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THEIR ROLE IN UNIVERSITY-INDUSTRY LICENSING

Jerry G. Thursby
Marie C. Thursby

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Jerry G. Thursby
Emory University
jthursb@emory.edu

Marie C. Thursby
DuPree College of Management
Georgia Institute of Technology
800 West Peachtree Street NW
Atlanta, GA 30332-0520
and NBER
marie.thursby@dupree.gatech.edu

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JERRY G. THURSBY and MARIE C. THURSBY

ABSTRACT: Understanding the nature of the involvement of faculty in university licensing is important for understanding how technology is transferred through licensing as well as more controversial issues, such as the need for university licensing. Using data from a survey of firms that actively license-in from universities we explore the importance of faculty in the licensing and development of inventions, as well as how and why they are used and how the use of faculty relates to characteristics of firms. In particular we find that the use of faculty through sponsored research in lieu of a license is closely related to the amount of basic research conducted by firms whereas the use of faculty within the terms of a license is related to the prevalence of personal contacts between industry R&D researchers and university faculty.

I. INTRODUCTION

Are faculty critical to university-industry licensing? The short answer is, of course, yes since without faculty there would be no university inventions to license. To stop here, however, would be short sighted, as recent research points to faculty involvement well beyond simply disclosing research, with faculty often identifying licensees as well as working with licensees in further development (see, for example, Agrawal and Henderson 2001, Colyvas et al. 2002, Jensen and Thursby 2001, Lowe 2002, Thursby *et al.* 2001, and Thursby and Thursby 2002).

Understanding the nature of this involvement is important for understanding how technology is transferred through licensing as well as more controversial issues, such as the need for university licensing. Some critics of university licensing argue that licensing is unnecessary. The argument is that to the extent faculty disseminate their research through publication, the staff of R&D intensive companies can pick up and use inventions without licensing. To the extent that faculty know-how is important in development, then a simple reading of the relevant literature is not always sufficient for commercialization of university research.

A second controversial issue related to faculty stems from the rate at which licensing has increased. The Association of University Technology Managers conducts an annual survey of licensing activity at US universities. Based on the 84 institutions that reported licenses executed in both 1991 and 2000, the number of licenses executed increased 161%. With such an increase, some critics question whether faculty have been diverted from their basic research mission.[1] Again, the extent and nature of faculty activity is at the heart of the controversy.

It is not surprising, therefore, that the role of faculty has been the focus of recent research on university-industry technology transfer. Thursby *et al.* (2001) provide evidence from a survey of university technology transfer personnel to suggest that the majority of inventions licensed are so embryonic that successful commercialization depends critically on faculty participation in further development. Jensen and Thursby (2001) examine the incentive problems associated with obtaining faculty participation. If faculty have a taste for academic research, as is suggested by Levin and Stephan (1991), Jensen and Thursby (2003), and Jensen *et al.* (2003), then license payments tied to commercial success, such as royalties or equity, are important to attract them to work on commercial development. Similarly, Lach and Schankerman (2003) provide empirical support for the view that faculty disclosure of inventions is positively related to their share of license revenue from their inventions.

Unfortunately the data underlying this work largely comes from universities, which may well overestimate the extent of faculty involvement, and may overlook important reasons that firms work with universities. In this paper we present the results of a survey of businesses that license-in university technologies. We use these data to examine the extent to which licensees use faculty input, not only in identifying inventions of interest, but also in further development (either through sponsored research or according to terms of the license itself). These data also allow us to examine the extent to which the nature of faculty research is a factor in the business's interaction with universities. Our results reinforce and add to those from earlier university surveys. Businesses in our sample report that the overwhelming majority of university inventions they license are no more than a lab scale prototype, and that for early stage technologies they often employ faculty assistance in further development. Our data also show that when inventions are too embryonic to license, firms often pursue the invention by sponsoring faculty research in lieu of a license.

We then present several econometric models that relate firm use of faculty either by sponsoring research or in the terms of the license contract, not only to invention characteristics, but also business characteristics such as "absorptive capacity." Cohen and Levinthal (1989, 1990) introduced the notion of absorptive capacity as a firm's ability to utilize university research and they have argued that this capacity is related to prior R&D. We use the portion of the firm's research that is basic as a measure of absorptive capacity. To the extent that faculty research is a substitute for firm R&D, one might expect firms with higher absorptive capacity to rely less on faculty. Alternatively, recent work shows that industry scientists often conduct research and publish jointly with university faculty (Cockburn and Henderson 1998, and Zucker and Darby 1995). In this case, we might expect faculty and industry basic research to be complementary, and our results support this hypothesis. Further, we argue here, and results support our claim, that absorptive capacity also allows a firm to more closely monitor faculty efforts. Such monitoring is more important with sponsored research agreements than with licenses since license agreements can and do include payment types that are linked to faculty effort (see Jensen and Thursby, 2001).

We also examine faculty participation in further development as a function of the extent to which firms use personal contacts of their R&D staff to identify inventions. We interpret the importance of faculty contacts as a measure of connectedness, which is a concept introduced by Cockburn and Henderson (1998) and Lim (2000), to reflect the extent to which firms augment their internal capacity with faculty contacts. We find that our measure of connectedness is negatively related to sponsored research which may be a function of the fact that some survey respondents cited "establishing relationships with faculty" as a reason for sponsoring research.

These results contribute not only to the literature on university licensing, but also to the extensive literature on faculty collaboration with industry. The bulk of this literature abstracts from licensing and the role of faculty in the license process (See, for example, Mansfield, 1995; Mansfield and Lee, 1996; Zucker, Darby and Armstrong, 1998; and Zucker, Darby and Brewer, 1998). Two exceptions are Adams (2001) and Cohen *et al.* (1998). Licensing and consulting are two means of knowledge transfer considered by Adams in his study of localization of industrial learning from academic research. Cohen *et al*. (1998) found that while R&D lab managers viewed public channels (e.g., publications and conferences) as their most important means for accessing university research, they tended to complement these channels with person-to-person interaction. Our results contribute to this literature by suggesting a complementary relation between private channels of transfer such as licensing and personal contacts.

In Section II, we characterize survey respondents. Section III gives the reasons respondents who increased their licensing from universities gave for the change, including the extent to which it was the result of changes in faculty research orientation Section IV focuses on the nature of inventions licensed-in, including their stage of development. As shown in our later modeling, this turns out to be an important determinant of faculty involvement. Section V presents summary statistics concerning the nature of faculty involvement in licensing while in Section VI we present the econometric models that relate business and invention characteristics to faculty participation in further development of their invention. Section VII concludes.

Throughout the paper, we report survey results in a common table format. Each table states the relevant survey question and then reports the number of respondents answering a particular question ("# Resp."), the simple average based on those responses ("Mean") and, for most of the questions, the average response weighted by the number of university licenses the firm had executed over the period 1993-97 ("Wgt. Mean"). Since the number of executed licenses was not provided by all respondents, the weighted average is typically based on a subset of those responding to the question; on average, the number of respondents for the weighted mean is about 80% of the number of respondents for the simple average. The weighted mean is given by

$$Wgt.Mean = \sum_{i=1}^{n} w_i X_i / \sum_{i=1}^{n} w_i$$

where n = number of respondents, w_i = number of university licenses executed by the ith business unit, and X_i = response of the ith business unit. The weighted mean gives a higher (lower) weight to those business units that executed large (small) numbers of university licenses over the period 1993-97 relative to other respondents. Further, we use paired t tests to test for significant differences in responses. The tests are based only on the un-weighted responses and they are two-tailed 5% tests. Below each table are results of the t tests.

II. CHARACTERISTICS OF THE RESPONDENTS

The survey questionnaire was designed to be answered by individuals actively engaged in executing 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. The majority of these units were firms, and hereafter will be referred to as such. As described in the Appendix, 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.

The majority of respondents were employed by small firms, with 46% answering for firms with less than one-hundred employees and 17% for firms with more than one hundred but less than five hundred employees. In terms of industry segments, 31% of the respondents identified pharmaceuticals as the main industry in which their firm operated, 36% indicated biotechnology and medical devices as their main industry, and 33% indicated other industries. Ninety-one percent of the sample conducted some R&D in-house. On average, 37% of the R&D conducted in-house was basic or discovery research, 44% was development of new products, and 18% was for process improvement.

III. THE ROLE OF FACULTY IN THE GROWTH OF LICENSING

The annual AUTM surveys of university licensing offices show substantial growth in university licensing over the years of the 90s. Firms in our sample generally follow this pattern. We asked respondents whether their contractual agreements (license, option and/or research agreements) with universities had increased, decreased or stayed about the same over the 5-year period preceding our survey (1993-97). Of the 106 answering this question, 50% indicated an increase while only 16% indicated a decrease; the remaining 34% said there had been no change in contractual agreements. For those indicating an increase, license agreements had increased by 86% in 1997 compared to the average of the preceding 4 years, and their research funding to universities doubled. On average, each of these firms executed 13 licenses per year over the period 1993-97 and provided $13.2Mil in sponsored research with U.S. universities.

We then asked respondents about the reasons for the changes, if any. Since there are so few firms indicating a decrease (only 17 firms so indicated), we concentrate on the firms who noted increasing contractual arrangements. Respondents were given five reasons for increasing contracts (in addition to an “other” category) and were asked to indicate importance using a 5-point Likert scale from “Extremely important," which we coded as a 1, to “Not important," which we coded as a 5; a "Don't know" response was permitted. Results are in Table 1. The first three reasons relate to university characteristics, including the nature of faculty research, while the last two relate to changes in corporate R&D. 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 for “universities’ receptivity” as recorded a 1 for “costs” or for “faculty orientation.” Further, a change in “reliance on external R&D” is more important then either “costs” or “faculty orientation.”[2] Of course, the firm’s “reliance on external R&D” could change for reasons other than internal factors; for example, it could relate to in universities. To examine this possibility, we computed the simple correlation between individual respondent answers to the "reliance on external R&D" question and the "costs," "faculty orientation" and "universities' receptivity" responses. The only significant correlation is between R&D and "costs;" the correlation is 0.49 suggesting that, to the extent that reliance on external R&D is related to university characteristics, it is the cost of university research that is important.

In our introduction we noted concerns that the recent growth in university licensing might well signal a change in the direction of university research; such a change is viewed by many as problematic to the extent that it signals a move away from basic research. Our results indicate that the major cause from the perspective of industry lies with university receptivity rather than faculty research orientation. Nonetheless, one can argue that the number who noted the importance of a change in faculty orientation signals a problem. For more on this issue see Thursby and Thursby (2003)

IV. INVENTION CHARACTERISTICS

A key to understanding the nature of faculty involvement in licensing is an appreciation of the nature of licensed university inventions. In this Section, we report survey results that characterize inventions in terms of the reasons they are licensed-in, importance to the firm, and the stage of development when the firm considered licensing them.

As shown in Table 2, 52% of the university inventions licensed-in were used in new product development and only 9% used for process improvement. Twenty-four percent of licenses were used as a research tool, and 18% were licenses for platform (or core) technologies. Interestingly, few respondents indicated that the licenses were to prevent a rival company from licensing the technology. The latter figure follows, we believe, from the fact that university technologies are so embryonic that few firms show interest in a given technology. In our survey of university technology transfer offices (Jensen and Thursby (2001) and Thursby *et al.* (2001)) we asked about the frequency of bidding on a technology by more than one firm. Forty-four percent said this occurred rarely or never and 51% indicated that it only occurred sometimes. Since it is rare that more than one firm shows an interest in a particular technology, it should follow that few firms license in order to prevent a rival from licensing that technology.

To get a sense of how important licensed university inventions are to firms, we asked respondents for the percentage of the time that universities had been critical to the development of new products or processes. Our definition of critical is the same as that used by Mansfield (1995) -- the product or process could not have been developed without substantial delay. Results are in Table 3. The average response for patents licensed-in from universities was 24%, for non-patentable technology it was 8% and sponsored research was 14%. By way of comparison, in-house patents were critical 49% of the time. When we weight these percentages by the number of licenses executed, the picture changes substantially. The percentage of in-house patents that is critical falls to 35%, and the percentage of non-patentable technology licensed from universities rises to 29%, while the percentage of patentable university inventions that is critical changes little. To the extent that in-house R&D is directed towards the firm's core competencies, it is not surprising that in-house patents are more important than university patents. What we find striking is that the importance of university patents is so close to that of in-house patents. This could follow from the basic nature of university research, so that university inventions may be more fundamental and less incremental than industry inventions. Hence, while the firms R&D is more directed at the firm's needs, university research, when applicable to the needs of the firm, is more fundamental.

Table 4 shows the percentage of time licensed-in technologies were in various stages of development. Only 7% of licensed-in technologies were deemed ready for practical or commercial use whereas 40% were simply a proof of concept (the earliest listed stage of development).[3] We also asked respondents about the failure rate of university inventions licensed-in. Forty-two percent of the firms who licensed-in university inventions indicated that these inventions had a higher failure than non-university licensed-in technologies (while only 11% reported a lower rate).[4] Those who noted a higher failure rate reported, on average, that 48% of their university licenses were for technologies that were only a proof of concept; all others reported only 31% to be in a proof of concept stage (these percentages are significantly different at a 5% level). Further, the correlation between the reported failure rate and the fraction of licenses that are in a proof of concept stage is 0.31 (significant at a 1% level) while the correlation with the fraction that are ready for practical or commercial use is –0.23 (significant at the 10% level).

Failure of a technology is associated with stage of development. In Table 5 we report on the reasons for failure of a technology. The first two reasons, failure of the technology and longer lag time than expected, are more closely associated with early than with late stage technologies. On average 47% of the time the reason was failure of the technology and 26% of the time the reason was a longer time to market than had been expected. Note that 18% of the time respondents felt that it was a failure of the faculty that was associated with failure of the licensed technology.

We compared the purpose of university technologies (reported in Table 2) with the fraction of university licenses in various stages of development. Of particular note is the relationship between technologies for process improvement and stage of development. Process improvement is negatively and significantly related to proof of concept (-0.178, significant at the 10% level) while it is positively and significantly related both to manufacturing feasibility known (0.324, significant at the 1% level) and to ready for practical or commercial use (0.18, significant at the 10% level). In other words, process improvement tends to be late stage. Other purposes of university inventions are not correlated with stage of development.

Finally, we asked about problems significant enough that the firm chooses not to license-in early stage technologies. Results are in Table 6. The first, and most important, reason relates to the firm's market niche. The next two reasons relate to funding problems, and internal funding problems are cited as being of greater importance than are external funding problems. We considered whether external funding problems were cited by small companies more often than for large companies. We used an employee size of 100 as our cut point, but we found no significant difference. The final choices relate necessary scientific expertise from either in-house staff or from faculty; neither issue was of substantial importance to our respondents.

V. FACULTY INVOLVEMENT

As noted in the introduction, recent research on university licensing shows that faculty are often involved in the license process well beyond disclosure. Respondents to our survey of university technology transfer offices estimated that 71% of the inventions they licensed could not be successfully commercialized without faculty cooperation in further development. One of the problems with this information is that it is based on the perceptions of TTO personnel. Moreover, one might expect university personnel to overstate the importance of faculty in the process.

In the current survey, we are able not only to discern whether businesses that license from universities agree on the need for faculty involvement, but also to examine faculty involvement in a broader context. To the extent that faculty are viewed as critical in the process, we explore the reasons for their involvement. We find that, in addition to the well cited role of faculty in further development of licensed inventions and sponsored research, respondents rely heavily on personal contacts in order to identify the inventions they license.

A. Identifying Inventions

How do potential licensees go about identifying university technologies? Using a five point Likert scale, we asked respondents about the importance of six methods for identifying university technologies. The question, methods and responses are found in Table 7. A "Don't know" category was included in our question but is excluded from the table. Note a similarity in responses across the questions concerning publications, patent searches and presentations at professional meetings; at any conventional level of significance the responses are not significantly different, however each is significantly different from each of the remaining three responses. Further, responses to "Marketing efforts …" and "canvass universities …" are not significantly different at conventional levels of significance.

What stands out is the extreme importance of personal contacts between the firm's R&D staff and university personnel. These responses are significantly different at all conventional levels from the responses for each of the other sources. Since the most likely university contacts are faculty inventors, this result underscores the central role that faculty, who are the ones most familiar with the technology, play in the transfer of technology *after* an invention is made.[5] We argue that this pivotal role of the faculty follows in large part because of the embryonic nature of most university technologies; the potential markets for embryonic technologies are unclear as are the identities of firms who might profit from licensing those inventions.

We can characterize the results in Table 7 as suggesting that mechanisms for identifying technologies fall into three categories: (1) reading journal publications, making patent searches and attending scientific presentations, which are indirect efforts in that they do not involve any personal contact with university personnel; (2) direct efforts either by the university technology transfer office via marketing or firms via routine canvassing, and (3) one-on-one approaches based on personnel contacts. The latter efforts are the most important with indirect efforts second in importance.

B. Faculty Involvement and Stage of Development

The common reason stated for faculty involvement in further development is the early stage in which most university inventions are licensed (Colyvas *et al.* 2002, Jensen and Thursby 2001, Thursby *et al.* 2001). In this survey we were able to investigate this in more detail by asking respondents the percentage of time that faculty are involved in further development for licensed inventions in each stage of development at the time of license. Results are in Table 8. For technologies in the earliest stages of development (proof of concept, prototype, and preclinical), respondents indicated frequent faculty involvement, whereas they noted less involvement for the latest stage technologies (manufacturing feasibility known and ready for use). Using the weighted mean figures in Table 8 in conjunction with the weighted mean figures in Table 5 indicating the percentage of inventions licensed in various stages of development, we can estimate that roughly 40% of all licenses require faculty involvement.[6]

In cases where respondents viewed faculty as important for further development, we asked them why they viewed them as such. The results are in Table 9. The most important reason given is specialized knowledge of faculty; note, however, the relative unimportance of the cost of faculty development compared to in-house costs. We computed the simple correlations of responses to our question about stage of development with responses to why faculty are important and found no association of stage of development of licensed-in technologies with reasons why faculty are important.

Table 10 gives the percentage of time that consulting and/or sponsored research agreements are used to obtain faculty assistance. Note that we separate consulting contracts into those negotiated directly with the university and those negotiated directly with the faculty member. The most common mechanism is a consulting arrangement. We calculated simple correlations of stage of development answers with mechanisms for obtaining help, but no significant associations were found.

C. Sponsored Research Agreements

Finally, when a decision is made not to license-in a technology, a firm might nonetheless decide to sign a sponsored research agreement for further development of the technology. In Table 11 are responses to our question regarding such decisions and the stage of development of the technology. As is clear from the table, it is a common practice, particularly for early stage technologies, to sign a sponsored research agreement in lieu of a license.

VI. ECONOMETRIC MODEL

The previous section focused on three means by which businesses use faculty in the process of transferring in university research: (1) identification of inventions, (2) further development when inventions are licensed, and (3) further research when inventions are not licensed. In this section, we examine the latter two mechanisms in econometric models that relate these mechanisms to firm and invention characteristics.

For each econometric model the dependent variable is the percentage of time that faculty are used in further development (either *via* cooperation within a license agreement or *via* a sponsored research agreement in lieu of a license). We weight the license data with the fraction of licensed-in agreements that are in various stages of development (see Table 4). Comparable weighting variables for the sponsored research variable are not available. The dependent variables are formed by "stacking" responses to the questions in Tables 8 and 11, so that each respondent can potentially provide six values of the dependent variable; one for each of the six stages of development.

As there are a large number of zero values and given that each respondent can appear in the data multiple times we use a random effects Tobit estimator. The random effects model assumes that each observation has, in addition to the "usual" disturbance, a respondent specific disturbance. After deleting missing observations we have 286 observations in the sponsored research equation and 188 are censored at zero. In the license equation there are 201 observations of which 49 are censored. Independent variables include indicator variables for stage of development, industry indicator variables and the employment size of the firm. In our survey we asked respondents about the purpose of university inventions (see Table 2). We include these responses as regressors. We also include variables to capture the research "intensity" of the firm.

For stage of development we include five indicator variables:

PROTO = 1 if the response is for the prototype stage of development, 0 otherwise;

PRECLIN = 1 if the response is for the preclinical stage of development, 0 otherwise;

CLINICAL = 1 if the response is for the clinical stage of development, 0 otherwise;

MANUF = 1 if manufacturing feasibility is known, 0 otherwise; and

READY = 1 if the technology is ready for practical or commercial use, 0 otherwise.

Note that the omitted stage is proof of concept.

The sample is divided into three industries based on the respondent's primary line of business. The two indicator variables are: PHARMA = 1 if the respondent's industry is pharmaceuticals (0, otherwise), MED = 1 if the respondent's industry is biotechnology or medical devices (0, otherwise). All other industries are in the omitted category.

We measure firm size using employment and divide the sample into three sizes: 1) less than 100 employees (EMPL100 = 1 if there are fewer than 100 employees, 0 otherwise); 2) between 100 and 500 (EMPL100-500 = 1 if there are between 100 and 500 employees, 0 otherwise); and, 3) larger than 500. The latter category is the one omitted from the regression.

Regressors reflecting the use of inventions come from the responses in Table 2, that is, the percentage of time that a licensed-in technology was for new product development (PRODUCT), process improvement (PROCESS), as a research tool (TOOL), as a platform technology (PLATFORM) or to prevent a rival from licensing the technology. We included only the first four responses from Table 2. We do not consider that a license to prevent a rival from licensing would affect whether or not faculty are used in further development unless the firm intended to license and then "shelve" the technology. In our earlier survey of university technology transfer offices respondents did not consider shelving to be a significant problem; in any event, few firms claim that they license-in to prevent a rival from licensing the technology. For the sponsored research equation it would be better to have information on the purpose of sponsored research agreements rather than license agreements; since the former is not available we assume that the purposes of licensed agreements and the purposes of sponsored research agreements are similar.

Finally, we include regressors to capture the firm's "absorptive capacity" in the sense of Cohen and Levinthal (1989, 1990) and "connectedness," which Cockburn and Henderson (1998) and Lim (2000) argue is an important input to absorptive capacity. Absorptive capacity, as the name implies, is the ability of the firm to assimilate and use new knowledge generated external to the firm; for our interests, this is the ability of the firm to absorb new knowledge generated by universities. Connectedness is the degree to which the R&D staff of a firm is in contact with or connected to external researchers; for our interests, this is the degree to which the R&D staff is connected to university researchers. We argue that absorptive capacity and connectedness may both be related to the use of faculty in further development of inventions. In particular, one might expect firms with higher absorptive capacity to have less need for the specialized knowledge of faculty, so that absorptive capacity is a substitute for faculty involvement.

Our measure of absorptive capacity is the fraction of the firm's research that is basic or discovery research (BASIC) as opposed to new product development or process improvement. If the firm does not conduct R&D, then a zero value is used for the amount of basic research. An alternative measure would have been R&D intensity defined by R&D expenditure relative to sales. The problem with this measure for our sample is that a number of firms had no reported sales.

Given our measure of absorptive capacity, one might well expect a complementary relation between faculty involvement and capacity, particularly in the sponsored research equation. There are two reasons for this. First, if the firm is conducting basic research, the R&D staff may have an interest in joint research and publication with faculty, as has been noted in much of the literature (see for example, Cockburn and Henderson, 1998, and Zucker and Darby, 1995). Second, to the extent that there is a monitoring problem with sponsored research agreements, one would expect firms conducting basic research to have a greater capacity to effectively monitor the progress of faculty in research. The latter effect may not be as important in the license equation as contract terms which stipulate royalty payment terms or equity can serve to mitigate the moral hazard problem associated with faculty efforts after an agreement is signed (see Jensen and Thursby, 2001).

Our measure of connectedness, CONTACT, comes from our question as to how firms identify inventions to license (See Table 7). CONTACT is the negative of the score respondents gave to the importance of personal contacts between the firm's R&D staff and university personnel (who are almost always university scientists). In our question to firms small scores indicated greater importance. We use the negative of the score for ease of interpretation, so that a positive coefficient indicates that greater connectedness leads to greater use of faculty. To account for differences in how respondents define "extremely important," etc., we measure the importance of contacts as the difference between the importance attached to personal contacts and the average response made to all sources for technologies; that is, we use a relative measure of the importance of personal contacts.

Initial results for our two econometric models are in Table 12, Part A. In both models the prototype stage (PROTO) is not significantly different from proof of concept whereas all other stages of development are less likely to use faculty (all coefficients are significantly different at least a 5% level). The coefficients of stage of development, except for PROTO, tend to be quite similar in both equations. We tested for equality of the stage of development coefficients and found that, for each model, the coefficients are not significantly different. CLINICAL, MANUF and READY are all late stage and their equality is not surprising; their equality with PRECLIN is somewhat surprising. This may reflect the availability of animal test data for many PRECLIN technologies.

In the sponsored research equation three of the variables reflecting use of technologies are significantly different from zero at 1% significance levels. If technology use is as a platform technology or as process improvement there is an increased chance of using sponsored research in lieu of a license whereas there is less of a chance if the technology is a new product. Research tools is not significant. None of the four coefficients regarding firm size or industry are significantly different from zero. BASIC, the fraction of R&D that is basic research, is positive and significant at a 1% level. The positive effect of BASIC suggests that the monitoring argument given above is important and/or there is a complementarity between basic research and the use of faculty in sponsored research agreements. Note that CONTACTS, our measure of connectedness, is not significant.

In the license equation faculty are more likely to be used in early stages and they are more likely to be used in the smallest size firms. Firms in the pharmaceuticals, biotech and medical device industries are also more likely to use faculty. The coefficients of PHARMA and MED are not significantly different from one another. Regarding the purpose of licensed-in technologies, only PROCESS is significant (at a 10% level). The sign on PROCESS is positive and follows, we believe, from the fact that process improvements are less likely to be within the core competencies of the R&D staff of a firm than are the other purposes. For example, process improvement can be in response to environmental or health and safety regulations; as such, one would not expect the R&D staff to be as prepared to develop further a technology than they would be in the case, for example, of new product development. The connectedness variable, CONTACT, is positive and significant at a 1% level; thus, faculty are more likely to be used the more important are contacts with the R&D staff. Note that our absorptive capacity variable, BASIC, is not significant.

To reduce the parameter space we dropped PROTO, which is never significant. Since the remaining stage of development variables are not significantly different we collected all stages other than PROTO or proof of concept into a single dummy, LATE, to capture late stage technologies. We did the same for PHARMA and MED. The resulting variable, MEDICAL, captures pharmaceuticals, biotechnology and medical devices. Results are in Table 12, Part B. The results change little from the regression in

Part A which include all variables; an exception is EMP100, which is now negative and significant at the 10% level.

In the models considered above the only difference across industries is in a possible shift in the constant term. However, it is quite possible that partial effects of other regressors might vary across industry. To capture that possibility we divided our sample into two parts, one for firms whose primary line of business is one of the life sciences (pharmaceuticals, biotechnology and medical devices) and a second for firms in other industries. We then re-ran our regressions. Unfortunately, there are too few observations in the second set of regressions (63 or fewer) to obtain meaningful answers.

Table 13 presents results of the regressions for the industries involved in the life sciences. Part A presents results based on all regressors, and in Part B we aggregate the late stage technologies (again, we find no significant difference across the coefficients of late stage technologies). The results are similar to those in Table 12 with two important exceptions. For the license equation, CONTACTS is no longer significant. For the sponsored research equation and the model with all regressors the coefficients for both BASIC and CONTACTS are significantly different from zero but they are opposite in sign (only the former is significant in the reduced regressor model reported in Part B). As is the case with the results in Table 12, the more BASIC research conducted, the more likely the firm is to use sponsored research when a license is not signed. However, the closer the contacts of the firm's R&D staff with university personnel, the less likely the firm is to use sponsored research. A possible explanation for the latter comes from discussions with industry licensing executives in which we were told on several occasions that sponsored research agreements were sometimes used as a method for establishing relationships with faculty inventors. Thus, if connectedness is low, there might be a bias towards the signing of a sponsored research agreement in order to establish a relationship (i.e., in order to create connectedness).

We conclude this section by noting that we also considered an econometric model relating responses in Table 10, how faculty input is obtained within the confines of a license agreement, with the characteristics used in the above econometric models. Here, of course, we do not stack responses. Rather, we estimate a different model for each of the three possible responses -- sponsored research, consulting negotiated with the faculty member and consulting negotiated with the university. We also considered a model with the sum of both consulting figures as the dependent variable. In no case was there significance of any variable indicating that the manner in which faculty input is sought through a license is not associated with firm characteristics. Note that our measure of absorptive capacity is important in the model of sponsored research in lieu of a license, but no such relationship holds for sponsored research *within* a license. We believe this supports our contention that absorptive capacity is important for monitoring when there is no license, but that license terms can deal with the moral hazard problem so that the ability to monitor faculty research within a sponsored research agreement is important only when there is no license.

VII. CONCLUSIONS AND UNANSWERED QUESTIONS

Not surprisingly, issues regarding faculty behavior and the concomitant implications for research and education are central to much of the debate surrounding the merits of university licensing. While there is a growing literature on the broader issues and the role of faculty, there is little evidence from the perspective of businesses as to their role and its importance. In this paper, we present evidence from a sample of 112 firms that have recently licensed university inventions. We focused on three ways in which these firms rely on faculty: identification of inventions to license, further development of licensed inventions, and sponsored research. Our results lend support to the view that faculty participation, through informal as well as formal channels, is an important part of the license process. While our results provide more detail on the nature and importance of faculty input from the business perspective, there are a number of questions left largely unanswered.

In particular, there is an interesting dilemma inherent in these results: on the one hand, successful licensing requires faculty efforts in further development, and on the other hand that effort potentially diverts faculty from their role in basic research. Thus successful technology transfer through licensing has a potentially disturbing downside that deserves further attention. We only partially addressed this issue, providing limited evidence on the nature of faculty research as a reason for increased business reliance on licensing. The results reported here indicate that faculty orientation is substantially less important in the growth of university licensing than is university receptivity to contacts with industry. This result is consistent with other results reported in Thursby and Thursby (2002), which show that the primary source of growth in university licensing stems from an entrepreneurial bent of university administrations rather than a change in faculty research. Nonetheless, it is still the case that nearly 11% of respondents noted a change in faculty orientation as extremely important in their increased contacts with universities (see Table 1). Some might view such a result as suggesting a move away from basic research, but there are different perspectives on this. For example, it may only signal an increased willingness to disclose rather than a fundamental shift in the nature of research. The problem with studies such as these is that these data are not the appropriate ones for examining the question of faculty research. What is needed to examine the direction of faculty research, and its relation to licensing, is micro data on faculty behavior, productivity and funding sources. This is a subject of an ongoing, separate study we are conducting.[7]

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APPENDIX. INDUSTRY SURVEY DESIGN

In preparing our survey we attended the annual meetings of the Licensing Executive Society, Inc. (U.S.A. and Canada) to interview licensing executives concerning the university/industry licensing process from their perspective. A preliminary survey document was prepared and further interviews were conducted with that document as the focus. A final survey document was prepared based on feedback from those interviews. A professional designer was employed to format questions. Pretests suggested that the document could be completed in about 30 minutes.

The sample was drawn from the mailing list of Licensing Executive Society, Inc. (U.S.A. and Canada) (LES). 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 those who do not license-in technology from any source as well as those that are no longer in business. This left us with 1385 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, though 61 of the latter had sponsored university research. We mailed the survey in late November of 1998 with a request for a response by December 14. A reminder card was mailed two weeks after the initial mailing. A second mailing of the survey was sent in early January. Each mailing was accompanied by a letter from the President of LES indicating that our survey had the support of the board of LES. We used Purdue University MBA students to call those who had not responded to encourage a response.

Many of the companies on the LES list are not publicly traded so it is impossible to conduct the usual tests for selectivity bias. While there is some public information for private companies, such information is difficult to find for small start-ups which comprise a significant portion of the firms who license from universities. In addition, and perhaps more importantly, our interests lie with those who actively license-in from universities, but we do not know which of the non-responding firms fall in that category. Thus, in any tests for selectivity bias we not know which of the non-responding firms should be compared to the responding firms. As an alternative to the usual tests for selectivity bias we make some comparisons of respondents with data reported by AUTM in their annual survey and we can compare responses from our business survey with responses to our earlier university survey.[8]

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.[9] Seventy-one respondents reported $307Mil of support, which is approximately 17% of the comparable AUTM figure of $1,786Mil 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.[10] 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. Further, as noted in the text and footnote 3, we asked both universities and firms for the fraction of inventions in various stages of development. The average response for each stage of development and for each group is very similar.

Finally, The employment profile of our respondents who license-in from universities is similar to that reported by AUTM for 1998. In the AUTM survey 64% of all university licenses were to start-ups or existing firms with fewer than 500 employees. About two thirds of our sample of firms have fewer than 500 employees, and less than half the respondents are responding for business units with no more than 100 employees. Sixty-three percent of those who actively license-in from universities had no more than $1,000,000 in revenues in 1997.

FOOTNOTES

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J. Thursby: Professor, Economics Department, Emory University, Atlanta, GA, 30306. jthursb@emory.edu

M. Thursby: Professor, Dupree College of Business and NBER, Georgia Institute of Technology, Atlanta, GA, 30322. marie.thursby@mgt.gatech.edu

[1] This growth has been sufficiently controversial to be the cover story of the March 2000 issue of *Atlantic Monthly* and, in the recent past, Congress, the National Academies' Committee on Science, Technology, and Economic Policy, and the President's Commission on Science and Technology have all undertaken review of the Bayh-Dole Act, the law underlying university licensing of federally funded research (which of course is the bulk of university research).

[2] For more on the sources of growth in university licensing see Thursby and Thursby (2002).

[3] In our survey of university technology transfer offices we asked about stage of development. They noted that 45% and 37% of licenses were in the stages "proof of concept" and "prototype available," respectively. Further, 15% and 12% were in the stages "manufacturing feasibility known" and "ready for practical use," respectively.

[4] We asked for the percent of licensed-in agreements with universities that were not successful; by not successful we mean the technology did not fit the need anticipated at the time of the license – as an example, it did not reach the royalty stage.

[5] See also Jansen and Dillon (1999) who report that 56% of the primary leads for over 1100 licenses executed at five universities and one national lab are inventors.

[6] This number is, of course, subject to error as the percentages in both tables do not necessarily sum to 100%. Typically, however, respondents provided percentages that did sum to 100%.

[7] For a preliminary analysis, see Thursby and Thursby (2003).

[8] This approach has been used by others to examine possible respondent bias. See, example, Graham and Harvey (2001) who compare respondents in their survey to the general population of firms rather than make sole use of a comparison of respondents and non-respondents (some of whom are not publicly traded).

[9] 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.

[10] 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.

Table 1
How important are the following in explaining the [increase in university contracts]?
NOTE: A "don't know" response and "other" category were included.

			Relative Frequency for Those Indicating an *Increase*				
Question		# Resp.	Extremely Important	2	3	4	Not important
1	Cost of university research	46	10.9	19.6	30.4	10.9	28.3
2	Faculty research is more oriented toward the needs of business	47	10.6	21.3	27.7	19.1	21.3
3	A change in universities' receptivity to licensing and/or research agreements	49	29.2	27.1	20.8	10.4	12.5
4	A change in our unit's reliance on external R&D	49	20.8	37.5	10.4	14.6	16.7
5	A change in the amount of basic research conducted by our unit	49	18.4	22.4	20.4	14.3	24.5

Responses significantly different at 5% level with the exception of question 1&2, 1&5, 2&4, 2&5, 3&4, and 3&5.

Table 2
When university technologies are licensed-in, approximately what percentage of the time is the purpose (percentages need not sum to 100%)

Question	# Resp.	Mean	Wgt. Mean	
1	96	42.6	51.5	**new product development**
2	96	14.1	8.8	**process improvement**
3	97	19.0	23.8	**as a research tool**
4	94	23.8	17.5	**as a platform (or core) technology**
5	94	4.4	1.4	**to prevent a rival company from licensing the technology**

Responses significantly different at 5% level with the exception of question 3&4.

Table 3
Approximately what percentage of the time have the following been critical to the development of new products or processes? By critical we mean the product or process could not have been developed without substantial delay. (Percentages need not sum to 100%.)

Question	# Resp.	Mean	Wgt. Mean	
1	101	48.9	35.0	**in-house patents**
2	98	24.4	23.1	**patents licensed-in from universities**
3	95	8.2	28.5	**non-patentable technology licensed-in from universities**
4	95	14.0	11.6	**university sponsored research**

Responses significantly different at 5% level with the exception of questions 2&4, and 3&4.

Table 4
For university technologies licensed-in over the last five years, approximately what percentage were in the following stages of development at the time the agreement was negotiated? (Percentages need notsum to 100%.)

Question	# Resp.	Mean	Wgt. Mean	
1	97	38.2	37.2	**proof of concept (no prototype)**
2	94	36	37.3	**prototype (only lab scale)**
3	90	15.3	8.7	**preclinical stage**
4	89	4.7	2.1	**clinical stage**
5	90	9.2	12.2	**manufacturing feasibility known**
6	91	6.5	13.6	**ready for practical or commercial use**

Responses significantly different at 5% level with the exception of questions 1&2, 3&5, 3&6, 4&5, 4&6, and 5&6.

Table 5
When a university licensed-in technology is not successful, approximately what percentage of the time is the reason (percentages need not sum to 100%)

Question	# Resp.	Mean	Wgt. Mean	
1	72	46.5	48.5	**failure of the technology**
2	70	26.3	30.0	**lag time to market application longer than expected**
3	64	17.6	17.9	**failure of the inventor to deliver know-how or cooperate in further development**
4	68	12.6	11.1	**technology would infringe on the intellectual property of others**
5	61	11.1	10.0	**other**

Responses significantly different at 5% level with the exception of questions 2&3, 4&6, and 5&6.

Table 6
Approximately what percentage of the time are the following significant enough problems with early stage technologies that you decide not to license them in? (Percentages need not sum to 100%.)

Question	# Resp.	Mean	Wgt. Mean	
1	92	50.5	51.9	**unsure about the technology's contribution to the company's market niche**
2	91	28.6	25.5	**problems obtaining internal funding to support further development**
3	86	10.1	7.4	**problems obtaining external funding to support further development**
4	90	16.3	10.5	**lack of scientific expertise of in-house staff to develop the technology**
5	85	9.6	11.2	**lack of needed faculty cooperation**
6	81	12.2	16.7	**other**

Responses significantly different at 5% level with the exception of questions 3&4, 3&5, 3&6, 4&5, 4&6, and 5&6

Table 7
When you license-in university technology, how important are each of the following in identifying the technology?
NOTE: A "don't know" response and "other" category were included.

			Relative Frequency				
Question		# Resp.	Extremely Important	2	3	4	Not important
1	Journal publications	102	19.6	31.4	31.4	13.7	3.9
2	Patent searches	101	24.0	33.0	24.0	10.0	9.0
3	Presentations at professional meetings	99	13.1	37.4	31.3	16.2	2.0
4	Marketing efforts by the university's technology transfer office	100	12.0	15.0	23.0	26.0	24.0
5	Personal contacts between our R&D staff and university personnel	106	45.7	31.4	14.3	2.9	5.7
6	Our licensing staff routinely canvass universities for new technologies	98	9.3	19.6	16.5	24.7	29.9

Responses significantly different at 5% level with the exception of questions 1&2, 1&3, 2&3, and 4&6.

Table 8
When you license-in technologies in the following stage of development, approximately what percentageof the time does the faculty inventor perform or cooperate in further development after the agreement? (Percentages need not sum to 100%.)

Question	# Resp.	Mean	Wgt. Mean	
1	71	55.2	39.6	**proof of concept (no prototype)**
2	72	54.2	44.0	**prototype (only lab scale)**
3	47	38.4	39.4	**preclinical stage**
4	31	18.4	36.1	**clinical stage**
5	38	15.0	25.5	**manufacturing feasibility known**
6	38	14.6	24.4	**ready for practical or commercial use**

Responses significantly different at 5% level with the exception of questions 1&2, 4&5, 4&6, and 5&6.

Table 9
When faculty input is considered important for further development of the technology, what percentage of the time is the reason (percentages need not sum to 100%).

Question	# Resp.	Mean	Wgt. Mean	
1	97	66.9	72.8	**faculty have specialized knowledge**
2	87	16.7	12.4	**faculty development cheaper than in-house**
3	88	27.5	28.3	**time constraints on company research staff**
4	88	14.3	8.0	**company lab specializes in late stage development**
5	94	22.7	27.7	**establish working research relationship for future technologies**

Responses significantly different at 5% level with the exception of question 2&4.

Table 10
When faculty input is critical for further development of the technology, what percentage of the time does the license include (percentages need not add to 100%.)

Question	# Resp.	Mean	Wgt. Mean	
1	88	46.0	38.7	**sponsored research agreements to develop the technology**
2	93	34.8	32.6	**consulting contracts negotiated directly with the faculty member**
3	84	27.7	25.7	**consulting contracts negotiated through the university**

Responses significantly different at 5% level.

Table 11
When you decide not to license-in a technology in the following stages of development, what percentage of the time do you sign a research agreement for further development of the technology?

Question	# Resp.	Mean	Wgt. Mean	
1	67	21.3	18.5	**proof of concept (no prototype)**
2	66	23.0	16.2	**prototype (only lab scale)**
3	50	8.8	10.4	**preclinical stage**
4	41	6.1	1.9	**clinical stage**
5	46	6.8	6.5	**manufacturing feasibility known**
6	45	6.9	13.8	**ready for practical or commercial use**

Responses significantly different at 5% level with the exception of question 6&7.

Table 12 Sponsored Research & License Agreements: All Respondents

Part A.

	Sponsored Agreement			License Agreement		
	Coef.	**t-statistic**		**Coef.**	**t-statistic**	
PROTO	1.289	0.26		-3.756	-1.05	
PRECLIN	-21.344	-3.63	***	-16.083	-3.60	***
CLINICAL	-45.179	-5.27	***	-22.945	-3.15	***
MANUF	-39.832	-5.49	***	-14.733	-2.35	**
READY	-44.489	-5.73	***	-13.442	-2.12	**
PLATFORM	0.539	3.00	***	0.207	1.39	
PROCESS	0.914	4.22	***	0.337	1.90	*
TOOL	-0.168	-0.91		-0.011	-0.07	
PRODUCT	-0.565	-4.10	***	0.040	0.27	
EMP100	-6.509	-0.85		23.052	3.28	***
EMP100-500	12.026	1.07		5.113	0.65	
PHARMA	9.122	1.26		14.362	1.94	*
MED	0.678	0.10		16.831	2.76	***
BASIC	41.017	4.98	***	7.423	0.87	
CONTACTS	-11.227	-1.38		24.277	3.08	***

Part B.

	Coef.	t-statistic		Coef.	t-statistic	
LATE	-34.281	-8.47	***	-14.492	-4.43	***
PLATFORM	0.506	2.91	***	0.201	1.31	
PROCESS	0.477	2.41	**	0.331	1.73	*
TOOL	0.057	0.30		-0.016	-0.10	
PRODUCT	-0.560	-3.79	***	0.025	0.17	
EMP100	-12.879	-1.79	*	23.721	3.33	***
EMP100-500	6.700	0.68		4.997	0.54	
MEDICAL	6.085	1.03		16.017	2.64	***
BASIC	38.457	4.63	***	8.699	1.04	
CONTACTS	-2.143	-0.26		23.288	1.75	*

*** Significant at the 1% level
** Significant at the 5% level
* Significant at the 10% level

Table 13 Sponsored Research & License Agreements: Pharma and Med only

Part A.

	Sponsored Agreement			License Agreement		
	Coef.	**t-statistic**		**Coef.**	**t-statistic**	
PROTO	-3.966	-0.75		-3.238	-0.69	
PRECLIN	-26.040	-4.34	***	-17.787	-3.25	***
CLINICAL	-44.897	-5.06	***	-26.972	-2.70	***
MANUF	-54.373	-6.29	***	-34.017	-2.93	***
READY	-51.572	-5.53	***	-23.704	-2.33	**
PLATFORM	0.434	2.50	**	0.340	1.74	*
PROCESS	-0.443	-1.35		0.120	0.29	
TOOL	-0.063	-0.37		-0.164	-0.87	
PRODUCT	-0.662	-4.82	***	0.038	0.23	
EMP100	-4.541	-0.56		16.916	1.55	
EMP100-500	21.421	2.44	**	3.326	0.29	
PHARMA	15.538	2.42	**	3.573	0.46	
BASIC	35.299	3.90	***	11.343	0.97	
CONTACTS	-22.780	-2.64	***	14.855	1.53	

Part B.

	Sponsored Agreement			License Agreement		
	Coef.	**t-statistic**		**Coef.**	**t-statistic**	
LATE	-36.204	-7.54	***	-19.529	-4.37	***
PLATFORM	0.690	3.46	***	0.353	1.71	*
PROCESS	1.164	2.64	***	0.128	0.31	
TOOL	0.565	1.67	*	-0.161	-0.83	
PRODUCT	0.049	0.24		0.053	0.30	
EMP100	8.814	0.92		15.247	1.37	
EMP100-500	35.784	2.72	***	1.078	0.09	
PHARMA	11.797	1.57		4.435	0.56	
BASIC	26.937	2.73	***	11.077	0.96	
CONTACTS	-15.671	-1.43		16.680	1.58	

*** Significant at the 1% level
** Significant at the 5% level
* Significant at the 10% level