Who is Selling the Ivory Tower? Sources of Growth in University Licensing

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Historically, commercial use of university research has been viewed in terms of spillovers. Recently, there has been a dramatic increase in technology transfer through licensing as universities attempt to appropriate the returns from faculty research. This change has prompted concerns regarding the source of this growth—specifically, whether it suggests a change in the nature of university research. We develop an intermediate input model to examine the extent to which the growth in licensing is due to the productivity of observable inputs or driven by a change in the propensity of faculty and administrators to engage in commercializing university research. We model licensing as a three-stage process, each involving multiple inputs. Nonparametric programming techniques are applied to survey data from 65 universities to calculate total factor productivity (TFP) growth in each stage. To examine the sources of TFP growth, the productivity analysis is augmented by survey evidence from businesses who license-in university inventions. Results suggest that increased licensing is due primarily to an increased willingness of faculty and administrators to license and increased business reliance on external R&D rather than a shift in faculty research.
(*University Licensing; Invention Disclosures; Patents; Entrepreneurial Activity*)

1. Introduction

According to the Association of University Technology Managers (AUTM) surveys, licensing activity in U.S. research universities has increased dramatically in the 1990s. For the 64 universities responding to the survey in each of the years 1994–1998, yearly invention disclosures increased 7.1% per year. Over the same period, new patent applications and licenses and options executed annually grew by 17.1% and 8.4%, respectively. In 1998 alone the 132 universities responding to the survey reported a total of 9,555 disclosures, 4,140 new patent applications, and 3,078 licenses and options executed.

This growth in the so-called "commercial outputs" of academic research has received considerable attention both from technology managers and university administrators who cite it as evidence of the increasing contribution of universities to the economy (e.g., AUTM press release, 1998) and policy makers who, in contrast, question the impact of commercial activity on the conduct and industrial impact of faculty research (Congressional Record 1999). Unfortunately, there is little evidence to evaluate the arguments since these growth rates alone tell nothing about the productivity of university resources devoted to technology transfer, nor do they provide evidence on the sources of increased licensing.

In this article, we explore the source(s) of this growth in university licensing. We focus on the role of inputs, including intermediate inputs, in the process, and we examine the extent to which the explosion in licensing is being driven by faculty and university administrators becoming more entrepreneurial. In particular, is the primary source of growth simply an increased propensity for university administrators to patent and attempt to license faculty inventions? To

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what extent is growth due to an increased propensity of businesses to license university inventions? Has the propensity of faculty to disclose inventions increased either because they are more willing to license as well as publish their research or because their research has shifted toward topics of more interest to industry? It is the latter element of faculty propensity that has been the focus of policy discussions.

We model technology transfer as a three-stage production process involving multiple inputs in each stage. The three stages follow the sequence of steps typically involved in licensing university inventions. First-stage outputs are invention disclosures, which are filed by faculty when they believe their research results have commercial potential. In addition to faculty, first-stage inputs include federal and industry research support as well as TTO personnel.[1] Disclosures are intermediate inputs to a second stage in which the TTO applies for patents on those disclosures they believe can be patented and licensed. Inputs for this stage also include a measure of faculty quality to capture patent potential. In turn, patent applications and disclosures are used along with other licensing inputs in a third stage to produce license and option agreements.

We provide two types of evidence on the sources of growth. The first is a productivity analysis using AUTM survey data for 64 U.S. universities for 1994–1998 that provide evidence on the extent to which growth in each stage is a direct result of increases in inputs devoted to technology transfer. The second is based on a survey of businesses that licensed university inventions over the period 1993–1997. These survey data, in conjunction with our productivity results, allow us to consider the extent to which licensing has grown because of changes in the propensity of faculty and administrators to engage in commercial activity and/or changes in business behavior toward universities.

In the productivity analysis, we use nonparametric programming techniques developed by Fare et al. (1994) to examine productivity growth. For each of the three stages, we construct a best practice frontier that represents the maximum feasible stage output given available inputs and existing attitudes or knowledge. This approach allows us to identify both frontier performance and operation within the frontier. Thus, total factor productivity (TFP) growth can be decomposed into two components: one reflecting a frontier shift and another showing movement toward (catching up) or away from the frontier. Given the dramatic growth of licensing activity and reorganization of a number of TTOs during the early 1990s, both components of growth are likely to be important.[2]

For the 64 universities in our sample, we find TFP growth rates for disclosures and patent applications that are roughly 5% lower than the nominal growth rates noted above, and, for licenses executed, TFP growth is negative. While this implies that much of the growth in university commercial activity stems from input growth, it also suggests that changed propensities are an important element of growth. Of particular note is the negative TFP growth in licenses that, coupled with increased disclosures and patent applications, can be interpreted as evidence of universities delving more "deeply" into the available pool of commercializable inventions. To the extent that universities are trying to increase the number of inventions licensed without a concurrent shift in the underlying distribution of inventions, we would expect a decline in the commercial appeal of inventions at the margin. Thus, we would expect inventions, on average, to have less commercial potential, even though the total value of inventions licensed would increase. This result is particularly interesting in light of Henderson et al.'s (1998) evidence from an earlier period (1965–1988) that as university patenting increased, the importance (as measured by citations) of university patents declined.

To examine why propensities to engage in university/firm licensing have changed—that is, to examine the possible sources of TFP growth—we draw on the results of our business survey as well as the productivity analysis. For the first stage, our interest is in whether the growth in disclosures (net of

[1] TTO personnel are university employees responsible for encouraging and aiding faculty in disclosing and for executing licenses agreements with industry.

[2] Thirty-five percent of the TTOs responding to our earlier university survey were reorganized during the 1990s (Thursby et al. 2000).

inputs) is due to a reorientation of faculty research toward the needs of industry and away from basic research, or whether the growth is due to a greater willingness on the part of faculty to disclose as well as publish the results of their research. For the second stage, we focus on whether productivity growth stems from a greater receptivity of university administrations to industry contracts. In the final stage, our major interest is the extent to which growth stems from changes in industry R&D[3] or from factors leading to the growth in disclosures and patent applications.

The survey supports the view that industry reliance on university inventions increased during this period, and, in indicating the reasons, respondents weighted changes in their own R&D more heavily than a change in faculty research toward topics of greater interest to industry. Together with the productivity results, this suggests that the primary reason for increased invention disclosures may indeed be an increased propensity for faculty to disclose rather than a change in research focus. The industry survey also supports an increased receptivity of universities to industry contracts. This result, together with the fact that these businesses increased their contractual agreements with universities, reinforces our interpretation of our stage three productivity results that negative TFP growth most likely reflects university efforts to patent and license inventions with marginal commercial potential.

Finally, we find that much of the growth in TFP for the disclosure and patent stages comes from catching up by universities that were operating within the frontier. Only for the patent stage do we find both a shift in best practice and catching up. Further, we find that growth patterns differ according to public/private status and whether a university has a medical school.

These results contribute to the growing literature on the industrial impact of academic research. The bulk of this literature has focused either on the role of patents and publications in the transfer process (see Adams 1990, Henderson et al. 1998, and Jaffe et al. 1993) or on consulting, sponsored research or institutional ties (see Cohen et al. 1998; Mansfield 1995; Zucker et al. 1994, 1998). While several recent papers provide evidence on the nature of university licensing (e.g., Jensen and Thursby 1999, Mowery et al. 1999, Mowery and Ziedonis 1999, Siegel et al. 1999, Thursby et al. 2001, Thursby and Kemp 2001), none of them provides a structure that allows analysis of the sources of growth.

One benefit from our structure is that we can comment on the growing policy debates on the Bayh-Dole Act of 1980, which gave universities the right to license inventions from federally funded research. Much of the concern of those who question the act's impact comes from fears that financial returns to licensing would divert faculty from basic to applied research. In their study of licensing activities at Columbia, Stanford, and the University of California system, Mowery et al. (1998) and Mowery and Ziedonis (1999) point out that faculty at these universities had a long history of applied research well before the Bayh-Dole Act. Since neither their work nor ours examines the pattern of faculty research, we *cannot reject* the notion that faculty research has shifted. However, the intermediate input structure of our productivity analysis, combined with our industry survey, allows us to show that changes in the direction of faculty research appear relatively less important than other factors, such as the dramatic increase in the propensity of administrators to patent and license faculty inventions. This was, in fact, an intended effect of the Bayh-Dole Act.

2. University Technology Transfer: A Multistage Process

In this section, we provide background information on the licensing process and present our multistage model. The programming approach we adopt for the productivity analysis is described in §3, and the results are given in §4. The business survey is discussed in §5; §6 concludes.

2.1. Disclosures

The licensing process begins with a faculty member reporting a discovery that he or she believes has commercial potential. This report, or disclosure, involves

[3] This explanation follows from discussions with industry licensing executives.

faculty providing the TTO with information on the invention and inventors, funding sources, potential licensees, as well as barriers to patent potential (such as prior publication).

It is important to realize that invention disclosures represent a subset of university research with commercial potential. The TTO personnel we interviewed in an earlier study of university licensing in U.S. universities indicated that they believe less than half of the faculty inventions with commercial potential are disclosed to their office (Thursby et al. 2001). In some cases faculty may not realize the commercial potential of their ideas, but often they do not disclose inventions because they are unwilling to risk delaying publication in the patent and license process. Half of the firms in our industry survey noted that they include delay of publication clauses in at least 90% of their university contracts (Thursby and Thursby 1999). The average delay is nearly four months, and some firms require as much as a year's delay.

Faculty who specialize in basic research may not disclose because they are unwilling to spend time on the applied research and development that is often needed for businesses to be interested in licensing university inventions.[4] Respondents to our TTO and industry surveys noted that 88% and 84%, respectively, of licensed university inventions require further development, and that 45% and 44%, respectively, of licensed inventions are no more than a "proof of concept" at the time of license. The firms noted that for such inventions, faculty cooperate in further development more than 40% of the time. Finally, some faculty may refuse to disclose for "philosophical" reasons related to their notions of the proper role of academic scientists and engineers. Thus, for a variety of reasons, the TTO personnel we interviewed indicated that one of their major challenges is obtaining faculty disclosures.

We model invention disclosures for university u ($DISC^u$) as a function of observable and unobservable inputs. Observable inputs are faculty size, research funds, and the number of full-time equivalent personnel in the TTO ($TTOFTE^u$). Since disclosures are generally based on research that has been ongoing for some time, we use the average over the preceding three years of the amounts of federal research support ($LAGFED^u$) and industry-sponsored research ($LAGIND^u$). For faculty size, we use the number of faculty in each of the major program areas—biological sciences, engineering, and physical sciences ($TOTFAC^u_{i=1,2,3}$). By not aggregating faculty across fields, we attempt to capture the fact that research methods and market interest in inventions can differ markedly across the sciences and engineering.[5]

The unobservable inputs are the faculty's *propensity to disclose* ($PROP^u_1$) and the probability of invention discovery (Π_1). Thus,

$$DISC^u = f_1(TTOFTE^u, LAGFED^u, LAGIND^u, TOTFAC^u_{i=1,2,3}, PROP^u_1, \Pi_1). \quad (2.1)$$

The propensity to disclose reflects both the direction of faculty research and faculty willingness to disclose, and it can be influenced by the policies and practices of university central administrations as well as the perceived potential for monetary gain. Π_1 represents the probability of discovery, conditional on the level of research effort (e.g., research support and faculty size) and split of effort between basic or applied research. In terms of an individual invention, Π_1 represents the "black box" probability that a given amount of research effort will result in an invention, which we assume is independent of the university. Given the short time frame of our analysis (five years), it is unlikely that Π_1 has changed significantly, if at all.

2.2. Patents

Once an invention is disclosed, the TTO evaluates patent and commercial potential. From our earlier survey, it is clear that many TTOs apply for patents only when they expect to find licensees easily. Mowery and Ziedonis (1999) note that six years after disclosure slightly more than 20% of disclosures at Stanford and the University of California system

[4] See Mansfield (1995) and Zucker et al. (1994) regarding faculty who are successful in both applied and basic research.

[5] As discussed in Thursby and Kemp (2000) engineering is more applied than the other fields, and it is also said that biological sciences have more of a seller's market than the other two.

have patents. Of course, many inventions, such as copyrightable software and reagent materials, are not eligible for patent protection.

We consider new patent applications ($PATENTS^u$) by university u, rather than patents awarded, as our measure of second stage output, in part because of substantial lags between application and issue, but also because patent applications are a better measure of a university's interest in commercialization than are patents awarded. Observable inputs to the patent stage are the number of disclosures, number of personnel in the TTO, and a measure of faculty quality. The latter is included to adjust for possible differences in commercial quality and novelty of disclosures across universities. Like our measure of faculty size, the quality measure is by major program field ($QUAL^u_{i=1,2,3}$). Patent applications are also a function of an unobservable *propensity to patent* ($PROP^u_2$). Since the decision to apply for a patent (which is ultimately owned by the university) is largely made by TTO personnel, the propensity to patent is indicative of the commercial aggressiveness of the university central administration.[6] Thus, university u's second-stage production is modeled as

$$PATENTS^u = f_2(DISC^u, TTOFTE^u, QUAL^u_{i=1,2,3}, PROP^u_2). \quad (2.2)$$

Note that faculty interests in commercialization enter through the observable $DISC^u$.

2.3. License Agreements

License and option agreements executed by university u ($LCEXEC^u$) are modeled as a function of the numbers of disclosures and patent applications as well as the size of the TTO office. We include both disclosures and patent applications because some licenses are executed without patent protection and the fact that a patent application is made may well provide information about the perceived quality of patentable disclosures. As was the case with patent applications, we include faculty quality in an attempt to adjust for possible differences in commercial quality and novelty of disclosures and patent applications across universities, and hence likelihood of finding a licensee. Unobservable inputs are the university's *propensity to license* inventions ($PROP^u_3$) as well as the distribution of industry interest in university inventions, Π_3. Our model of licenses and options executed is

$$LCEXEC = f_3(DISC^u, PATENTS^u, TTOFTE^u, QUAL^u_{i=1,2,3}, PROP^u_3, \Pi_3). \quad (2.3)$$

$PROP^u_3$ reflects the TTO's ability and knowledge as well as their aggressiveness in finding potential licensees. Π_3 represents market conditions that are independent of the other inputs. In terms of a single invention, it is the probability of finding a match in the market conditional on invention characteristics. Since both $PROP^u_3$ and Π_3 could have changed during our sample period (and our business survey indicates a change in Π_3), we are not able to identify their separate effects. Note that faculty and administration propensities enter through $DISC^u$ and $PATENTS^u$.

An alternative approach to modeling the last stage would be to include license revenue and/or sponsored research associated with licenses as outputs. This would allow us to analyze TFP in terms of the returns to licensing, and the programming techniques we employ are well suited for examining multiple outputs. There are, however, several problems with taking this approach. While AUTM collects information on royalty income and sponsored research associated with licenses, royalty income in any given year comes not only from current licenses but also from licenses executed in previous years. In many cases, the licenses executed may have been 10 or more years prior. It is also not clear how systematic the relation between royalty income and license inputs is since the distribution of royalty revenue is highly skewed. In our earlier survey, we found that on average 76% of the license revenue reported by universities is attributable to their top five inventions. Sponsored research associated with licenses is clearly a function of licenses and inputs within the same year. The problem with using this as a measure of output is that we know TTO personnel often trade off royalties and sponsored research in their negotiations.

[6] It is often the decision of the TTO as to whether a patent is applied for. In our survey of TTOs we found that the TTO believes it closely reflects the interests of their central administration (see the analysis in Jensen and Thursby 1999).

As discussed in §4.1, we calculate TFP for sponsored research, but we believe licenses executed is a more reliable measure of output.

3. A Frontier Analysis of Total Factor Productivity

We examine productivity in each of the three stages using an approach developed by Fare et al. (1994). The approach is based on data envelopment analysis (DEA), which is a nonparametric linear programming approach to comparing inputs and outputs. For each of the three stages and for each of the universities, DEA produces a yearly efficiency rating or score by first determining the set of universities that exhibit "best practice" for the stage under consideration. These universities are said to form the production frontier that relates inputs and outputs. All other universities are then compared to the subset of best practice universities that they most resemble in terms of inputs and outputs. Thus, for each stage and for each university and year, DEA determines whether the university lies on the frontier (exhibits best practice) or, if not, how "far" from the frontier it lies. Yearly changes in the frontier and performance relative to it allow us to examine growth in each stage.

It is important to note that the programming approach is not statistically based and therefore does not allow for statistical tests of hypotheses.[7] Its advantage is that it imposes very little structure on the problem. DEA was developed to examine technical efficiency of not-for-profit institutions that provide (possibly) multiple outputs (or services) using multiple inputs where price data are either unavailable or distorted. The only data required are input and output quantities, and no assumptions are made on functional form. No restrictions are placed on institutional objectives. This is particularly important for our case since universities have multiple objectives in their technology transfer. In our earlier university survey, we found that many TTOs view themselves as balancing a variety of objectives ranging from attracting industry-sponsored research for faculty to maximizing license income for their central administration. Others, particularly public university TTOs, view the public use of university technology within their state as one of their objectives.

The idea behind the best practice frontier is most easily seen in the case of a single input and single output. Suppose university u produces output y^u from input x^u, then any other university j with input $x^j = x^u$ should be able to produce at least y^u; otherwise, it is inefficient. If j produces more than y^u when using the same input level as u, then university u is inefficient. Similarly, if university j produces $y^j = y^u$, then it should use no more than x^u or it is inefficient. If j uses less than x^u, then u is inefficient. Best practice performance for a university in any stage and year simply means that no other university is doing better in that stage and year given their inputs and outputs.

In our case, each stage has a single output but multiple inputs so that DEA involves the maximization of the ratio of a single output to a linear combination of inputs. Essentially, in DEA each university in each stage is compared to all other universities in the same stage to determine if some combination of other universities has a larger ratio of output to a linear combination of inputs. If no combination of universities has a larger ratio, then the university under examination is said to be efficient and it lies on the best practice frontier. Otherwise, the university is said to be inefficient. An efficiency score for a university is the fraction of potential output produced by the university; for example, a score of 0.6 implies that, based on the performance of comparable universities on the frontier, the university is producing 60% of what it could be producing. A precise statement of the linear programming problem is found in Appendix A.

Once we have established the best practice frontier for each year for some stage and the position of each university vis-à-vis that frontier, we can then measure TFP changes from year to year for each university. The measure of TFP growth is the geometric mean of two Malmquist indexes, one of which is based on the best practice frontier in period t and the other based on the frontier in $t+1$.[8]

[7] There has been some recent work on distribution theory with regards to DEA output, but that work is nascent (see the discussion in Grosskopf 1996). A problem we face here is that the efficiency scores (and, hence, TFP growth rates) are not independent so that standard statistical tests are inappropriate.

[8] See Caves et al. (1982) for the properties of the Malmquist index.

TFP growth can be decomposed into two components. One is the component of productivity change that stems from movement toward or away from frontiers in successive years; it is growth due to either catching up or lagging of universities not on the frontier in at least one period. The other is the component of productivity change that is due to frontier shifts between successive years. This effect is said to represent technical change. This notion of technical change is quite general and simply represents changes in output that cannot be attributed to a change in input usage or to a change in relative efficiency. Readers interested in a more precise statement of this measure of TFP growth and its decomposition are directed to Appendix A.

Since the DEA analysis controls for observable inputs, both technical change and changes in efficiency reflect changes in the unobservable inputs, hence they are useful in examining the sources of growth. That is, the unobservable component ($PROP_1^u$) of $DISC^u$ reflects both changes in faculty research and propensity to disclose; both of which can be influenced by university policy. In the $PATENTS^u$ stage, faculty attitudes are captured by the observable $DISC^u$, and the unobservable input ($PROP_2^u$) reflects TTO (central administration) attitudes. In the $LCEXEC^u$ stage, unobservable inputs reflect TTO and market characteristics ($PROP_3^u$ and Π_3). Thus, changes in TFP in Stage 1 reflect changes in $PROP_1^u$, while for Stage 2 TFP changes reflect changes in $PROP_2^u$, and for Stage 3 TFP changes reflect changes in $PROP_3^u$ and/or Π_3.

4. Productivity Analysis

In this section, we present both efficiency and TFP growth rates for each of the stages defined in §2 for a sample of 64 universities. The TFP growth rates are based on a constant returns to scale production frontier. Information on data is in Appendix B.

Before turning to results, we note that our sample of 64 universities represents a substantial fraction of all research conducted by and commercial activity of U.S. universities. In 1998, our sample accounts for almost 54% of federal research support and 57% of industry support to all U.S. universities. The sample accounts for 61% of licenses executed, 59% of disclosures, and 62% of new patent applications by the 132 respondents to the 1998 AUTM survey. We are confident that our sample represents more than half of the population of research and licensing conducted at U.S. universities during the period of our observations (1994–1998).

Table 1 Growth Rates, 1994–1998

	Nominal Growth Rates	Technical Change	Efficiency	Total Factor Productivity
Invention disclosures	1.071	0.983	1.045	1.027
Patent applications	1.171	1.094	1.025	1.121
Licenses	1.084	1.130	0.870	0.983

4.1. Total Factor Productivity Growth

Table 1 gives the geometric means of our computed indexes of TFP growth, as well as the output (nominal) growth in each stage. Our measures of productivity growth give a more tempered view of growth in commercial activity than do output indexes (which are typically reported). For example, the growth rates in disclosures and patent applications are 4.4% and 5% higher, respectively, than the TFP growth rates. For licenses the difference is dramatic, with licenses executed growing at 8.4% per year and TFP falling 1.7% per year.

What immediately stands out is the large annual TFP growth rate (12.1%) in the patent stage as compared to either disclosures (2.7%) or licenses executed (−1.7%).[9] These growth rates account for growth in observed inputs, so that TFP growth can be interpreted as reflecting changes in the unobservable

[9] Beginning in June 1995, provisional patent applications were permitted. Some have argued that this has increased patent activity in universities since it allows faculty to more quickly publish results without compromising U.S. patent rights, although provisional patents can endanger foreign patent rights. Unfortunately, the AUTM survey counts a provisional patent application as a new patent application (although a provisional that is converted to a regular application is only counted once), thus some of the patent growth could be a result of the introduction of provisional applications. However, the TFP growth rate between 1993 and 1994 is 1.078 so that TFP growth in new patent applications was still substantial without provisional patenting.

inputs. In particular, they suggest a modest increase in the propensity of faculty to disclose ($PROP_1^u$) and a substantial increase in the propensity for university administrators to patent ($PROP_2^u$). While we cannot separate $PROP_1^u$ into effects from research focus or output, as opposed to the willingness to disclose, the industry survey results reported in §5 suggest that research focus is, at least from industry's perspective, not a major reason for growth in licensing. Further, the stark difference in TFP in the first two stages is consistent with industry responses that universities are more "receptive" to licensing.

What might account for the negative TFP growth in licenses? One possibility is a bias resulting from the fact that our growth rates do not fully account for lags between disclosure and patent application and the signing of license agreements. It is unlikely, however, that this effect is systematic. Licenses executed today may have come from disclosures and patent applications filed several years earlier, so that the measured productivity of disclosures and patent applications today may be higher than actual productivity. On the other hand, the fact that today's disclosures and patent applications may lead to licenses in later years implies that measured productivity today may be lower than the actual. Since the growth rates we report are geometric means over a four-year period, these effects may wash out.

A second explanation is that TTOs have become more demanding in their contract negotiations (i.e., conditional on commercial "quality" of a technology, asking price has increased). Several industry licensing executives with whom we spoke claimed that universities were "asking for too much." We tend to discount this explanation for several reasons. Responses to our industry survey suggest that business executives believe universities are more receptive to contracts. While this does not negate higher asking prices, it casts some doubt. We also calculated TFP growth using sponsored research as a measure of the return or valuation of licenses executed. As we noted in §2.1, sponsored research tied to licenses is flawed as a measure of current valuation since there is a trade-off between royalties and sponsored research funds. If we are willing to assume that our time frame (five years) is sufficiently short that there have been not substantial shifts in preferences for one source of income over the other, then we can examine research funds tied to licenses as a measure of the valuation of licenses. The TFP growth in such funds is −10.7%. Valuation, therefore, is falling at a more rapid rate than are licenses executed. This leads us to our next explanation.

A third, and we believe a more plausible, explanation is that the observed growth in disclosures and patent applications reflects universities delving more "deeply" into the available pool of commercializable inventions. Increasing contracts and falling TFP together suggest declining commercial appeal for the *marginal* disclosures and patent applications. That is, since TFP growth is net of disclosures and new patent applications (which themselves have been growing), the implication is that, while many more technologies are being offered and licensed to industry, the proportion of licenses executed to those offered is falling. This productivity result reinforces Henderson et al.'s (1998) evidence of a decline in the importance of university patents (as measured by citations) from an earlier period (1965–1988).

To look further at the relation between TFP growth in licensing and growth in disclosures and patent applications, we regressed the log of the annual licensing TFP index on the logs of the growth rates in disclosures and patent applications.[10] TTO staff is the only other measured input for licenses that changes in our data, so we included the log of its growth rate. The R^2 is 0.13 and both patent applications and TTO staff are negatively related to licensing TFP and are significant (t ratios are smaller than -4.3). The disclosure TFP growth index is not significantly related to licensing TFP growth (t ratio $=$ 0.28). The patent and TTO elasticities are -0.303 and -0.529, respectively. The negative patent elasticity is consistent with our interpretation of declining productivity of the marginal invention. While the negative TTO elasticity may seem to be an anomaly, it actually provides an additional explanation for falling

[10] The regression variances are not strictly correct as they do not account for the nonindependence of the TFP observations, which follows from DEA calculations that are based on the comparisons of a university's outcomes with that of other universities.

TFP in Stage 3. Rapidly expanding TTOs may exhibit lower TFP because there is a steep learning curve for new hires (they may be unfamiliar with faculty and industrial networks important for finding licensees, etc.) so that new staff are, on average, less productive, which implies negative effects on TFP.

4.2. Efficiency Growth and Technical Change

To what extent can we say that best practice has changed over this period, and to what extent has TFP growth reflected inefficient universities catching up to the frontier? Returning to Table 1, we again find our results differ markedly across stages. Only for the patent stage do we find both a shift in the best practice frontier and a movement, on average, of universities closer to the frontier. The latter result implies universities are becoming more similar in their patenting propensity. This increasing efficiency is modest over the four years as average efficiency rises from 0.597 in 1994 to 0.628 in 1998.

The 2.7% growth in TFP for disclosures appears to come primarily from universities moving closer to the frontier, with a slight inward shift of the frontier. As with patents, we interpret the efficiency growth as indicating universities are becoming more similar in their disclosure behavior. Average efficiency rises from 0.556 in 1994 to 0.661 in 1998. In contrast, the decomposition of licensing TFP into efficiency and technical change suggests that there is increasing diversity in the success rate of universities in turning patents and disclosures into licenses. On average, there is growth in the frontier, but there is increasing inefficiency among universities with average efficiency falling from 0.697 in 1994 to 0.517 in 1998.

4.3. Feedback Effects

In modeling the stages involved in licensing we have allowed early stage outputs to affect productivity in later stages, but we have not allowed for success in later stages to affect early-stage activity. It is natural, however, to expect faculty to disclose inventions only if they believe their TTO can successfully license them. We also know from our earlier university survey that TTOs tend to apply for patents only when the likelihood of finding a licensee is high. Thus, past success in licensing may well affect the propensity of faculty to disclose and the propensity of the TTO to patent. In this section, we consider such feedback effects.

One way to incorporate feedback effects would be to include financial rewards from licenses executed as inputs in the first two stages. The problem with this is the same problem (discussed above) with using financial returns to licenses in measuring TFP in the third stage. That is, financial returns to licenses executed can appear either as royalty income or as sponsored research money directed to the inventor's lab. In our interviews with TTO professionals we were told that some universities actively seek sponsored research at the expense of royalty income, so that information on royalty income, for many universities, is an incomplete measure of financial rewards.[11] In addition, royalty income in any given year can be attached to licenses executed in the distant past and current licenses might not result in income for a number of years.

As alternatives, we consider both the number of licenses and the ratio of licenses to disclosures in the recent past as inputs to the disclosure decision. One can think of licenses executed as a "demonstration" that the disclosure process has value, either because of potential royalty revenue and/or sponsored research or simply as an indication that companies value their work. In our earlier survey, several TTO personnel claimed that some faculty treat the very fact that a license is signed as a nonpecuniary gain, attaching value to the fact that their discoveries have commercial appeal. The ratio of licenses to disclosures is a measure of the success rate of the TTO and should also serve to encourage faculty to disclose. The measures we use are (i) the average number of licenses executed over the preceding three years and (ii) the ratio of the three-year average of licenses to the three-year average of disclosures.

Including both measures of this demonstration effect produces a marked change in the first-stage

[11] For more on this issue, see Thursby and Kemp (2000). It should also be noted that the tax treatments of a firm's royalty expenses and a firm's sponsored research expenses are different; the former is a deduction, while the latter can be a credit. Thus, firms are not indifferent across the two methods of payment for a license.

results. Rather than TFP growth of 2.7%, the growth rate falls to 1.5%. In decomposing this growth into technical change and efficiency change we find that there has been negative growth in technical change (−4.8% per year) and positive growth in efficiency (6.6% per year). If we drop the ratio of licenses to disclosures, the results remain virtually identical. If, however, we drop the average number of licenses and retain the ratio, the results are very similar to our results without feedback effects. The implication of this is that the growth in faculty propensity to disclose is clearly linked to licensing success as measured by the number of licenses executed in the recent past.

Finally, including these two measures of past licensing success as feedback effects in the patent stage has a smaller relative effect on the propensity of university central administrations to patent. TFP growth falls from 12.1% to 10.5%, and we continue to find TFP growth in both efficiency and technical change.

5. Industry Survey

The picture that emerges from our analysis of the AUTM data is that, while the so-called commercial outputs from university research have grown substantially, this growth reflects increased TFP only in the first two stages. We find negative TFP growth in Stage 3, which we believe is indicative of the declining commercial appeal of license disclosures and patent applications at the margin. While this highlights the role of university inputs in increased commercial activity, the productivity analysis provides limited information about the sources of TFP growth, and it does not provide any evidence on the role of business behavior in the process. That is, we cannot tell the extent to which growth in university licensing activity was due to a shift in faculty research toward topics with more commercial appeal, an increase in university attempts to market inventions, or to an increase in demand for university contracts because of changes in industry R&D.

To examine these issues we conducted a survey of businesses that transfer-in technologies via license or research agreements. The questionnaire was designed to be answered by individuals actively engaged in executing such agreements and focused on the extent to which they had executed licenses, options, and/or sponsored research agreements with universities between 1993-1997. We received responses from 112 business units that had licensed-in university inventions. As described in Appendix C, firms in our sample accounted for at least 15% of the license agreements and 17% of sponsored research agreements reported by AUTM in 1997. Seventy-nine firms in the sample responded to a question on the top five universities with whom they had contractual agreements. The 85 universities mentioned include 35 of the top 50 universities in terms of industry-sponsored research and 40 of the top 50 licensing universities in the 1997 AUTM survey. Slightly less than half the respondents are responding for business units with no more than 100 employees, and about two thirds have fewer than 500 employees. The portion of small firms in our sample is in fact representative of all university licensing; in 1998, the AUTM survey reported that 64% of all university licenses were to start-ups or existing firms with fewer than 500 employees. Sixty-three percent of those who actively license-in from universities had no more than $1,000,000 of revenues, and 20 of the respondents reported that they did not have a product in the marketplace.

We asked respondents about changes in their relationship with universities, as well as the reasons for any change. In particular, we asked whether their contractual agreements (license, option, and/or research agreements) with universities had increased, decreased, or stayed about the same over the preceding five-year period. Of the 106 answering this question, 50% indicated an increase and 16% indicated a decrease. For those with an increase or decrease in arrangements we asked, on a 5-point scale with 1 indicating *extremely important* and 5 indicating *not important* (a *don't know* response was permitted), how important a set of factors were in explaining the change. Since there are so few respondents (17) indicating a decrease, we will not consider their reasons for the decrease.

It is worth noting the magnitude of the changes reported. For those noting an increase in agreements, the number of licenses increased by 86% in 1997 compared to the average of the preceding four years, and their research funding to universities doubled. On

Table 2 Relative Frequencies of Reasons behind INCREASING Contracts

		Extremely important	2	3	4	*Not important*	*Don't know*
Q1	Cost of university research	10.4	18.8	29.2	10.4	27.1	4.2
Q2	Faculty research is more oriented toward the needs of business	10.2	20.4	26.5	18.4	20.4	4.2
Q3	A change in universities' receptivity to licensing and/or research agreements	30.6	26.5	20.4	10.2	12.2	0.0
Q4	A change in our unit's reliance on external R&D	22.4	36.7	10.2	14.3	16.3	0.0
Q5	A change in the amount of basic research conducted by our unit	18.4	22.4	20.4	14.3	24.5	0.0

average, each of these firms executed 13 licenses per year and provided $13.2 mil in sponsored research with U.S. universities.[12]

Table 2 gives the relative frequency of responses regarding the reasons for the increase in their contracts. Table 3 gives unweighted and weighted average responses where the weights are the number of licenses executed with universities over the period 1993–1997. The weighted averages are baaed on the 35 respondents who provided sufficient information to calculate the number of licenses—'these 35 respondents represent 409 university licenses over this period. The first three questions in Tables 2 and 3 relate to changes in universities, while the last two relate to changes in corporate R&D.

Consider the two questions related to a business unit's research: "A change in our unit's reliance on external R&D"[13] and "A change in the amount of basic research conducted by our unit." Approximately 60% and 41% indicated either a 1 or a 2 for Q4 (change in reliance) and for Q5 (change in basic research), respectively, suggesting that business demand for university technologies increased as a result of changes in industry R&D. This, of course, does not rule out the possibility (discussed below) that industry R&D changed in response to university characteristics.

The first three questions in Tables 2 and 3 relate to university characteristics: "Cost of university research," "Faculty research is more oriented toward the needs of business," and "A change in universities' receptivity to licensing and/or research agreements." What stands out is the greater importance attached to university receptivity than either costs or faculty research orientation; three times as many respondents recorded a 1 (*extremely important*) for university receptivity as recorded a 1 for costs or for faculty research.

We tested for significant differences in responses to the five questions. Our tests suggest a difference significant at the 1% level between responses to Q1 (cost) and Q3 (university receptivity) and to Q1 and Q4 (reliance on external R&D). Responses to Q2 (faculty orientation) are also significantly different from those to Q3 and Q4 at significance levels 1% and 10%, respectively. Responses to Q5 (basic research) are signficantly different from Q3 (10% level) and Q4 (5% level). No other distributions of responses are significantly different.[14] These tests further support the

[12] Those who report decreased contracts indicated levels and changes in levels that are of the same order of magnitude as those who increased contracts.

[13] Note that a change in a firm's reliance on external R&D does not necessarily reflect a change in their reliance on universities as only 47% of the licenses executed in 1997 by the firms in our sample are with U.S. universities.

[14] Because the responses are not independent, the test we use is a test of difference in means where we take account of the dependence in computation of the variance of the difference in sample means. In the case of independence a more appropriate test would be to use tests for equivalence of the five-category multinomial distributions (*don't know* is excluded). The main differences in the outcomes of the two tests is the non-significance of Q5 from both Q3 and Q4.

Table 3 Average Responses of Reasons behind INCREASING Contracts

		Unweighted	Weighted
Q1	Cost of university research	3.22	3.98
Q2	Faculty research is more oriented toward the needs of business	3.57	3.79
Q3	A change in universities' receptivity to licensing and/or research agreements	2.42	2.88
Q4	A change in our unit's reliance on external R&D	2.65	2.54
Q5	A change in the amount of basic research conducted by our unit	3.04	3.35

importance of changes in industry R&D and in university receptivity to contracts relative to costs and changes in faculty orientation.

We also calculated simple correlations of the individual responses to the five questions. Not surprisingly, the correlation between Q4 and Q5, the questions related to changes in industry R&D, is fairly high (0.6, significant at the 1% level). To examine whether changes in industrial R&D might be related to university characteristics, we consider the correlations between responses to the R&D questions and responses to the other three questions. Responses to the cost question (Q1) have correlations of 0.49 (significant at 1% level) and 0.45 (significant at 5% level) to Q4 and Q5, respectively. Neither Q2 (faculty orientation) nor Q3 (university receptivity) is significantly correlated with the R&D questions. Thus, while the cost of university research is less important to overall increases in industry/university contracts than changes in university receptivity to such contracts, university cost is an important reason behind changes in industry R&D. Finally, the correlation between Q2 and Q3 is 0.61 (significant at the 1% level), implying that, while university receptivity to contracts is more important than faculty orientation in explaining changes in industry/university contacts, changes in faculty orientation and changes in university receptivity to industry contracts go, to some extent, hand in hand.

What do these results tell us about $PROP_1^u$ and $PROP_2^u$, the propensities of faculty and central administrations to commercialize inventions? First, our earlier finding of substantial TFP growth in patent applications indicated a substantial change in $PROP_2^u$, and the survey results corroborate this as an important source of the growth in commercial activities of universities. Second, we earlier noted that $PROP_1^u$ could change either through a reorientation of faculty research toward the needs of business or through a change in the willingness of faculty to disclose. The industry survey suggests that, while there may have been some reorientation of faculty research, a reorientation is much less important than changes in university receptivity and in industry R&D.

Finally, while we are not able through either the productivity study or the survey to disentangle the relative importance to the third stage (licenses executed) of changes in TTO ability and knowledge ($PROP_3^u$) from market conditions (Π_3), it would appear that industry demand for university technologies has increased, at least in part, due to changes in industry R&D. The latter changes are related to the cost of university research rather than a reorientation of faculty or a change in university receptivity to industry contracts.

6. Conclusion

We began this article with observations on substantial growth in disclosures, new patent applications, and licenses executed. This increased activity has prompted policy makers in government and academic circles to question the implications for faculty research, and, in particular, whether faculty research has become more applied in response to license opportunities. This has been discussed in recent Congressional hearings as an "unintended" effect of the Bayh-Dole Act of 1980. The act was intended not to redirect faculty research, but to facilitate industrial application of university research by expanding university rights to patent and license inventions from federally funded research. To the extent that increased licensing reflects a greater willingness of faculty and university administrators to facilitate technology transfer, the surge in licensing reflects the intended effect of the legislation. While our analysis is intended primarily to examine the sources of the dramatic growth in licensing activity, it also contributes to the policy debate.

In particular, we find modest TFP growth in disclosures (2.7% annual growth), which could reflect changes in faculty research or simply an increased propensity to license as well as publish their work. While our productivity analysis does not allow us to separate the two, our industry survey suggests that the modest growth in TFP of disclosures comes primarily from an increased willingness of faculty to disclose. In indicating the reasons for their increased interest in university inventions, survey respondents weighted changes in their own reliance on external R&D and increased university receptivity to industrial contracts more heavily than the orientation of faculty research toward business needs. It is worth noting that, while our evidence does not rule out some shift in faculty focus, it is consistent with statistics on the split between basic and applied research in U.S. universities as reported by universities to the National Science Foundation (*Science and Engineering Indicators*). The average proportion of basic research to total research expenditures for 1977–1980 is 0.67, while for 1994–1998 it is only 0.005 smaller. This difference represents about $119 mil of the more than $24 bil of research expenditures at all U.S. universities.

By far, the greatest growth in commercial activity is in the second stage, patent applications. Patent applications could have grown because of an increase in the propensity for university administrators to commercialize faculty inventions, but they could also have grown because of the increase in disclosures. While disclosures have increased, our productivity analysis and industry survey also support the first explanation. That is, after accounting for input growth, patent applications have grown substantially (annual TFP growth of 12.1%), and this growth is attributed to increasingly entrepreneurial university administrators. Respondents to our industry survey corroborate this result by placing a relatively high weight on a change in university receptivity to industrial contracts as being important in the growth of their university contracts. Here, again, our finding is consistent with intended effects of the Bayh-Dole Act.

Perhaps the most surprising result is the negative total TFP growth of licenses executed (−1.7% annual growth). That is, growth in disclosures and patent applications has been greater than the corresponding growth in licenses executed. We interpret this to mean that the marginal university innovation offered to the market has declined in commercial appeal; universities are apparently delving more deeply into the available pool of innovations in their efforts to increase their commercial activities. Again, delving deeply into the available pool of innovations is consistent with the intent of the Bayh-Dole Act.

Finally, we do not have evidence on the importance of learning by doing on the part of TTOs except to note our finding of a negative association between TTO growth and TFP growth in licensing, which would suggest at least the possibility of learning by doing effects.

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Appendix A: DEA and TFP Computation

Let there be $u = 1, \ldots, U$ universities using $n = 1, \ldots, N$ inputs $\mathbf{x}^{ut}$ in stage s to produce stage output y^{ut} in period $t = 1, \ldots, T$. The position of university u' relative to the frontier in stage s (where we suppress the stage notation) is determined by the solution to the programming problem:

$$D^{u',t}(\mathbf{x}^{u',t}, y^{u',t})^{-1} = \text{Max } \theta^{u'} \tag{6.1}$$

$$\theta^{u'} y^{u',t} \leqq \sum_{u=1}^{U} z^{u,t} y^{u,t} \tag{6.2}$$

$$\sum_{u=1}^{U} z^{u,t} x_n^{u,t} \leqq x_n^{u',t} \qquad n = 1, \ldots, N \tag{6.3}$$

$$z^{u,t} \geqq 0 \qquad u = 1, \ldots, U. \tag{6.4}$$

The inverse of $\theta^{u'}$ is a measure of the distance of u' from the frontier. If $1/\theta^{u'} = 1$, then u' lies on the frontier; otherwise, u' lies interior to the frontier, and $1/\theta^{u'}$ represents the fraction of possible output produced by u'. The best practice frontier (that is, the frontier determined by the subset of efficient universities) is given by Equations (6.2)–(6.3) for $\theta = 1$.[15]

[15] For discussions of DEA, see Seiford and Thrall (1990), Charnes et al. (1994), Ali and Seiford (1993), or Fare, Grosskopf and Lovell (1994).

To examine changes in university performance over time, we compute Fare et al.'s (1994) measure of total factor productivity growth (TFP) for each stage. This measure is the geometric mean of two Malmquist indexes, one of which is based on the best practice frontier in period t and the other based on the frontier in $t+1$, and is given by

$$m(\mathbf{x}^{u',t+1}, y^{u',t+1}, \mathbf{x}^{u',t}, y^{u',t}) = \left[\left(\frac{D^{u',t}(\mathbf{x}^{u',t+1}, y^{u',t+1})}{D^{u',t}(\mathbf{x}^{u',t}, y^{u',t})}\right)\left(\frac{D^{u',t+1}(\mathbf{x}^{u',t+1}, y^{u',t+1})}{D^{u',t+1}(\mathbf{x}^{u',t}, y^{u',t})}\right)\right]^{1/2}, \quad (6.5)$$

where $D^{u',t}(\mathbf{x}^{u',t}, y^{u',t})$ and $D^{u',t+1}(\mathbf{x}^{u',t+1}, y^{u',t+1})$ are given by the solution of (6.1) for $k=t$ and $t+1$; that is, they are, respectively, DEA solutions for years t and $t+1$. $D^{u',t}(\mathbf{x}^{u',t+1}, y^{u',t+1})$ is given by the solution to

$$\begin{aligned} D^{u',t}(\mathbf{x}^{u',t}, y^{u',t+1})^{-1} &= \text{Max } \theta^{u'} \\ \theta^{u'} y^{u',t+1} &\leqq \sum_{u=1}^{U} z^{u,t} y^{u,t} \\ \sum_{u=1}^{U} z^{u,t} x_n^{u,t} &\leqq x_n^{u',t+1} \qquad n = 1, \ldots, N \\ z^{u,t} &\geqq 0 \qquad u = 1, \ldots, U \end{aligned} \quad (6.6)$$

and $D^{u',t+1}(\mathbf{x}^{u',t}, y^{u',t})$ is given by the solution to

$$\begin{aligned} D^{u',t+1}(\mathbf{x}^{u',t}, y^{u',t})^{-1} &= \text{Max } \theta^{u'} \\ \theta^{u'} y^{u',t} &\leqq \sum_{u=1}^{U} z^{u,t+1} y^{u,t+1} \\ \sum_{u=1}^{U} z^{u,t+1} x_n^{u,t+1} &\leqq x_n^{u',t} \qquad n = 1, \ldots, N \\ z^{u,t+1} &\geqq 0 \qquad u = 1, \ldots, U. \end{aligned} \quad (6.7)$$

Note that Equations (6.6) and (6.7) involve observations from both t and $t+1$. The solution to (6.6) involves period $t+1$ inputs and outputs in reference to the period t frontier; it gives the proportional change in output necessary to make $(\mathbf{x}^{u',t+1}, y^{u',t+1})$ feasible given the best practice technology at t. The solution to (6.7), on the other hand, uses period t inputs and outputs in reference to the period $t+1$ frontier; it gives the proportional change in output necessary to make $(\mathbf{x}^{u',t}, y^{u',t})$ feasible given the best-practice technology at $t+1$.

We rewrite $m(\bullet)$ by factoring the ratio of $D^{u',t+1}$ $(\mathbf{x}^{u',t+1}, y^{u',t+1})$ to $D^{u',t}(\mathbf{x}^{u',t}, y^{u',t})$ from the right-hand side of (6.5) to obtain

$$\begin{aligned} m(\mathbf{x}^{u',t+1}, y^{u',t+1}, \mathbf{x}^{u',t}, y^{u',t}) &= \left[\left(\frac{D^{u',t+1}(\mathbf{x}^{u',t+1}, y^{u',t+1})}{D^{u',t}(\mathbf{x}^{u',t}, y^{u',t})}\right)\right] \\ &\times \left[\left(\frac{D^{u',t}(\mathbf{x}^{u',t+1}, y^{u',t+1})}{D^{u',t+1}(\mathbf{x}^{u',t+1}, y^{u',t+1})}\right)\left(\frac{D^{u',t}(\mathbf{x}^{u',t}, y^{u',t})}{D^{u',t+1}(\mathbf{x}^{u',t}, y^{u',t})}\right)\right]^{1/2}. \end{aligned} \quad (6.8)$$

This ratio (the first bracketed term in (6.8)) is the ratio of the efficiency measure $\theta^{u'}$ in period t to $\theta^{u'}$ in period $t+1$, and it is the component of productivity change that stems from movement toward or away from frontiers in periods t and $t+1$; it is growth due to either catching up (the ratio is greater than 1) or lagging (the ratio is less than 1) of universities not on the frontier in at least one period. The other term in (6.8) is the component of productivity change that is due to frontier shifts between t and $t+1$. This latter term is said to represent technical change.

Efficiency results are based on the solution to the programming problem given by Equations (6.1) through (6.4). TFP results are calculated using Equation (6.5).

Appendix B: Data

The AUTM licensing survey (AUTM, various years) has data on the technology transfer programs of many U.S. universities. In the survey is information on the output of each of the three stages (numbers of licenses executed, new patent applications, and invention disclosures) as well as the number of full-time equivalent staff employed in the TTO and federal and industry research support. These latter measures are the average level of support over the preceding three years. For universities that did not respond to all of the first three years, we use the average support values for the years in which they respond.

Data on faculty size and quality are from the National Research Council's (NRC 1995) 1993 survey of all Ph.D.-granting departments in the United States. No information is provided for departments that do not grant the Ph.D. degree. It is plausible to assume that substantial research programs have difficulty existing in the sciences and engineering—the departments from which 90% of commercial activity originate (see Thursby et al. 2000)—without the presence of Ph.D. students. We accept the reasonable proposition that science and engineering departments that do not grant the Ph.D. are not strong research departments and, hence, provide less inventive input to a university's commercial activities; the AUTM data support this proposition.

There are 65 universities with information sufficiently complete to compute frontier production functions and growth rates.

Appendix C: Survey Design

The sample was drawn from the mailing list of Licensing Executive Society, Inc. (United States and Canada). We phoned companies with multiple entries to ensure a single response from each suitable business unit and to identify the most appropriate respondent. Further calls allowed us to eliminate businesses that do not license-in technology from any source or sponsor university research, as well as firms that are no longer in business. This left us with 1,385 business units in the sample, and 300 responded (21.7% response rate); 112 indicated that they had licensed-in university technologies, and 188 indicated that their licenses were from other sources, although 61 of the latter had sponsored university research.

Many of the companies on the LES list are not publicly traded, so it is impossible to conduct the usual tests for selectivity bias. We can, however, compare the total of all licenses and industry-sponsored research reported by AUTM to the number of licenses and amount of sponsored research of our respondents. Of the 112 firms who licensed-in university technologies, 104 gave information on the number of their license agreements with universities. These 104 respondents had 417 licenses in 1997, which represents approximately 15% of the total reported by AUTM.[16] Seventy-one respondents reported $307 mil of support, which is approximately 17% of the comparable AUTM figure of $1,786 mil for 1997. If the firms with missing sponsored research expenditures had the same average research expenditure as the 71 usable responses, then our 114 respondents account for about 28% of all industry research support at U.S. universities. Seventy-nine firms listed the primary universities with whom they licensed during the preceding five years, and 64 listed the primary universities with whom they sponsored research.[17] Eighty-five universities are mentioned (many are mentioned by a number of firms), and they cover most of the major U.S. research universities; based on the 1997 AUTM survey, they represent 35 of the top 50 industry supported universities and 40 of the top 50 licensing universities. It is reasonable to conclude that our sample represents a substantial portion of all industry/university contractual agreements of the recent past.

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[16] The survey is explicit in differentiating between licenses and options, whereas AUTM lumps both together, thus our estimate and the AUTM figure are not strictly comparable; however, the bulk of university contracts (aside from research agreements) are licenses. In our survey, licenses outnumbered options by about 4 to 1.

[17] Many who did not answer this question indicated confidentiality concerns. They were reluctant—in spite of assurances of confidentiality—because knowledge of the universities with whom they deal can give competitors information as to the strategic direction the firm might take in the future.