were providing young scientists in the range of $250,000 to $500,000 to set up their labs. The start up costs of attracting distinguished senior scientists was often alleged to be much greater and even if these senior faculty members had federally funded research grants, these costs too were often not recoverable in indirect cost recovery pools because the institutions faced caps on their recoveries in a number of categories.

Because no systematic data on start up costs has previously been collected, the Cornell Higher Education Research Institute conducted a "Survey of Start Up Costs and Laboratory Space Allocation Rules" at research and doctoral universities during the summer of 2002. We surveyed the chairs of 3 to 6 narrowly defined science and engineering departments at each institution, the deans of the colleges in which each of these departments were located and the vice president or vice provosts for research in each university. In total 1031 department chairs, 408 deans, and 206 vice presidents or vice provosts received survey questionnaires.

These questionnaires began by describing things that are generally included as start up costs (such as construction or renovation of labs, materials and equipment, support for laboratory staff, graduate assistants or postdoctoral fellows, summer salaries for the faculty member, reduced teaching loads, travel money, unrestricted research funding) and then asked respondents to provide information on the average and/or range of start up costs that they incur for new assistant professors and senior faculty members in their field, on the most expensive sub field in their discipline, on the sources of funding for start up costs, and on the types of laboratory space allocation rules that their units used.

Full results from this survey will be presented elsewhere. Table 2 summarizes some of the information from the responses of the 553 department chairs (representing a response rate of 53.6 percent) that we have received as of October 1, 2002. The department are grouped her into four broad areas – physics/astronomy, biology, chemistry and engineering – and data are reported separately for private Research I, private other, public Research I and public other universities.

Chairs were asked to report either the average start up costs for faculty, or the range of costs for faculty, that they had experienced in the last year or two. Some reported both measures. Table 2 presents the average mean start up costs that the chairs reported for new assistant professors and senior faculty, as well as the average of the high end costs that they reported; in each case the numbers in parentheses are the number of reporting departments in the category

Table 2 suggests that, with few exceptions, at the new assistant professor level Research I universities provide larger start up packages than other universities and private universities provide larger start up packages than public universities. Average start up costs for assistant professors at private Research I universities in the four fields varied between $337,000 and $475,000. Estimate of the average high-end (most expensive) assistant professor start up cost package at the private Research I universities varied across fields between $609,000 and $725,000.

Start up cost packages for senior faculty members are considerably larger. For example, for the private Research I universities, the average start up costs varied across fields from a low of about $570,000 in physics to a high of $1,500,000 in engineering. While in general the same pattern of results holds that holds for new assistant professors, namely that packages at Research I universities are larger than packages at non-Research I universities and packages at privates are larger than packages at publics, sometimes at the senior level start up costs are larger at Research I publics than at Research I privates. This may reflect efforts by the publics to move to a higher level by bringing in a few key senior faculty members. In any event, start up costs are clearly a major expense faced by American universities.

III. Who Pays for the Growing Importance and Cost of Science?

How have universities responded to the growing importance and costs of science? One might expect that the growing importance of science has provided an incentive for universities to allocate a greater share of their faculty positions or faculty salary dollars, to scientists. However, using data from a set of arts and sciences colleges at leading private research universities, a recent study concluded that over a 20-year period neither the share of faculty positions nor the share of the faculty salary budget devoted to scientists had increased at these colleges.[8] Controlling for the growth of enrollments in the various disciplines or for whether overall faculty size was increasing or decreasing at each college, did not alter these conclusions.

Of course it may well be that the increasing cost of science is felt throughout a university's budget. Colleges of Arts and Sciences may receive a declining share of their university's total faculty positions, even if enrollment changes do not warrant this loss, as more positions are allocated to science intensive engineering and medical colleges. This particular hypothesis is difficult to test because some faculty in the latter two types of colleges, especially in medical colleges, are funded on soft money that they raise themselves.

[8] Ehrenberg and Epifantseva (2001)

More generally, to the extent that the other sources of income that a university receives, such as state appropriations, annual giving, and endowment income are directed toward supporting an increasingly large scientific infrastructure, this may put upward pressure on undergraduate tuition or cause the university to cut back its expenditures on other areas. Inasmuch as the faculty salary bill represents a large chunk of institutional costs, it is possible that the increasing costs of science are distributed throughout the university in the form of slower rates of increase in faculty salaries and/or in the form of slower rates of increase in faculty size than would otherwise be the case, all other factors held constant. It is to tests of these hypotheses that we now turn.

A. Does the Increasing Cost of Science Cause a Cutback in Full-time Faculty?

Table 3 uses data from a panel of 228 research and doctoral universities for 22 years during the 1970-71 to 1997-98 period to explain why an institution's ratio of full-time equivalent undergraduate and graduate students to its full-time professorial ranked faculty varies over time.[9] The explanatory variables, all measured in 1998 dollars, are the institution's research expenditures per professorial ranked faculty out of its own internal funds, its undergraduate tuition level (in-state tuition for public universities), the share of its enrollments that are in PhD and nonprofessional masters programs, the level of contributions that it received during the year from all sources per student, its endowment per student, and its state appropriation per student. All equations include institutional fixed effects and, as a result, our estimates indicate the impacts of changes over time in the explanatory variables on student/faculty ratios. Separate estimates are provided for private and for public universities and, for each sample, we estimate models without and

[9] Professorial ranked faculty members include assistant, associate and full professors. As indicated in figure 1, faculty data were not reported in WebCaspar for 5 of the 27 years during the sample period.

with year fixed effects. The inclusion of year fixed effects allows for the possibilities that there are omitted macro level variables that influence student/faculty ratios.

Our key finding is found in the first row of the table. Other factors held constant, universities whose research expenditures are increasing the fastest in absolute terms are also the ones whose student/faculty ratios are increasing the fastest. The magnitude of the relationship is greater for private universities than it is for publics and we cannot reject the hypothesis for the former that each $10,000 increase in internal research expenditures per faculty member is associated with an increase in the student/faculty ratio of close to one. During the period the weighted average real institutional research expenditure per faculty member at the private universities in the sample increased from about $7.7 to $17.5 thousand dollars. So on average, the growth in internal research expenditures at the privates has caused an increase in student/faculty ratios at private universities of close to one.

The magnitude of the relationship is somewhat lower for the public university sample, depending upon the specification the coefficient ranges from .531 to .652. However, the growth in absolute terms of real research expenditures per faculty member out of internal university funds has been larger for the public universities; the weighted average for public universities in the sample rose from about $7.6 to $31.3 during the period. Hence the impact of the increase in public universities expenditures on research out of their own funds on student/faculty ratios has probably been larger, increasing, other factors held constant, by about 1.25 to 1.50 during the period.

Our estimates of the impact of changing internal expenditures on research on the student/faculty ratio prove to be robust to a number of specification changes. Including full-time equivalent student enrollments on the right hand side of the equation did not alter the finding. When we used five-year averages for each institution to capture longer-run changes we found much larger student/faculty ratio effects, although they tended to be less statistical significant because of the reduction in our sample sizes. When we treated internal research expenditures per faculty members as endogenous and allowed it to depend upon the levels of external research funding at the national level allocated to different federal agencies in a year, the shares of the institution's external research funding in the previous year coming from each agency and the institution's indirect cost rate in the previous year, the estimated student/faculty effects were again always much larger than those found in table 3, although again they were often not statistically significant.

When we repeated the analyses, using total full-time faculty (including lecturers and instructors) in the denominator of the student/faculty ratio rather than professorial ranked faculty, similar positive coefficients on the research expenditure per faculty member variable were obtained. However, the magnitudes of these coefficients were somewhat smaller than the coefficients in the first row of table 3 in three of the four specifications.[10] Hence while the data suggest that an increase in research expenditures per ranked faculty member probably does lead to some substitution of full-time lecturers and instructors for professorial ranked faculty, the ratio of students to all faculty (including the lecturers and instructors) also increases when institutional expenditures on research per ranked faculty member increases.

[10] The corresponding coefficients of the research expenditure variables in these specifications were .573, .752, .598 and .433 respectively. Only the third is larger than the corresponding coefficient (.531) in row 1.

Briefly mentioning other findings from table 3, in the main year-to-year changes in the other financial variables – tuition, total giving per student, endowment per student and state appropriations per student, do not appear to significantly alter an institution's student/faculty ratio. Only for private institutions in the specification without year fixed effects do tuition changes matter and, as expected, increased real tuition levels are associated ceteris paribus with lower student/faculty ratios.[11]

What is striking, however, is the impact of changing the share of the total student body enrolled in PhD and nonprofessional masters programs. In the private institutions, growing the share of these programs is associated, other factors held constant, with a higher student/faculty ratio, while in the public institutions it is associated with a lower student/faculty ratio. The private result is intuitive; growing PhD programs may require more money for graduate assistantships and the substitution of graduate assistants for full-time faculty. The public finding is less intuitive. A number of states provide more resources per student to public universities for graduate students than undergraduate students and this might lead to a lower student/faculty ratio. However, we have already controlled for state appropriations per student in our model, so this cannot be the explanation for this finding.

B. Does the Increasing Cost of Science Cause a Slow Down in Faculty Salary Increases?

Table 4 provides estimates of equations similarly specified to those found in table 3, save that the dependent variable is now the real weighted (across ranks) average faculty salary at the institution. For private institutions, we find no evidence that increasing an

[11] We return to this point below because if increases in research expenditures per faculty member out of university funds are associated with increases in tuition levels this will moderate the effect of increased research expenditures on the student/faculty ratio.

institution's internal research expenditures per faculty member leads, other factors equal, to lower faculty salaries. In contrast, for publics we find that increases in internal research expenditures per faculty member are associated with increases in average faculty salaries. This may reflect reverse causality – high paid faculty members with strong research records being recruited and requiring (see the previous section) considerable funding for start up costs.

For both the publics and the privates, greater increases in tuition are associated, not unexpectedly, with greater increases in average salaries.[12] Increases in giving levels per student and endowment per student are associated for privates, at least in the specification including year fixed effects, with greater increases in faculty salaries. Similarly increases in state appropriations per student are associated in public universities with increases in average faculty salaries. For publics, an increase in the share of students that are in PhD or nonprofessional masters programs is associated with higher average salaries; this may again reflect the university's ability to hire better and more highly paid faculty with larger PhD programs. Finally, increases in total giving per student are associated with smaller (not larger) increases in faculty salaries, other factors held constant.[13]

C. Does the Increasing Cost of Science Cause Increases in Tuition Levels?

Table 5 provides similarly specified equations, save that now the dependent variable is the institution's real tuition level and this variable is excluded from the right-hand side of the equation. The results suggest that private universities that increase their expenditures per faculty members out of their own funds on research, other factors held

[12] Again we caution that if increased university expenditures on research per faculty member lead to higher tuition levels, this will in turn have a feedback effect on faculty salaries.

[13] As financial conditions facing publics worsened during the 1990s, many seriously began fund raising for the first time. However, the finding is a ceteris paribus finding, and the model already controls for changes in the other major sources of revenues public universities receive, tuition and state appropriations.

constant also increase their tuition levels at higher rates. However, the magnitude of the relationship differs substantially in the models with and without year fixed effects. Treating the two coefficients as upper and lower bounds to the true relationship, given that the weighted average internal expenditures on research at private universities in the sample increased by about $10,000 per faculty member over the period, our estimates suggest that undergraduate tuition levels at these institution were between $184 and $1077 higher in real terms in 1998 than they otherwise would have been. The evidence for publics is more mixed, however, the model without year fixed effects suggesting a positive relationship but the one with year fixed effects suggesting a negative association between changes in internal research expenditures per faculty member and changes in tuition levels.

All the models suggest that as the share of PhD and nonprofessional masters students increases at these universities that tuition levels also increase, other factors held constant. During the period, these shares rose, on average, from .240 to .306 at the private research universities and from .145 to .178 at the public research universities. Our estimates thus imply that tuition levels at the private research universities were between $264 (model with year fixed effects) and $1804 (model without year fixed effects), and those at the public research universities between $15 (model with year fixed effects) and $160 (model without year fixed effects) higher at the end of the period, in real terms, than would otherwise have been the case.

Hence, other factors held constant, undergraduate students bear some of the cost of increased size PhD programs in the form of higher tuitions. We place greater weight on the lower bound estimates that are based on models that include year fixed effects, because omitted macro level variables, such as family income, influence students' financial need and ability to afford to attend college, and thus likely influence tuition. Hence the costs that the undergraduate students bear are probably not very large. In addition, if growing PhD programs attract better faculty to universities, undergraduate students may also benefit from increases in the relative size of these programs.

In 3 of the 4 specifications, increased annual giving per student and increased endowment per student are both statistically significantly associated with higher levels of tuition per student. Higher levels of endowment and annual giving provide increased subsidies for students, increase the attractiveness of the university to students and hence should increase the tuition levels that students are willing to pay to attend the university.[14] Results for the increase in state appropriations per student are more mixed, without the inclusion of year fixed effects state appropriations per student are positively associated with tuition increases in the public sector, but when the year effects are included the relationship becomes negative. [15]

D. Some Sensitivity Analyses

In table 6 we summarize the results of some sensitivity analyses that we conducted to see how the coefficient of the institutional research expenditure per faculty member variable in the student/faculty ratio equation varies when tuition is excluded from the right-hand side of the equation and when we separately analyze data for Research I and

[14] This is in keeping with Gordon Winston's (1999) views. Empirical evidence that in-state and out-of-state tuition levels are positively associated with levels of endowment per student at public university was provided in Rizzo and Ehrenberg (2002).

[15] Of the 23 private research universities receiving state appropriations, 14 were in New York State and under the Bundy Aid program these institutions received grants for each New York State resident who received a degree from them. During the sample period, the real value of the Bundy aid per graduate declined, as did the share of their graduates coming from New York State. Thus, the negative coefficient of the state aid variable in the private tuition equation may simply reflect the increased need for tuition revenue that they faced as this source of revenue was falling. Once we control for year specific effects, this negative coefficient becomes statistically insignificant.

non-Research I institutions. The coefficients in the first row of the table are our baseline estimates; they have been previously reported in table 3.

Because the results in table 5 suggest that increased institutional research expenditures per student are associated with increased levels of tuition, increases in tuition should be treated as endogenous in tables 3 and 4. However, the same set of variables appears on the right-hand side of the tuition change equation as appears in the student/faculty and the faculty salary change equations. In the absence of a structural model or a set of variables that might be used to obtain an instrument for tuition changes, we simply reestimate the student/faculty change equation excluding tuition from the equation. The coefficient of the institutional research variable in this equation now captures both its direct impact on the student/faculty ratio and its indirect impact operating through its impact on tuition levels.

These coefficients appear in the second row of table 6. For both the models with and without year fixed effects, increased institutional research expenditures per faculty member at public research universities continue to be associated with a reduction in the student/faculty ratio, although the magnitude of this reduction is much smaller than that reported in table 3. At the private research universities, the effect becomes insignificant in the model without year fixed effects. However, in the model with year fixed effects, which we have previously argued is the preferred specification, the negative relationship remains and the marginal effect is only slightly smaller than before.

The remaining panels of table 6 report the coefficients of the institutional research expenditures per faculty member in the student/faculty equation when the samples of institutions are divided into Research I and Non- Research I institutions. Focusing first on the Research I samples, for the private institutions the coefficients are smaller than those in the overall private sample and are insensitive to the exclusion of tuition from the equation. For the publics, the coefficients are smaller than in the overall sample when tuition is included but larger when it is excluded.

In both cases, however, the predicted impact of the growth in institutional research expenditures per faculty member during the sample period on the student/faculty ratio is much larger than that predicted by the overall equations because the weighted (by faculty size) average institutional research expenditures per faculty member rose by much more in the Research I's (on average $15.2 thousand in the privates and $36.7 thousand in the publics) than it did in the entire private or public samples during the period. As a result, these equations suggest that student/faculty ratios averaged about .438 higher in the private Research I universities and 1.594 higher in the public Research I universities at the end of the period than they would have been if institutional research expenditures per faculty member had remained constant in real terms during the period.[16]

Turning to the results of the Non Research I institutions, which are reported in the bottom panel of table 6, we find much larger estimated coefficients for the privates and statistically insignificant coefficients for the publics. While the estimated impact of a dollar increase in institutional research expenditures per faculty member is largest for the Non- Research I privates, on average institutional research expenditures per faculty member increased very little in institutions in this group during the sample period, the weighted average growing from $1.9 thousand to $4.4 thousand dollars, an increase of only $2.5 thousand. As a result, we estimate that at the end of the period, the

[16] These estimates use the coefficients from the specifications that include year fixed effects and exclude tuition.

student/faculty ratio at these institutions was about .354 higher than it would have been if institutional research expenditures per faculty member had not increased during the period.[17] So while the net impact of growing research expenditures per faculty member on the student/faculty ratio was slightly higher for the private Research I's than it was for the other privates (the Research II, Doctoral I and Doctoral II institutions) during the period, institutional research expenditures per faculty member grew much more rapidly in the former than they did in the later during the period.

For comparison purposes, table 7 presents analogous coefficients of the institutional research expenditures per ranked faculty member variable from various specifications of the faculty salary equation. Focusing one's attention on the estimates that include year fixed effects, increases in institutional research expenditures per faculty member do not appear to significantly influence faculty salaries at either private Research I or the other private universities. However, strong positive relationships appear for all categories of public universities. Other variables held constant, an increase in institutional research expenditures per faculty member of $10,000 is associated with about a $250 increase in average faculty salaries at the public Research I's and a $400 increase in salaries at the other public universities. As before, we interpret this as implying that public institutions trying to enhance their status must spend more on research out of their own pockets and pay higher salaries to attract better faculty.

[17] This calculation again uses the coefficient from the specification that includes year fixed effects and excludes tuition.

IV. Concluding Remarks

Our research suggests that undergraduate students bear at least part of the increased costs that American universities are undertaking for their faculty members' scientific research in the forms of higher faculty student ratios, some substitution of lecturers for professorial rank faculty and, in private universities, higher tuition levels. Whether these costs are more than offset by the benefits the student receive from being educated in proximity to scientific researchers who are at the cutting edge of their disciplines is an open question that deserves serious study.[18]

Our research also suggests that as the share of PhD students and nonprofessional masters students increases at both the public and private research universities that undergraduate tuition also increases at these universities, other factors held constant. While Gordon Winston's (1999) work indicates that no undergraduate student at a major university bears the full cost of his or her education, our results suggest the undergraduates bear a part of the cost of graduate education, in the sense that the average subsidy (in Winston's terms) that they receive from attending the university is lower because of the presence of more graduate students. Again whether these are costs are more than offset by the benefits that the students receive from being educated close to (and sometimes by) graduate students is an open question deserving of serious study.

Our study has only begun to touch on the impact on the university that the growing cost of science has had. The growth of science may have crowded out other things. For example, increased institutional support for teaching or research assistants for scientists

[18] Later drafts of the paper will provide some information here on the probabilities that graduates of selective private liberal arts colleges and selective private research universities, of roughly comparable student selectivity, go on to receive PhDs.

and for stipends for graduate students in the sciences may have led to decreased availability of funds to support teaching assistants or graduate students on fellowships for humanists and social scientists, or slower rates of growth of graduate student stipends in these fields.[19] Or to take another example, increased institutional support for scientific research facilities and start-up costs for scientists may have reduced the funding that otherwise would have been available for travel and other "perks" in the humanities and social sciences.

It is possible, of course, that the increasing costs of research that are borne by universities may be eventually at least partially offset by revenues that the universities receive from increased commercialization of their faculty members' research. The Association of University Technology Managers (AUTM) reported in their fiscal year 2000 survey of their members that American colleges and universities received more than $1 billion dollars in licensing income and other forms of royalties relating to patents that year. While this figure seems large, it was concentrated in a few large "winners"; 90% of the universities in their sample received less than $2 million and almost half received less than $1 million.[20]

Licensing income received in one year depends upon the flow of investments in research that universities have made in the past. If we ignore this and the fact that the return on any particular research project may occur for a number of years in the future, a simple way of looking at the commercial returns that universities receive from their faculty members' research is to ask how the licensing income received by a university in

[19] It is not surprising that the leaders of the growing movement to union graduate assistants on private university campuses tend to be graduate students from the humanities and soft social sciences (Ehrenberg et. al forthcoming).
[20] See Blumenstyk (2002a). Some of these large winners were universities that cashed in equity positions that they had taken in companies, in lieu of receiving licensing income.

one year relates to its own expenditures on research in that year. Licensing income received in fiscal year 2000 averaged 3.23% of total research expenditures in the year across the institutions in the AUTM sample. As we have noted, universities fund about 20% of their research expenditures out of their own resources, which suggests that licensing income averaged about 16% of institutions' research expenditures out of internal university funds in the year.

At first glance this seems like a significant return but this calculation is misleading for at least three reasons. First, the licensing income that universities receive is divided between the university and the researchers. So only a share of the revenue actually comes to the university itself. Second, focusing on the average ratio ignores the skewness in the distribution of research returns. The median institution in the sample licensing income was 0.83% of its total research revenue, which is about 4.2% of its internal volume of research expenditures.

Third, given the volume of a university's research, licensing income and other forms of revenue from patents that are related to this research do not simply fall off trees. Rather, they must be "harvested". Considerable efforts must be made by universities and their faculty members to decide if faculty members' discoveries have potential commercial value, to patent the discoveries, to then develop or seek partners to develop commercial potential, to negotiate licenses or equity positions, and to enforce patents.[21] All of these activities take resources. Indeed, the cost of trying to enforce patents alone can prove very expensive.[22]

[21] Thursby and Thursby (2000) describe this process in much more detail and provide estimates of licensing production functions.
[22] The University of Rochester has established an "eight figure" legal fund in its effort to obtain billions of dollars in royalties from the makers and marketers of the arthritis drug Celebrex (Blumenstyck 2002b).

While no comprehensive source of data on the costs that universities occur in trying to generate licensing income is currently available, summary information from the AUTM licensing survey permits us to make some back of the envelope calculations. During fiscal year 2000, the 142 U.S universities in the AUTM sample employed a total of 479.95 "licensing" full-time equivalent employees (FTEs) and 494.53 other FTEs in their technology transfer offices. They also incurred $117,927,842 in legal fees, of which third parties reimbursed only $53,685,716.[23] Hence these universities' net legal fees for technology transfer activities were roughly $64 million and they employed a total of about 975 employees. These employees include patent attorneys, other professionals and support staff. If we assume that the fully loaded costs of each employee (salaries, benefits, office space etc.) averaged $100,000 that year, the total expenses of technology transfer activities for these institutions were in the range of $161.5 million dollars, or an average of about $1.15 million per university.

Maintaining the assumption that the average fully loaded cost of each employee was $100,000, the AUTM survey responses allow us to compute an estimate of the net licensing income (income after expenses) for 138 of the universities in the sample. The mean net licensing income in this sample was $6,554,200, but the median was only $343,952. By our calculations 51 of the 138 institutions actually lost income that year on their commercialization activities and we estimate that the median net licensing income for the 87 that made money was $1,309,828. When one remembers that the licensing income received by universities is split between them and the faculty members whose patents have generated the income, it seems clear that commercialization of research has

[23] Association of University Technology Managers (2001), attachment D

yet to provide most universities with large amounts of <u>net</u> income to support the universities' scientific research activities.

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Table 1

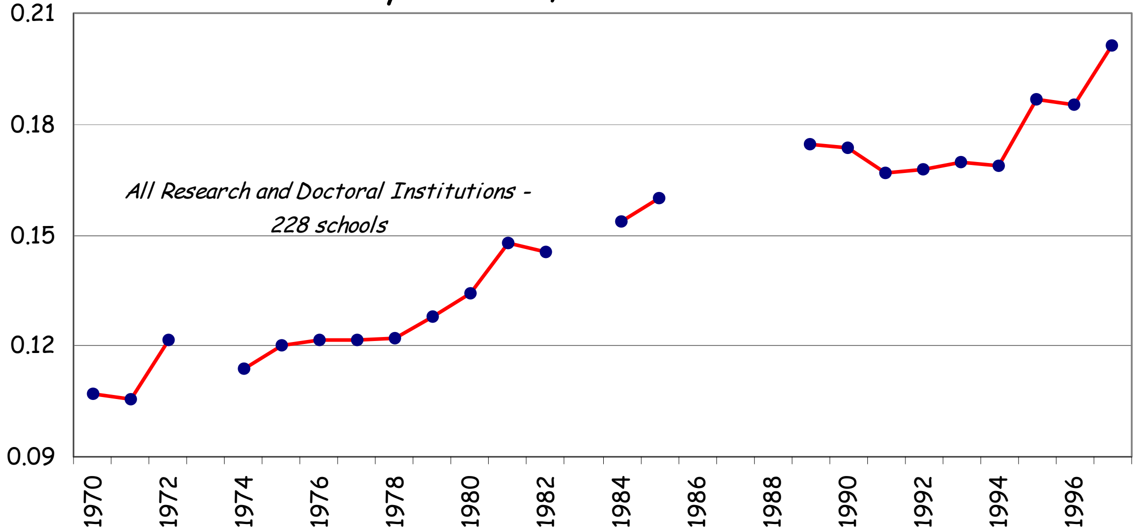
SELECTED CORNELL NEWS SERVICE PRESS RELEASE HEADLINES THAT RELATE TO RESEARCH AT CORNELL DIRECTED AT IMPROVING HUMAN HEALTH: JANUARY- SEPTEMBER 2002

1. A simple, cost-effective screening test for those at-risk for abdominal aortic aneurysms (9/4)
2. Experimental therapy for deadly brain tumors can be more effective with longer treatment time (8/1)
3. Cooking sweet corn boosts its ability to fight cancer and heart disease by freeing healthful compounds (8/8)
4. "Good cholesterol not only healthy for the heart, but also could be beneficial for the lungs (8/5/02)
5. Gene discovery in petunias could boost hybrid food yield (7/3)
6. Discovery of ripening gene could make store-bought tomatoes as tasty as homegrown (4/9)
7. E.Coli detection in food reduced from days to minutes (3/15)
8. Dog model for studying inherited human blindness (5/7)
9. Estrogen's role in preventing female cardiac disease (3/22)
10. How Vitamin C prevents cancer- but apples are better (1/22)
11. Cooking tomatoes boosts disease-fighting power (4/19)
12. Ergonomic changes help muscular skeletal problems (2/28)
13. Scientists demonstrate new strategy of using bone marrow stem cells to restore aging cardiac blood vessel-forming capacity (6/7)
14. Study illuminates cardiac scarring that leads to heart failure (5/24)
15. Harvesting stem cells for transplant in non-hodgkin's lymphoma still possible after treatment with Bexxar (5/19)
16. Researchers report encouraging results with first combined antibody treatment for lymphoma (5/20)
17. HIV vaccines and low-daily does of Interleukin 2 may lead to permanent HIV immunity (3/1)
18. Researcher sees promise in use of stem cells and progenitor cells for brain repair (2/18)
19. First robot-assisted coronary bypass surgery in the U.S performed at New York-Presbyterian hospital (1/17)
20. Researcher describes the immune deficiency at the root of the commonest form of type 1 diabetes (1/2)

Source: Cornell University News Service 2002 Press Releases (available on the World Wide Web at http://www.news.cornell.edu)

Figure 1

Average Fraction of Total R&D Expenditures per Faculty Contributed by Institution, 1970 - 1997 Academic Years



Data from National Science Foundation (NSF) Survey of Research and Development Expenditures at Universities and Colleges and from IPEDS via WebCASPAR. Faculty data unavailable for 1973, 1983, 1986, 1987 and 1988 academic years.

Table 2

Average Mean Start Up Costs for Departments Reporting in the Category*

(Number of reporting departments)

		R1 Private	Other Private	R1 Public	Other Public
AA	PHY	353,905(3)	77,750(8)	306,741(13)	152,318(22)
AA	BIO	371,857(7)	203,867(15)	313,565(23)	174,357(28)
AA	CHEM	475,294(17)	202,353(17)	469,025(27)	211,020(50)
AA	ENG	337,000(11)	150,769(13)	192,839(30)	118,906(35)
HA	PHY	670,875(8)	303,000(10)	531,151(33)	303,400(35)
HA	BIO	586,666(9)	281,818(12)	420,500(20)	186,379(29)
HA	CHEM	725,000(5)	338,285(14)	524,051(23)	302,885(38)
HA	ENG	609,333(11)	290,625(8)	297,367(30)	123,128(19)
AP	PHY	569,875(4)	800,000(1)	686,469(13)	339,333(15)
AP	BIO	750,000(3)	434,375(8)	573,437(16)	346,111(18)
AP	CHEM	991,667(12)	612,857(7)	825,250(20)	568,461(26)
AP	ENG	1,5000,000(6)	226,667(9)	391,518(30)	202,038(19)
HP	PHY	1,250,000(4)	175,000(1)	1,176,428(14)	641,428(7)
HP	BIO	1,550,000(4)	550,000(3)	1,092,857(7)	796,505(10)
HP	CHEM	850,000(3)	506,250(4)	1,387,500(16)	800,333(9)
HP	ENG	1,800,000(3)	680,000(5)	635,000(10)	428,000(5)

*Preliminary tabulation of responses to the CHERI Survey of Start Up Costs and Laboratory Space Allocation Rules that was mailed to 3 to 5 chairs of selected biological science, physical science and engineering departments at each research and doctoral university during the summer of 2002

Where
AA average start up costs for new assistant professors
HA high end start up costs for new assistant professors
AP average start up costs for senior faculty
HP high end start up costs for senior faculty

PHY physics and astronomy
BIO biology
CHEM chemistry
ENG engineering

Table 3
Panel Data Regression Results
Dependent Variable: FTE Undergraduate and Graduate Enrollment per Ranked Faculty

Explanatory Variables	***Privates (78 schools)***		***Publics (150 schools)***	
Research per faculty, in $10,000	**0.804** **(0.185)**	**0.832** **(0.188)**	**0.531** **(0.214)**	**0.652** **(0.223)**
Tuition, in $1,000	**-0.478** **(0.051)**	-0.137 (0.134)	-0.388 (0.385)	-0.242 (0.664)
Share of enrollments - graduates	**10.0** **(3.5)**	**9.7** **(3.6)**	**-25.6** **(8.6)**	**-20.8** **(8.6)**
Total giving per student, in $1,000	0.099 (0.055)	0.090 (0.056)	0.181 (0.284)	0.168 (0.285)
Endowment per student, in $1,000	0.007 (0.004)	0.005 (0.004)	-0.081 (0.062)	-0.082 (0.062)
State apps per student, in $1,000	-154.7 (508.0)	-150.6 (512.0)	-109.9 (85.7)	-67.8 (87.0)
Fixed Institution Effects?	Yes	Yes	Yes	Yes
Fixed Year Effects?	No	Yes	No	Yes
R^2	0.086	0.094	0.007	0.027

(Standard errors)
Significant at 95% level in ***BOLD***
All dollar values in $US 1998 dollars
Sources: NSF, HEGIS and IPEDS via WebCASPAR and Council on Aid to Education

Table 4
Panel Data Regression Results
Dependent Variable: Weighted Average Ranked Faculty Salaries

Explanatory Variables	***Privates (78 schools)***		***Publics (150 schools)***	
Research per faculty, in $10,000	-60 (110)	68 (95)	**885** **(48)**	**512** **(40)**
Tuition, in $1,000	**1828** **(30)**	**670** **(70)**	**5239** **(89)**	**1610** **(120)**
Share of enrollments - graduates	-3196 (1910)	32 (1651)	510 (1822)	-259 (1444)
Total giving per student, in $1,000	**111** **(33)**	**135** **(29)**	**-327** **(66)**	**-204** **(53)**
Endowment per student, in $1,000	**29** **(2)**	**28** **(2)**	23 (14)	10 (11)
State apps per student, in $1,000	-60 (293)	121 (252)	**175** **(19)**	**86** **(16)**
Fixed Institution Effects?	Yes	Yes	Yes	Yes
Fixed Year Effects?	No	Yes	No	Yes
R^2	0.830	0.878	0.697	0.814

(Standard errors)
*Significant at 95% level in **BOLD***
All dollar values in $US 1998 dollars
Sources: NSF, HEGIS and IPEDS via WebCASPAR and Council on Aid to Education

Table 5
Panel Data Regression Results
Dependent Variable: Instate Tuition Level

Explanatory Variables	***Privates (78 schools)***		***Publics (150 schools)***	
Research per faculty, in $10,000	**1077** **(92)**	**184** **(40)**	**164** **(10)**	**-13** **(6)**
Share of enrollments - graduates	**27332** **(1636)**	**3968** **(740)**	**4820** **(413)**	468 (249)
Total giving per student, in $1,000	**203** **(28)**	**49** **(12)**	-23 (14)	**26** **(8)**
Endowment per student, in $1,000	**24** **(2)**	**4** **(1)**	**21** **(3)**	1 (2)
State apps per student, actual $	**-1121** **(264)**	-56 (112)	**18** **(4)**	**-11** **(3)**
Fixed Institution Effects?	Yes	Yes	Yes	Yes
Fixed Year Effects?	No	Yes	No	Yes
R^2	0.424	0.901	0.325	0.773

(Standard errors)
Significant at 95% level in ***BOLD***
All dollar values in $US 1998 dollars
Sources: NSF, HEGIS and IPEDS via WebCASPAR and Council on Aid to Education

Table 6
Coefficient of Institutional Research Expenditures per Ranked Faculty Member in the Student-Faculty Equation
(Standard Errors)

Explanatory Variables	***Privates (78 schools)***		***Publics (150 schools)***	
Baseline (Table 3)	**0.804** **(0.185)**	**0.832** **(0.188)**	**0.531** **(0.214)**	**0.652** **(0.223)**
Baseline - Tuition Excluded	0.225 (0.137)	**0.626** **(0.139)**	**0.138** **(0.037)**	**0.108** **(0.040)**
Research I Institutions	**0.292** **(0.071)**	**0.282** **(0.073)**	**0.360** **(0.064)**	**0.403** **(0.070)**
Research I Institutions - Tuition Excluded	**0.234** **(0.066)**	**0.288** **(0.073)**	**0.248** **(0.057)**	**0.414** **(0.071)**
Non-Research I Institutions	**1.463** **(0.473)**	**1.554** **(0.481)**	0.050 (0.051)	0.009 (0.050)
Non-Research I Institutions - Tuition Excluded	0.699 (0.490)	**1.419** **(0.484)**	0.079 (0.050)	0.015 (0.051)
Fixed Institution Effects?	Yes	Yes	Yes	Yes
Fixed Year (period) Effects?	No	Yes	No	Yes

Significant at 95% level in ***BOLD***
All dollar values in $US 1998 dollars
Sources: NSF, HEGIS and IPEDS via WebCASPAR and Council on Aid to Education

Table 7
Coefficient of Institutional Research Expenditures per Ranked Faculty Member in the Faculty Salary Equation
(Standard Errors)

Explanatory Variables	***Privates (78 schools)***		***Publics (150 schools)***	
Baseline (Table 4)	-60 (110)	68 (95)	**885** **(48)**	**512** **(40)**
Baseline - Tuition Excluded	**1856** **(195)**	**197** **(97)**	**1676** **(68)**	**495** **(41)**
Research I Institutions	51 (121)	-53 (105)	**1055** **(83)**	**268** **(66)**
Research I Institutions - Tuition Excluded	**1871** **(215)**	-74 (106)	**2318** **(110)**	**247** **(68)**
Non-Research I Institutions	**-846** **(311)**	-521 (276)	**599** **(60)**	**418** **(51)**
Non-Research I Institutions - Tuition Excluded	**1530** **(536)**	-290 (282)	**1016** **(81)**	**411** **(52)**
Fixed Institution Effects?	Yes	Yes	Yes	Yes
Fixed Year (period) Effects?	No	Yes	No	Yes

Significant at 95% level in ***BOLD***
All dollar values in $US 1998 dollars
Sources: NSF, HEGIS and IPEDS via WebCASPAR and Council on Aid to Education