Organizational Structure as a Determinant of Academic Patent and Licensing Behavior: An Exploratory Study of Duke, Johns Hopkins, and Pennsylvania State Universities

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ABSTRACT. This paper examines the influences of university organizational structure on technology transfer performance. The analysis treats the organizational structure of the technology-transfer office as an independent variable that accounts, in part, for measured differences in inter-institutional patenting, licensing, and sponsored research activities. We derive and investigate three hypotheses that link attributes of organizational form − information processing capacity, coordination capability and incentive alignment − to technology transfer outcomes. A detailed analysis of three major research universities − Johns Hopkins University, Pennsylvania State University, and Duke University − provides evidence of the existence of alternative organizational structures. The data also suggest that these organizational capabilities result in differences in technology transfer activity.

JEL Classification: O31, O32, O33, O34

1. Introduction

Research on university technology transfer has documented several salient trends in the aftermath of the Bayh-Dole Act. These include an increase in the number of universities that established or expanded their technology transfer offices, the clustering of academic patents into a small number of patent classes, the skewed distribution of patents, licenses and licensing income in a small number of institutions, and temporal changes in the quantity and quality of academic patents (see, for example, Eisenberg, 1996; Etzkowitz and Peters, 1991; Feller, 1997; Government−University−Industry Research Roundtable, 1986; Lee, 1995; Mansfield and Lee, 1996; Mowery, Nelson, Sampat, and Ziedonis, 1999; Trajtenberg, Henderson, and Jaffe, 1997). Most recently, attention has begun to focus on the organizational determinants of academic patenting and licensing, particularly the efficiency of technology transfer offices (Siegel, Waldman, and Link, 1999; Thursby and Kemp, 1999). Interest is shifting from studying the number and impacts of patents and licenses per se to understanding inter-institutional variations in the range and efficiency of technology transfer activities.

This paper adds to this emerging literature by considering how organizational structure mediates the relationship between inputs that give rise to intellectual property and the level and forms by which the university generates revenues from this intellectual property. We propose that technology transfer activities, manifested as eliciting and processing invention disclosures, licensing university-created knowledge, seeking additional sponsorship of R & D projects or a combination of these three, are shaped by the resources, reporting relationships, autonomy, and/or incentives of technology transfer offices (TTOs). Our analysis treats the structure of the TTO as an independent variable that accounts, in part, for measured inter-institutional differences in patenting, licensing, and sponsored research activities. This analytical lens permits a sharpened focus for examining variations that others have alluded to in caveats or qualifying statements but have not systematically studied. For example, Siegel, Waldman and Link (1999) have noted that technology transfer outcomes may depend on organizational practices that potentially attenuate palpable dif-

[1] *Duke University*
[2] *Johns Hopkins University*
[3] *Pennsylvania State University*

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ferences in the motives, incentives, and organizational cultures of the players involved in this process.[1]

The paper is organized as follows: Section 2 briefly reviews the organizational theory literature to identify alternative organizational structures and explicate the distinctive competencies of these alternative forms. Section 3 generates testable propositions that link our framework to the set of outcome variables commonly found in studies of academic patenting and licensing. Findings for this paper are based on detailed studies of technology transfer at Duke University, Johns Hopkins University and Pennsylvania State University. Our selection of these three universities is shaped by access to key information and individuals. Section 4 provides an overview of the three universities and an analytic test of the hypotheses. The small number of institutions and their purposive selection obviously tempers conclusions about the generalizability of our findings to the larger set of institutions. However, this paper offers a detailed preliminary examination of institutional patent and licensing data in the context of institutional structures. Our results suggest the merits of this approach. Section 5 offers conclusions and plans for future research.

2. Theoretical umbrella

Our attention to the intervening role of structure on university technology-transfer activities rests on the theoretical foundation provided by Chandler (1962, 1977, 1990). Chandler's studies of the evolution of modern business enterprises led to the characterization of different types of organizational structures. In early work, Chandler (1962) identified two distinct organizational structures: the functional or unitary form (U-Form), a centralized, functionally departmentalized structure in which decision-making and coordination responsibilities lie with a small team of top executives; and the multidivisional (M-Form) structure in which the organization is decomposed into semi-autonomous operating divisions along customer, product or geographic lines. Williamson (1975, 1985) coined a third organizational structure—the holding company or H-Form. Like the M-Form, this structure adopts a divisional approach, but relies on a weak, rather than strong, central office. A relatively recent organizational design is the Matrix structure—the MX-Form. A matrix structure combines two or more dimensions of function, product, customer or place.

Each organizational structure has unique competencies. Table I provides a summary of how these four organizational structures differ in terms of information-processing capacity, coordination capability across organizational units, and the alignment of incentives across organizational units. These competencies support different strategic intentions and are expected to lead to systematic variation in performance.[2]

The Unitary or U-Form places decision-making authority at the top of the organizational hierarchy − university administration. Each organizational unit, grouped by some specialty function, does its own tasks and then passes its output on to other units.[3] Top management sets organizational goals, makes strategic decisions, and oversees and coordinates the efforts of individual units. This hierarchical structure, while adequate for single business firms, quickly becomes inefficient as business complexity increases and the information-processing capabilities of boundedly rational management are reached. A secondary ramification of complexity for this organizational structure is the deterioration of coordination and incentive alignment capabilities. Lacking a clear understanding of global organizational goals, functional managers "rationally" optimize on the local goals associated with their individual functions. These local unit goals may not be compatible across units or in line with overall organizational goals.

The M-Form structure provides a solution to these limitations by decomposing the organization into semi-autonomous operating divisions (often with profit center incentives) along customer, product, or geographic lines. Simultaneously, a central authority or headquarters is established to monitor and coordinate the individual divisions.[4] By segmenting decision-making responsibility, the M-Form structure reduces informational processing demands and thus enables management to work more effectively within their cognitive limits. By providing a mechanism for central control, the M-Form limits sub-goal pursuit and enhances across-division incentive alignment. The top-level goals of the organization can be mapped directly

Table I
Competencies of alternative organizational structures

Organizational structure	Information-processing capacity	Coordination capability (across units)	Incentive alignment (across units)
U-Form	0 Limited by HQ size; the need to funnel decisions through top management group creates a bottleneck	+ Coordination capabilities among sequential work units are relatively strong given vertical control	+/0 Difficult to create unit-level incentives compatible across units and in-line with organizational goals
H-Fom	+ + Decentralized decision-making leads to higher overall information-processing capacity	+/0 Weak central body allows for limited top-down coordination across units	+/0 Strong unit-level incentives; sub-goal pursuit often problematic due to weak organizational ties
M-Form	+ + Decentralized decision-making leads to higher overall information-processing capacity within units	+ Strong central body allows for moderate top-down coordination across units	+ Strong unit-level incentives; Sub-goal pursuit problematic but tempered by stronger organizational ties
MX-Form	+ Multiple dimension responsibilities may tax information processing capacity within units	+ + Dual Dimension responsibilities drive coordinated action	+ + Dual Incentives: Functional and product incentives are integrated to reflect organizational goals

Impact on Capabilities: 0 = weak; + = semi-strong; + + = strong

onto the goals of the individual units to achieve higher across-unit incentive alignment.

A third organizational structure is the holding company or H-Form. Like the M-Form, this structure adopts a divisional approach, but relies on a weak, rather than strong, central office. As such, it gains the advantages of distributed decision-making, but it may not be able to harness the efficiencies arising from the coordination of action across independent divisions. This form allows for strong unit-level incentives that facilitate unit goal pursuit but the weak organizational ties may not optimize global organizational goals.

The final organizational form is the MX or matrix form which operates simultaneously with both a functional and product hierarchy. It is a structure in which an individual or subunit is responsible for multidimensional functions.[5] The downside of this structure, which places decision-makers at the intersection of two organizational dimensions, is the increased complexity that may strain information processing capabilities. The upside, however, is that the MX-Form heightens internal incentive alignment and reduces the costs of coordination across diverse, previously unconnected, dimensions. For the remaining of the paper, we use the designation MX-form to represent both traditional and collapsed matrix structures. A collapsed matrix is a version of a matrix structure in which unit managers hold primary responsibility along both organizational dimensions.

These organizational structures offer insights for analyzing universities. While all U.S. universities have acquired broader intellectual property rights since 1980, considerable diversity exists in technology transfer procedures and policies as well as the organization of technology transfer and intellectual property offices developed in response to legislation and market opportunities. This diversity may be viewed as a natural experiment in which the various actors search for efficient means to organize their activities to promote both the diffusion of university research and the generation of additional revenue, while maintaining the traditional university mission of creating knowledge and educating students.[6]

3. Organization structure and university technology transfer outcomes

We posit that the structure of the technology-transfer office provides a set of independent variables that may be used to explain technology transfer outcomes across universities. This section provides a set of testable propositions that link organizational form with performance ramifications in technology transfer. For simplicity, we build hypotheses centered on each of the three key performance attributes – information processing capacity, coordination capabilities, and incentive alignment properties.[7] Each of these competencies optimally support or match different strategic intentions which, in turn, may be expected to lead to systematic variations in performance.

Coordination capability

Coordination is the capability to orchestrate the activities of different work units. Relevant units may include any sub-entity that has interaction with what is typically considered the "customer." These may include units involved with sponsored research, intellectual property management, corporate giving and student hiring. University technology transfer offices generally describe themselves as having multiple customers, including most prominently faculty, administration, and firms. Given this paper's focus on university-industry interactions, we use customer to refer to firms only.

The H-Form, with its weak central administrative office, has limited capabilities to coordinate across operating units. Each unit is, therefore, expected to pursue its self-interest in relative isolation. Coordination capabilities increase with the adoption of the M-Form structure, which offers a stronger central office. With the separate units directly reporting to the same central office, it is possible for "management" to promote the exchange of information between units. Similarly, the U-Form structure offers enhanced coordination capabilities as between-unit coordination is dictated from above by top management and emerges from below given required unit-level interaction. Finally, the MX-Form presses the degree of coordination/incentive alignment even further. Under this structure, coordination is promoted by both managerial oversight and the tight links arising from the multiple roles of each subunit. Thus, as summarized in Table I, column 2, the coordination capacity of the alternate organizational forms is: $H < M \approx U < MX$.

In the context of university technology transfer, the degree of coordination among licensing, sponsored research, and related technology transfer units can determine the extent to which these units integrate their activities and share information related to customer needs and opportunities. Lacking coordinated action, each unit, for example licensing or sponsored research, would interact with its own set of customer firms and any overlap of customer firms would be random events. Higher levels of coordination would allow the individual units to exchange information about customer firms' needs and, when appropriate, leverage existing relationships across units for greater involvement with the university. As such, the expected likelihood of interacting with firms on both sponsored research and licensing is highest for the MX-Form, followed by the M-Form and the U-Form – which are roughly equivalent – and lowest for H-Forms. Thus, the following proposition:

P1: The likelihood that "customer-firms" will be shared across units will be greatest when technology-transfer activities are structured as a Matrix (MX-Form), followed by Divisional M-Forms (M) and U-Forms, and least likely when organized as a Holding company, H-Form (H).

Information-processing capacity

The information processing capabilities of individuals operating under the MX-Form become more quickly strained when compared to the information processing capabilities of individuals operating under H-Form or M-Form organizational structures. Under the MX-Form each manager holds responsibilities along two organizational dimensions. This broader span of responsibility increases the complexity of the job and thus depletes information processing capabilities more quickly.[8] Information processing capacity is expected to be lowest under U-Form structures given the role top management plays in the decision-making activities across all units. In general, information processing capabilities should not vary significantly under the H-Form and the M-Form. In both cases, the individual manager within a unit is focused on a single dimension and, assuming comparable skill-levels, these individuals are expected to handle similar levels of complexity. In sum, and as highlighted in Table I, column 1, information processing capacities of the alternate organizational forms is ordered as: $U < MX < M \approx H$.

Information processing capabilities should be reflected in the relative effectiveness of the technology transfer officers. One measure of such effectiveness is the throughput or yield achieved by the office, normalized by staff size. That is, the average number of technology transfer transactions − invention disclosures, licenses, or sponsored research agreements − handled per officer is expected to vary across organizational structure, *ceteris paribus*. The U-Form is expected to have the lowest yield, followed by the MX-form, and then by the roughly equivalent M and H-Forms. Thus:

P2: Effectiveness will be lowest when technology-transfer activities are structured as a U-Form followed by a Matrix (MX) organizational form. Yield across the M-Form and H-Form, while higher, are expected to be roughly equivalent.

Incentive alignment

Related to the differing coordination capabilities, the four organizational forms are also characterized by differing levels of incentive alignment across units. Incentive alignment across units is relatively low in U-Form structures. Though, in theory, a strong top management team can affect incentive alignment by closely monitoring unit-level behavior, this requires a significant commitment of managerial resources (Ouchi, 1980). In practice, managerial oversight is often lacking, in which case the individual units may actively pursue incompatible sub-goals. Similarly, incentive alignment is relatively low under the H-Form as in this type of organization each unit is rewarded solely by the returns generated by its own actions. The weak central office rarely, if ever, becomes involved in redistributing income across units as necessary to engender across-unit alignment. With its stronger central office, M-Form organizations are better positioned to direct/coordinate such redistribution programs and thus may potentially achieve higher levels of incentive alignment across units. Incentive alignment is highest, however, in MX-Form organizations, where returns are generally a function of activities undertaken along both axes of the matrix. In sum, and as highlighted in Table I, column 3, the level of incentive alignment across the alternative organizational structures is: $U \approx H < M < MX$.

Commercializing university technology may require a combination of licenses and sponsored research. Technology-transfer officers who are only rewarded for performance on one mechanism, licensing activity for example, will attempt to maximize the return from that mechanism. If incentives are aligned to reward technology transfer activity across mechanisms, then trade-offs can be negotiated with other income generating activities in order to maximize the overall university technology-transfer gains. Thus, the following proposition:

P3: Leveraging (the trade-off between royalty rate/licensing fees and sponsored research dollars) will be greatest when technology-transfer activities are structured as a Matrix (MX) organizational form, followed by a Divisional M-Form (M), and least likely when organized as a Holding company H-Form (H) or a U-Form.

4. Data and analysis

Our sample of research universities includes Duke University, Johns Hopkins University and Pennsylvania State University. Much of the data used to gain an understanding of the organization of technology transfer at these institutions was collected through a series of round-robin interviews with technology transfer personnel, faculty and research administrators at each university during the fall of 1999 and the winter of 2000. In total, we conducted 21 interviews, several of which were with multiple respondents. Each interview lasted between 1 hour and 3 hours. We used a loosely structured interview protocol to insure that the same questions were asked at each university while remaining flexible to allow participants to lead the discussion and inform our inquiry. We also collected documentation on policy statements and organizational charts for each of the universities. Data used to evaluate the specific performance propositions detailed above are drawn directly from these interviews and the technology-transfer databases maintained at each of these universities. In addition we also examined the history of the three universities since this sets the stage for the organizational structure of the technology transfer operations.

Similarities and differences exist among the three universities studied as demonstrated in Table II. Johns Hopkins, Pennsylvania State University, and Duke are each research-intensive academic institutions (Association of American Universities-Carnegie I) with established medical schools. Johns Hopkins University was founded on the German university model in 1876; it has historically kept considerable distance from industrial activity and followed a basic research strategy. Pennsylvania State University is a public land grant institution established in 1854: it has retained an emphasis on agricultural and materials and engineering research that has economic development potential. By contrast, Duke University is younger (established in 1924); it was built upon the existing Trinity College with a strong educational mission and an endowment upon which to build.[9] In terms of patent and licensing activity, Duke and Penn State are what Mowery and Ziedonis (1999) have termed "low intensity incumbent" universities − institutions with limited patent and licensing activities, and thus little in the form of technology transfer offices or organizational arrangements, prior to 1980.[10] Johns Hopkins University, in contrast, had more patents issued and a fledgling technology transfer operation prior to the passage of the Bayh-Dole Act in 1980. In the past twenty years, distinct well-staffed technology transfer organizations have emerged at each institution, and now, in terms of the efficiency scores developed by Thursby and Kemp

Table II
Comparative summary of the three universities

	JHU	Duke	PSU
Type of institution	Private	Private	Public
University founded	1876	1924	1854
Medical school	Yes	Yes	Yes
Founded/affiliated (year)	1893	1930	1980
Distance from main campus	2 Miles	Adjacent	90 Miles
Number of U.S. patents issued 1980−1990[11]	153	56	6
Number of U.S. patents 1991−1997	201	134	96
1998 Total R & D expenditures ($000)	$853,620[a]	$282,388	$362,643
Percent federal sources	88.2%	61.1%	51.4%
Percent industry sources	1.7%	23.1%	17.5%
Rank in academic R & D expenditures	8th	26th	10th
1998 invention disclosures: Internal data	228	113	190
1998 patents: AUTM survey	76	37	25
1998 active licenses: AUTM survey	149	45	68
1998 licensing income: AUTM survey	$5,513,284	$1,318,680	$2,012,584
1998 spin-off companies: AUTM survey	5	1	5
1977−1980 patents granted	28	1	2
Efficiency rating (Thursby & Kemp)	100%	100%	100%
Organizational structure	H-Form	MX-Form	M-Form

[a] Includes Applied Physics Laboratory ($443 Million). Other data also reflect activity at the Applied Physics Lab.

(1999), each of these universities operates an "efficient" technology transfer office. That is, each of these universities operate on the technology-transfer production frontier and can be considered "best practice" institutions.

In studying these three universities, we find that institutional history, culture and norms of behavior, while not sole determinants of the structure of the university technology-transfer efforts, appear to play an important role in the universities' approach to technology transfer. As briefly touched upon above, the existing structure of the technology transfer offices at each of these three universities is compatible with that institutions' history and evolutionary path. Given space limitations, in the following sections we focus only on the post-1980 period, considering each university in turn and describing the technology transfer operations of each as of the completion of our interviews in March 2000.

Johns Hopkins University

Johns Hopkins University is geographically spread throughout Baltimore reflecting a historical and spatial differentiation with a large degree of decentralization and autonomy among its constituent units. The Homewood main campus is eight miles from the downtown School of Medicine. The Peabody Music School is located in midtown while the Applied Physics Lab is located in the suburbs. Each of these units has a technology transfer office. These offices are only loosely connected by an overarching governing body consisting of the University President and the Board of Trustees (see Figure 1). Independent sponsored research units, which maintain a coordinated reporting system, also exist at each site. Each technology transfer office is supported by its relevant division. No systematic allocation of licensing revenue exists to provide an incentive to the offices. Thus, the Johns Hopkins University's technology-transfer operations appear to be organized in an H-Form structure.

The Homewood Office of Technology Transfer (OTT), created in 1976, oversees the Schools of Arts and Sciences, Engineering and Public Health. The OTT operates under the auspices of the Vice-Provost for Research.[12] Falling loosely under the umbrella of the OTT, but basically in-

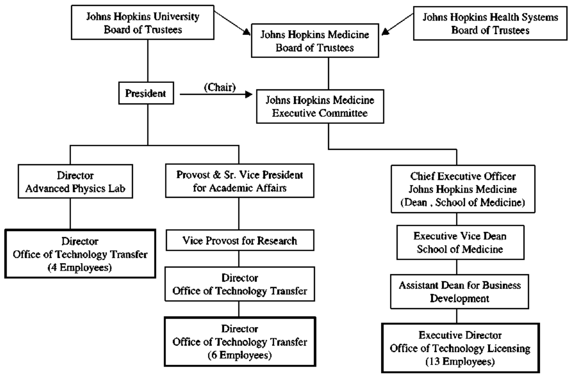

Figure 1

dependent, is the technology transfer operation of the Peabody Institute, a music conservatory founded in 1857 and affiliated with JHU in 1977. Peabody has aggressively combined its traditional strengths in music with an entrepreneurial vision to develop products related to multimedia composition and performance and digital audio processing systems.[13]

The Office of Technology Licensing (OTL) at the School of Medicine is located one subway station, or a ten-minute car ride, away from the Medical School campus. Created in 1986, it operates under the School of Medicine's Research Administration Department. OTL works closely with the Office of Corporate Liaison, which is responsible for cultivating industrial relationships, and the Research Administration Office, which is responsible for negotiating research agreements.[14]

The Applied Physics Laboratory added the Office of Technology Transfer (APL-OTT) in September 1999.[15] The new office was created with the following goal: "In addition to a typical technology-push approach… the office will also establish a market-pull approach: identifying the needs of the commercial sector that match the unique capabilities and multi-faceted strengths of the Laboratory" (APL Press Release, 1999).

In summary, the organization of Johns Hopkins University's technology transfer effort is consistent with an H-Form structure, with four decentralized technology transfer operations. Each unit is funded largely by, and reports to, divisional offices and there is limited central administrative control.[16]

Pennsylvania State University

As a land grant institution, Pennsylvania State University (PSU) began with a mandate of service to the public, and has continued a commitment to the development of practical sciences for the purpose of enhancing economic growth and general well being. Pennsylvania State University has evolved as a M-Form organization. In 1987, the Board of Trustees endorsed a set of initiatives that included strengthening the University's research and technology transfer facilities; developing programs to assist faculty, students and staff in entrepreneurial activities; and building recognition of and support for an active role in state economic development. These initiatives catalyzed a reorganization of the University's office of the Vice-President for Research, the creation of the position of Associate Vice-President for Research, and the establishment of an office of Technology Licensing. Reflecting the University's commitment to technology transfer, the new associate vice-president's position also included responsibility for administration of the sponsored research activities thus administratively linking sponsored research with licensing activities.[17]

In the mid-1990s, the consensus at PSU was that technology transfer, although increasing, had not generated the financial outcomes or state economic development contributions commensurate with the University's research base.[18] In response, technology-transfer was again reorganized. A Task Force recommended splitting responsibility for sponsored research and licensing/technology transfer that led to the creation of assistant vice-presidents for both technology transfer and research and strategic initiatives, each reporting to the Vice-President for Research. In addition, a new position, Director of Technology Transfer, was established in 1995 to support technology transfer at the Hershey Medical Center, located 90 miles away.[19] Over the past 5 years Penn State's organization of its technology transfer activities has moved closer to a true M-Form structure (see Figure 2).

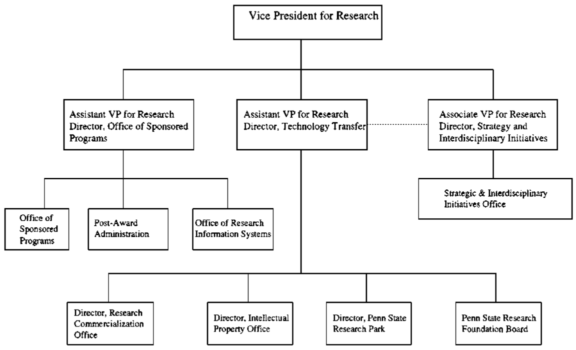

Figure 2

Duke University

Duke University, in contrast to Johns Hopkins and Penn State, is more integrated both in form and geography. The Medical School is located on the university quadrangle and is an integral part of the university. From the beginning, there has been one human resources, payroll, accounting, and administrative services for all of the university. Duke's Office of Science and Technology (OST) has evolved as a collapsed Matrix structure (see Figure 3).[20] The head of the OST, the Vice Chancellor of Science and Technology Development, reports directly to the Chancellor of Health Affairs, who, in turn, reports directly to the University President. Within OST, there are four Associate Directors. Three of these individuals have PhDs in the sciences, while the fourth holds an MBA. In the collapsed matrix, each Associate Director has primary responsibility for one or two facets of the university-industry technology transfer interface broken-out by Sponsored Research Agreements, Patents and License Administration, Spin-off Activities, Material Transfer Agreements, and Corporate Partnering and Business Development. Simultaneously, each of these individuals oversees a specific technology area –

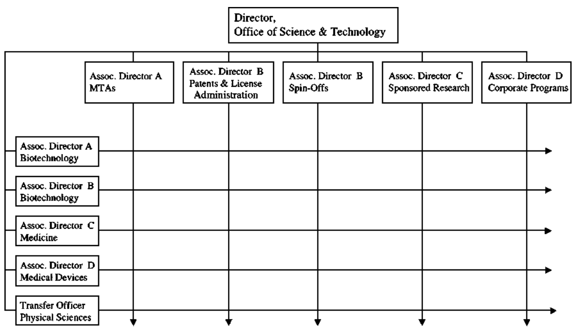

Figure 3

medicine, medical devices, biotechnology (biomedical and agricultural), or chemical, physical sciences and engineering.[21] Each of the Associate Directors manages patenting and licensing within his or her technology area.

The Office of Science and Technology is funded through remitted shares of the intellectual property revenues generated, receiving 0.5% of the university indirect charges for sponsored research. According to the University's Patent Policy, the OST receives 10% of licensing royalties after expenses. In practice, the share captured by OST is closer to 30% of licensing revenues as the University has chosen to direct to the OST the 20% share of royalties designated to "provide research support in the University as determined by the President upon the advice and counsel of the Chancellor for Health Affairs" (Duke University Patent Policy, 1996). The Office receives revenues based upon both licensing royalties and research funding. Given the higher risk associated with the uncertain yield and timing of licensing royalties, the Associate Directors have sufficient incentives to pursue either mechanism.[22]

The OST staff is housed in several different buildings across, as well as off, campus. Coordination is maintained through frequent telephone calls, e-mails, meetings, and use of the common technology-transfer database in which all invention disclosures, patenting efforts, licensing activities, and sponsored research agreements are tracked.

Hypothesis testing

We find that the three universities in our study have chosen to organize their technology transfer activities using different organizational structures. Johns Hopkins University most closely aligns with an H-Form structure with many decentralized technology transfer units and limited central control. Pennsylvania State University organizes its activities as an M-Form in which separate offices for licensing and sponsored research report to the University's Office for the Vice President of Research. Duke University, in contrast, has opted to organize these activities within one office via a collapsed MX-Form. None of the institutions we studied adopted the U-Form structure.

Having identified the unique organizational structures in place at these institutions, we now turn to evaluating the three hypotheses detailed earlier in this paper. Our quantitative tests are obviously limited by the small size of our sample. However, there is value in the following exercises both to validate with preliminary findings our theoretical approach and to provide impetus for conducting larger, follow-on studies.

Coordination capability

P1: The likelihood that "customer-firms" will be shared across units (licensing and sponsored research) will be greatest when technology-transfer activities are structured as a Matrix (MX) organizational form, followed by Divisional M-Forms (M) and U-Forms, and least likely when organized as a Holding company, H-Form (H). That is, the expected likelihood of shared customer firms is $MX > M \approx U > H$.

To provide a quantitative test of Proposition One, we compiled lists of the top 30 firms active in licensing and sponsored research transactions at each of the three universities. We used data for the six-year period from 1993–1998 to capture a window during which shared activity could reasonably develop. We ranked the companies in terms of the number of transactions (licensing or sponsored research agreements, as appropriate). We then calculated the percentage of companies common to both of the sponsored research and licensing lists to get an approximate measure of customer-firm overlap.[23]

Table III provides the percentage overlap for the number of transactions at Duke University, Penn State University, and Johns Hopkins University.

Table III
Data for the test of P1

Institution	Organizational form	Customer overlap I (count of transactions)
Duke University	MX-Form	23%
Penn State University	M-Form	17%
Johns Hopkins University	H-Form	10%

The numbers are supportive of Proposition 1. We find that, when calculated by transaction counts, the customer overlap percentage at Duke, a matrix organization, is more than twice the customer overlap at Johns Hopkins, an H-form. Overlap at Penn State, the M-form, falls between that of Duke and Johns Hopkins.

While these findings are in-line with P1, we acknowledge that there are significant limitations in the above test. Notably, given data constraints, we can not (1) tell if the differences in overlap uncovered are statistically significant or (2) effectively control for other factors, such as the university's research focus and/or research quality, that might influence customer overlap. However, we believe that these findings, are tantalizing enough to show that the structure-performance framework outlined here merits further quantitative study.

Information processing capacity

P2: Yield, as measured by Invention Disclosures/TTO; Licenses/TTO; Sponsored Research Agreements/TTO, will be lowest when technology-transfer activities are structured as a U-Form followed by a Matrix (MX) organizational form. Yield across the M-Form and H-Form, while higher, are expected to be roughly equivalent: U < MX < M ≈ H.

To test hypothesis 2, we collected the annual number of invention disclosures, licenses and sponsored research agreements from the university databases for the six years from 1993 to 1998. We then divided these counts by the Full-Time Equivalent (FTE) Licensing staff employed by each university for each year to provide the yield. Table IV presents the average annual number of disclosures, patents and licenses per FTE and the standard deviation for the three universities.

Table V
Test of P2

	Mean disclosure yield	Mean patent yield	Mean license yield
Parametric test for equivalence of the means: t-statistic reported with unequal variance with 2 tailed significance (significance level in parenthesis)			
$\mu_M = \mu_H$	0.393	1.51	0.957
	(0.703)	(0.179)	(0.374)
$\mu_{MX} = \mu_{MH}$	7.653	2.418	1.692
	(0.00)	(0.031)	(0.114)

We tested the null hypothesis that the average mean number of disclosures, patents and licenses were equal between the M-Form and H-Form using a t-test for equality of means and then tested for differences between these two forms and the MX-form. Results are presented in Table V. The t-test for the equivalence of means assumes unequal variances.

The statistical tests confirm that there are no significant differences between the M-Form yields and the H-Form yields as expected for all three measured outcomes: disclosures, patents and licenses. With ten degrees of freedom, the t-statistic was not statistically significant at 0.95 for any of the three yields. Thus, the yields under the M-Form and the H-Form are statistically the same. Next, comparing the mean yields for the MX-Form against the yields for the M-Form and H-Form we find that the mean yields are statisti-

Table IV
Data for the test of P2

Institution	Organizational form	Mean disclosure yield	Mean patent yield	Mean license yield
Duke University	MX-Form	22.02	16.93	6.89
		(2.91)	(3.32)	(1.64)
Penn State University	M-Form	38.56	21.38	8.48
		(6.12)	(6.49)	(3.14)
Johns Hopkins University	H-Form	40.14	32.65	12.17
		(7.69)	(17.10)	(8.88)

Standard deviations for the annual averages are provided in parenthesis.

cally significantly different for the disclosure and patent yields but not for license yield. With 16 degrees of freedom, the difference in yields between the organizational forms were statistically significant at 95% for both disclosures and patents.

This differences of means test is consistent with our hypothesis, but again our analysis does not control for alternative explanations. Rather, as in the above tests, it serves as a first step in confirming the predictive merit of our approach.

Incentive alignment

P3: Leveraging (the trade-off between royalty rate/licensing fees and sponsored research dollars) will be greatest when technology-transfer activities are structured as a Matrix (MX) organizational form, followed by a Divisional M-Form (M), and least likely when organized as a Holding company H-Form (H) or a U-Form. That is, the expected likelihood of leveraging is $MX > M > H \approx U$.

The issue of revenue trade-offs, or leveraging sponsored research revenue against licensing revenue, was introduced by the TTOs in multiple interviews. Differential comments provide us with substantial qualitative data on this issue. Johns Hopkins has no specific strategy regarding leveraging. When specifically asked, technology transfer personnel were willing to entertain the idea of trading-off licensing royalties for sponsored research dollars, noting that having a balance between revenue sources would be desirable. Upon reflection, however, the general consensus was that, "in practice the natural flow of deals leads to a mixture of ... sources of return to the institution," and thus, there was no need to overtly manage revenue flows (Theodore Poehler, Vice Provost for Research, Johns Hopkins University). Broadly, the belief is that the University's goals can best be served by allowing each independent unit to pursue a self-defined focused rent-maximizing strategy – whether the focus is on royalty income from licenses, equity in startups, or sponsored research funding.

Recognizing the importance of revenues flows from "leveraged research," research support that would not have been obtained but for the filing of patents, Penn State's Intellectual Property Office (IPO) has expressed a willingness to negotiate reduced royalty rates on licenses for increased research support.[24] Faculty, particularly those in materials sciences, engineering and/or agricultural sciences, are reported to be accepting of this trade-off valuing immediate support of ongoing research (and importantly, the funding of graduate students) over licensing returns. In these research areas, more "singles" rather than "home runs" in royalty income are expected.

Two institutional factors, however, appear to be limiting implementation of this stated leveraging strategy. First, the current incentive structure of the IPO does not fully support this strategy. Under the University's current accounting conventions, leveraged research dollars are counted as part of industrially funded R&D, as reported by the Office of Sponsored Programs, not as outcomes generated by the IPO. Thus, technology transfer officers in the IPO acknowledge that they can actually better serve their office by maximizing licensing returns to enhance direct dollars captured as well as to create a record of performance that justifies requests for increased budget allocations (for staff and patent filings) for the IPO. Second, evolving legal precedent has increased the perceived risk of adopting a leveraging strategy. A recent Court decision upheld the claims of two former faculty members at the University of California (Lawrence Crooks and Jerome Singer) that they were shortchanged in royalties because the University negotiated a lower royalty rate in exchange for increased research funding.[25] This decision is seen as having a chilling effect on the implementation of the IPO's leveraged research strategy.

Technology Transfer Officers at Duke are also quite aware of the recent California case and, with the case in mind, state that the University has no formal strategy in support of royalty-sponsored research dollar trade-off practices. Several TT officials did note, however, that when Duke does a licensing deal which includes research support each facet is carefully examined. That is, royalties and sponsored research are examined as part of a total income package and, through negotiations, trade-offs do occur. Further, these individuals commented that though the incentive structure in place for the Office of Science and Technology allows the Office to benefit directly from the closure of deals based upon either mechanism, in practice, research funding is preferred (and thus encouraged) over royalties given that with such deals the revenues flow directly to the university whereas license royalties are shared with the inventor.

This qualitative evidence is in-line with Proposition Three (see Figure 4). Within the bounds of evolving legal precedent, the tendency to trade-off royalty revenues for sponsored research support appears to be greatest at Duke University (the MX-form), followed by Penn State University (the M-form), and least likely at Johns Hopkins University (the H-form). With respect to leveraging activities, we find that Duke University exhibits strategic intent which is furthered by the presence of a supportive incentive structure. While strategic intent is evident at Penn State University, the incentive backing is lacking. Johns Hopkins University displays neither the strategic intent nor the incentive structure necessary to exploit a leveraging strategy.

5. Conclusions and further research

This paper has offered an interpretative framework to examine a set of organizational variables that affect the relative productivity of university technology and licensing operations. While prior work has noted this potential and relied on qualitative methods to begin to identify these influences, we have provided a set of possible quantitative hypothesis that connect university organizational structure to technology transfer outcomes.

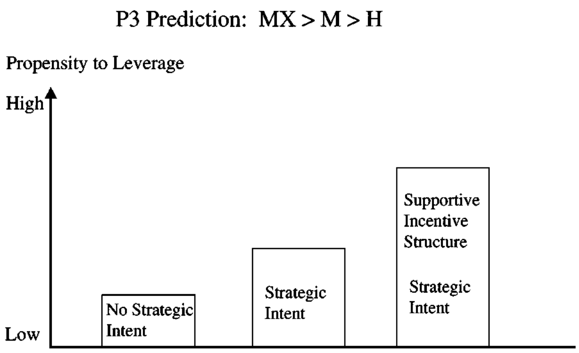

Figure 4

Our results, based on detailed case studies of three very dissimilar universities, indicate that this approach has some predictive merit. The three universities in our study differ in their organizational form and strategies for establishing intellectual property rights and in securing revenues from these rights. The structures uncovered fit, to a great degree, the generic organizational forms identified in earlier research on organizations. Further, the evidence suggests that these structures affect performance in a predictable manner. Given the limits of our sample size, we can not draw strong conclusions from this analysis. However our initial findings suggest the potential of this approach to offer insights into technology transfer outcomes.

Universities, like other types of organizations, have unique histories, differing capabilities and resources, and evolve different types of organizational structures. Specifically, we find that Johns Hopkins University most closely aligns with an H-Form structure with multiple decentralized technology transfer units and limited central control. This is reflective of both the university's historical development and the strength and autonomy of individual units. This form optimizes unit-level information processing capacity and unit-level incentives. One expected performance ramification − confirmed by the test of proposition 2 − is strong unit-level yields. Duke, in contrast, has opted to organize its activities within one office via a collapsed MX-Form. This reflects its more unified history. This organizational form, though it may sacrifice local yields, results in greater across unit coordination and incentive alignment. Indicative of these competencies is the findings of proposition 1 showing that Duke leads the other two universities in customer overlap. Finally, Penn State has created an M-form organization, with a centralized administrative office, and decentralized units. This organizational form, while similar in information-processing capacity, offers slightly more across unit coordination and incentive alignment competencies than the H-form. The qualitative evidence found in support of propositions 1 and 3 are in-line with these performance expectations.

To be able to generalize the findings presented in this paper, additional data on a larger number of universities is needed. It is our hope that these in-depth case studies and the results presented here have stimulated interest about the organizational characteristics of universities and the ways in which organizational factors affect technology transfer outcomes and inter-institutional variation in the range and efficiency of technology transfer activities.

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Notes

1. The focus on the strategy-structure linkage admittedly is a partial approach to examining the full set of factors that account for inter-institutional variations. At a minimum, other determinants include: a) the level and composition of sources of a university's research funding (federal/state/industry/foundation/other); b) the composition of funding by federal agency or industry, with attendant implications both upon the mix of basic/applied/development projects conducted by a university, and the match between the specific scientific and technological content of these projects and knowledge-intensity of new product and process development in prospective licensee firms and industries; c) the quality of the research performed by the university; d) the university's commitment to patenting and licensing, which, in turn relates to its mission, history, culture, and resource and legal environment. We address several of these other determinants in companion studies currently being conducted as part of the larger project.

2. Chandler (1962) also offered the thesis that "structure follows strategy." This notion of a tight link between structure and strategy – i.e., that structure and strategy exist as a unified pair – is widely accepted in the organizational theory literature. (See Galunic and Eisenhart, 1994, for a summary of research in this area.) Additional research is needed, however, to explicate the strength of the strategy-structure link in the university setting. Given that universities generally operate under a weaker selection environment than do for-profit organizations, it is possible that other influences – such as culture, history, etc. – may, along with deliberate strategic decision-making, have a more significant role in driving structural outcomes.

3. In business firms, we see such units as purchasing, accounting, financing, marketing, and sales, production or operations, human resources, etc. In universities, units may be allocated functions such as sponsored research, intellectual property management, academic affairs, student services, etc.

4. A classic illustration of the M-form is General Motors, which organized its activities around the various automobile brands: Chevrolet, Oldsmobile, etc. (Chandler, 1962: 130–142).

5. The matrix form is commonly used in consulting firms where a client team will have both a specialist focus and a client focus. It is also often used in firms that rely on product teams or brand manager units (Burton and Obel, 1998). In a university technology transfer setting the functions might include management of all industry relationships for a specific field, such as engineering or medicine.

6. For a fuuler treatment of the objective functions of universities, see Becker and Lewis, 1992.

7. In developing the following propositions, we choose to emphasize a particular performance attribute. We acknowledge that each organizational form may actually reflect a system composed of complementary elements (Milgrom and Roberts, 1990; Holmstrom and Milgrom, 1994; Brickley, 1999)

8. At low levels of information throughput – before managerial bounded rationality constraints have been reached – the observed information processing performance of the MX-form is expected to be roughly equivalent to the observed information processing performance of H-forms and M-forms. The differing performance competencies between these forms will become increasingly apparent, however, in situations where high ranges of information throughput are called for. One common complaint heard from all of our respondents (and noted by other researchers) regards the understaffing of technology transfer offices. The officers interviewed assured us that they are operating at high levels of information throughput. Thus, we feel confident in hypothesizing the performance ordering detailed below in Proposition 2.

9. Among the three, Duke and JHU have the closest connections. Interestingly, Duke's first Medical School Dean and a significant part of its initial faculty (1930) came from Johns Hopkins School of Medicine.

10. Low intensity incumbents, as defined by Mowery and Ziedonis, are universities with at least one but less than ten patents applied for after 1970 that issued during 1975–1980.

11. Source: U.S. Patent and Trademark Office

12. Among its stated goals, the office is to encourage and evaluate faculty's disclosure of new inventions and copyrightable works, to insure that disclosures comply with federal

obligations, to manage operating budget and distribution of royalty income, to perform industry outreach, to support faculty start-up companies and initiatives for economic development and to facilitate commercialization of JHU's technology through negotiating and drafting patent, license, option, biological material and copyright agreements. The current head of the office, a former Wall Street securities analyst and National Institute of Health technology transfer specialist, was brought in as a part-time consultant in 1995 and appointed as the first full-time director in January 1998. The office budget was increased in 2000 to allow, among other things, the hiring of licensing associates with expertise in information technology, life sciences and physical sciences. Funding for these positions is partially funded from the department and schools related to these technical areas.

13. A for-profit corporation, Peabody Digital SoundWorks, LLC, was incorporated in 1997 to develop high-end digital audio processing software. The new corporation is a subsidiary of Peabody Ventures, a non-profit entity formed in 1995 to manage the portfolio of Peabody's intellectual property. A faculty member directs Peabody Ventures.

14. The OTL director is a PhD scientist and former patent examiner. Even though OTL's traditional mission has been to secure intellectual property rights and to license technologies, in recent years new emphasis has been put on creating start-up companies.

15. The Homewood OTL previously managed APL's intellectual property.

16. While there are plans to provide incentives for the offices at OTT and OTL to share in licensing revenues there was no formula in place at the time of our interviews.

17. To some faculty, the new organizational structure appeared to subordinate sponsored research to licensing activities. In this way, the structure had some resemblance to a traditional U-Form.

18. Task Force on Research Administration and Technology Transfer report (January 1998) expressed concern that the University's technology transfer operations were neither sufficiently user friendly nor service oriented; moreover, the report contended that the University had "not followed the lead of other institutions in encouraging the commercialization of technology grown from (its) research base" (p. 22).

19. Historically, the responsibility for patenting and licensing medical technologies had been handled through the Intellectual Property Office at University Park, with modest impact. Placement of a technology-transfer officer at Hershey – though this individual is officially assigned to both University Park and Hershey – is regarded by Penn State officials and faculty as one of the causes for the steady increase in the number of disclosures at the Medical College (32% of the University's 184 disclosures in 1997).

20. A collapsed matrix is a version of a matrix structure in which unit managers holds primary responsibility along both organizational dimensions.

21. Highlighting Duke University's traditional emphasis on medically based technologies, it was only in 1999 that the office added an additional licensing associate with specific responsibility for the management of technologies from the chemical, physical sciences, and engineering departments of the University.

22. While presently self-sufficient, OST is not required to depend on external funds. The University administration, recognizing the intangible benefits of an active technology-transfer program has expressed the willingness to provide supplemental funds if needed to support the Office of Science and Technology's efforts.

23. For Duke University and Johns Hopkins University, we were also able to capture firm-level data on the total dollar value of licensing and sponsored research agreements for the 1993–1998 period. We find that the overlap ordering, when evaluated by transaction dollars of the top 30 firms, is also as predicted by proposition 1. Overlap at Duke, the MX-form, is higher at 17%, as compared to the overlap at Johns Hopkins University, the H-form, at 12%.

24. Between 1990–1997, leveraged research ranged from $573,467 in 1990 to $3.6m in 1991. In 1997, leveraged research amounted to $1.7M, compared with licensing revenue of $1.3 million and $265,500 received directly by the College of Agricultural Sciences for Turf grass licenses.

25. In his decision upholding the $2.3M dollar verdict against the University of California, First District Justice J. Clinton Peterson concluded, "...the University, which was aggressively seeking research funds, reallocated this money overwhelmingly to itself, in breach of its contractual duty to share royalty compensation from licensees equally." Singer v. Regents of the University of California, A076331.

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