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Article *in* Journal of Management Studies · June 2009

Impact Factor: 4.26 · DOI: 10.1111/j.1467-6486.2009.00835.x · Source: RePEc

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JOURNAL OF MANAGEMENT STUDIES

Journal of Management Studies 46:4 June 2009
0022-2380

Supply-Side Innovation and Technology Commercialization

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ABSTRACT The majority of research and practice tends to conceptualize innovation as a vertically coupled, intra-organizational process. We expand this perspective by conceptualizing innovation as a vertically decoupled, inter-organizational process and by studying the role of research universities as suppliers of discoveries to this *market for innovation*. We combined logic from agency and real options theories to explain why the outcomes of technology commercialization are a function of licensing strategies, the autonomy of technology licensing offices (TLOs), and the incentives bestowed on scientists, research departments, and TLO officers. We rely on data from licensing surveys, interviews with 128 TLO directors, and – for convergent validity – from web-based searches of the TLOs of American universities and the US Patent and Trademark Office. Results suggest that commercialization outcomes (in this case, revenue and start-up creation) are enhanced when TLOs employ diverse licensing strategies, TLOs enjoy greater autonomy, universities share revenues with scientists' departments, and universities compensate TLOs officers well. Results also show that late entrants – typically underperforming universities – inflate royalty shares to scientists as a means to rectify their commercialization record. We conclude with a discussion of this study's contribution to the literature on innovation and technology commercialization.

INTRODUCTION

The sourcing and deployment of innovation comprise a major research theme in the fields of strategic management and industrial organization economics (Bontis et al., 2002; Holmqvist, 2004; Markman et al., 2008b; Reinganum, 1989; Salaman and Storey, 2002). The extant literature holds that innovation is a product of exploration followed by exploitation, and that organizations engaging exclusively in either exploration or exploitation will eventually face obsolescence. Exploration-focused firms will fold in the absence of useful discoveries, while those that are exploitation-oriented will disband in

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the absence an inflow of exploitable inventions (Gupta et al., 2006; March, 1991; Nelson and Winter, 1982). In such conceptualizations, innovation is predominantly a tightly coupled, vertically integrated activity taking place within the bounds of a single firm or in a closely-held network dominated by a few players (Lavie, 2006).

In this view, studies tend to focus more on innovation as an outcome than a process (cf. Holmqvist, 2004; Levinthal and March, 1993; Rothaermel and Deeds, 2004). Naturally, the disentanglement or decoupling of exploration from exploitation is not complicated conceptually, but because the division of research and development (R&D) is seldom disclosed in corporate reports, unpacking the two empirically is no menial task. With a few exceptions, then, many scholars see the R&D variable as a *unified construct*; yet to managers, R&D is becoming increasingly divisible. For example, many large firms downsize, disband, relocate overseas, or repurpose their R&D facilities, essentially shifting their focus (and capital) from 'R' to 'D' (Chesbrough, 2006). Furthermore, the focus of strategy research is results-oriented (i.e. superior performance, rent, competitive advantage, etc), so it comes as no surprise that even when studies partition innovation into inputs and outputs or explorations and exploitations, the focus on observable outcomes leave early processes that drive said innovations relatively underexplored.

The view of innovations as intra-firm activities has certainly advanced theory and practice, but important questions remain regarding the division of labour within broader innovation ecosystems. In general, how do exploration-focused organizations appropriate value from their discoveries and what are the driving impetuses behind the sourcing of innovation within these ecosystems? Specifically to this study, how do research universities exploit the value embedded in embryonic discoveries? The current study addresses these questions by examining the supply side of innovation, assessing how structural, strategic, and human-resource related factors influence the commercialization of discoveries stemming from US research universities.

This study contributes to the literature on technology and innovation management in two ways. First, we relax the assumption that innovation is a *unidirectional process* (Benner and Tushman, 2003), thus shedding light on the course by which exploration in one organization may become the basis for further exploration and exploitation in another. Second, extant theory is predicated on the view that innovation results when R&D is tightly coupled or firmly nested within the bound of a single organization or inter-firm network. Here, we uncover a complementary view – namely, that a marketplace for innovation can ease the transaction costs related to the exchange of inventions by facilitating access to and accelerating movement of discoveries across organizational boundaries. Increasingly, then, organizations exchange not only final goods and services in product markets, but also inputs such as technology, science, and discoveries in factor markets (Markman et al., 2009). In this view, innovation is a loosely coupled, inter-firm process in which one organization 'exports' and another 'imports' the building blocks of innovation. Viewing innovation as part of a broader ecosystem (not merely as an outcome) is critical for advancing theory on explorer–exploiter relations. We will discuss the theoretical model and attendant hypotheses shortly, but first we offer additional background on this innovation marketplace and on the role of research universities as supply-side innovators.

INNOVATION SOURCING

We advance the view that the market for and sourcing of innovation are functions of loosely coupled, semi-disintegrated inter-organizational activities. In this view inventions may be rudimentary in terms of discoverability and nominal in their tangible impact, but they are evolving co-creations that increase in value as they are shared and recombined when they cross organizational boundaries. An initial discovery might have little value in one organization but considerable utility in another because of differences in asset complementarities, technology spillovers, absorptive capacity, or scale economies in exploration and exploitation (Markman et al., 2009). For example, online technology exchange portals such as Yet2.com, InnoCentive, and TekScout expand the universe of opportunities by reducing search costs, eliminating barriers to market entry, and accelerating the process by which the supply and demand for technology equalizes. At the Myelin Repair Foundation (MRF) – a non-profit entity that researches multiple sclerosis (MS) – scientists from various university use an IP-sharing agreement that grants MRF the right to license discoveries to pharmaceutical companies. Inter-organizational R&D spurs innovation in other areas including bioinformatics, telecommunications, nanotechnology, and bioengineering.

The sourcing out of innovation is not limited to research-focused organizations. IBM holds about 40,000 patents and generates approximately $1 billion a year in licensing revenues. Merck also has a sizable R&D budget, but its annual report (2000) notes that it accounts for only 1 per cent of the biomedical research in the world, so to tap into the remaining 99 per cent it must reach out to research universities and companies worldwide. Similarly, Procter and Gamble's annual report (2006) states that the firm aims to source 50 per cent of its innovations from external partnerships – up from an estimated 20 per cent in 2004. Combined, Merck and Procter and Gamble employ thousands of scientists; however each firm must tap into external resources (technological and human) to sustain their flow of innovation. External sourcing of basic and applied research is important because it improves a firm's absorptive capacity, lowers its search costs, and reduces its risk of technological and market lockout.

Although our study focuses on technology licensing offices (TLOs) in research universities, basic research is not limited to academic institutions. There are TLOs in national laboratories and in traditional firms (NAICS 5417), which collectively employ thousands of scientists and generate over $63 billion in revenues annually (US Census Bureau, 2002). Government laboratories, such as the National Institutes of Health and Centers for Disease Control, utilize TLOs to offset R&D costs and defray concerns regarding return on taxpayers' funds (Jaffe et al., 1998).[1] Still, given our emphasis, we offer a brief background of technology commercialization within US research universities.[2]

University-Based Technology Commercialization in the USA

Since the passage of the Bayh–Dole Act of 1980, which granted US universities the right to exploit inventions derived from federally funded research, the number of universities that established TLOs to manage the exploitation of intellectual property (IP) has increased eightfold, to more than 200, and the number of university patents has increased fourfold (Mowery and Shane, 2002). From 1991 to 1997, university revenues from licensing IP have increased over 315 per cent, from $220 million to $698 million (AUTM, 2002). A recent study suggests that for every one dollar invested in a TLO, a university receives more than six dollars in licensing income (DeVol et al., 2006). The number of firms that utilize university-based technologies has also increased, and although venture capitalists (VCs) invest mostly in ventures that have progressed beyond the seed stage (Wright et al., 2006), VCs increase their interest in firms founded on the basis of university technology (Small Business Association, 2002).

Conceptualizing universities as supply-side innovators is also important for normative reasons. First, public support of research universities is generally justified on the grounds that basic research will result in sizeable returns to society. Although universities continue to defend their position as generators of knowledge, it is increasingly difficult to ignore public pressure to show net returns on investments in science and technology (Bozeman, 2000). Put differently, to protect and extend their research mission, universities must begin to earn greater returns on public investments in basic research. Second, institutions that generate healthy cash flows from their research today enhance their ability to pursue breakthrough research tomorrow, because they attract and retain top scientists while reducing the reliance on the public purse.

Having briefly described the broader context of university technology transfer, the next sections assess the extent to which innovation sourcing – licensing revenues and new venture creation – are related to: (1) sponsored and licensing agreements; (2) the autonomy of TLOs; and (3) pay contracts.

THEORY AND HYPOTHESES

We investigate innovation sourcing in the context of university technology transfer – the institutional environment in which TLOs operate, including university administration, scientists, and industry players; hence, the unit of analysis is the university. TLOs assess the commercial potential of discoveries in their portfolio, seek IP protection for promising discoveries, solicit licensing agreements from key industry clients, and manage and enforce these contractual agreements (cf. Markman et al., 2005b). Thus, TLOs are responsible for managing the cradle-to-grave commercialization processes of scientific discoveries stemming from basic research. To remain parsimonious, we model innovation sourcing with a single broad construct called *commercialization outcomes*. The construct incorporates financial and non-financial effects of commercialization (i.e. amount of revenue generated from science and the number of new ventures that rely on university IP). While variations exists, there are three main strategies by which TLOs monetize the value of their universities' research: (1) signing a contract that gives licensees access to future IP resulting from a specific programme, in exchange for research dollars; (2) licensing IP for cash; and (3) trading the expected value of IP for equity. For the third strategy, TLOs rarely realize immediate cash payouts; instead they must approximate a discovery's future economic value, which often is quite small (AUTM, 2003).[3] In order to provide an unambiguous test of our model, which focuses on immediate monetization of technology transfer, we bound the study to the first two licensing strategies – sponsored research and licensing for cash. Our empirical model, then, reduces Type I errors.

Sponsored Research Agreements

To minimize the cost of basic research, TLOs pursue sponsored research agreements by allowing firms to diversify their R&D portfolios. Sponsored research agreements can take many forms, but usually TLOs retain ownership of IP arising from research while sponsoring firms hold an option to negotiate the licensing of any resulting discoveries. By securing a corporate sponsor, TLOs increase the probability that future discoveries will attract a licensee because the sponsoring firm is the party that places the highest net present value on the commercial value of the research. In addition, these agreements specify the length of an option period and stipulate a firm's non-royalty-bearing rights as a result of future research related to the initial scientific discovery. Thus, from a TLO's point of view, sponsored research agreements monetize the basic research performed by a university. For industry, sponsoring research gives firms access to external discoveries and talent – university professors and graduate students. In addition, the sponsorship of external research provides firms with early insights into alternative experimentation paths and lowers abandonment costs when negative outcomes occur.

Basic research usually results in embryonic discoveries, so most firms are unable to determine in advance the economic value of discoveries, at least not until they invest additional research capital and imbue them with their own capabilities (Markman et al., 2009). Given the uncertainty, firms use sequential investments and abandonment heuristics to limit downside risk (Adner and Levinthal, 2004). Real options theory holds that when return on investment is indeterminate at the outset – normally because of unknown maturity and uncertain cash flows – firms parse said investments into sequential options that limit downside risks while keeping opportunities to capture upside gains. For example, reduction in option uncertainty is done through a two-stage, irreversible yet stoppable wait-and-see logic, where an investment creates the opportunity but not the obligation for further investments (Adner and Levinthal, 2004). Thus, real options theory calls on firms to commit restricted investments in embryonic discoveries, and then withhold capital commitment until uncertainty is resolved as to whether to harvest or abandon the initial investments (McGrath, 1999).

Although industry–university relationships result in broad positive spillover effects for each party, sponsored-research processes can also interfere with competing priorities and activities relating to other discoveries in a university's portfolio. First, embryonic discoveries are those farthest from commercial usage, entailing great ambiguity. While early-stage technology by itself does violate the traditional risk–return ratio, stretching uncertainty over long periods of time stands to create conflicts between universities and industry, particularly as partners' expectations about the science's milestones begin to diverge. Second, industry-sponsored research tends to take place in university laboratories. This operational context hinders industry oversight, slows knowledge spillover, and decelerates redirection of research agendas, and these challenges intensify as the physical distance between a firm and university increases. A third factor that deters firms from partaking in sponsored research initiatives stems from universities' proclivity to place advance claims on technology ownership, and control over future licensing agreements. Contracts are inherently incomplete because of unobservability and the high degree of uncertainty over the future value of basic research (Grossman and Hart, 1983), so the escalating costs related to monitoring partners and disputing research strategy or IP ownership discourage firms from sponsoring university research. The different cultures of non-profit research institutions and profit-seeking corporations can also escalate transaction costs (e.g. negotiation, administration, etc) (Bercovitz and Feldman, 2008), intensifying the risk of legal action.[4] Finally, competing time demands are placed upon personnel who are charged with both structuring sponsored-research agreements and crafting licensing agreements. Generally, licensing agreements are more profitable than sponsored research agreements, so each time TLO officers handle the latter, they essentially divert critical human capital and time to lower-yielding activities. Hence, downside risks do not automatically create negative outcomes, but given the broader context in which sponsored-research processes unfold, the above logic suggests the following:

Hypothesis 1: Sponsored research is negatively related to commercialization outcomes.

Licensing-for-Cash Agreements

TLOs attempt to profit from useful discoveries by signing licensing-for-cash agreements with firms – a process that can yield considerable revenues and prestige to universities and career benefits to TLO personnel over an innovation's lifespan (Markman et al., 2005b). While occasionally university scientists do make discoveries that hold considerable commercial promise, basic research tends to yield undeveloped discoveries that require substantial enhancements before their utility becomes apparent in product markets. This suggests that even though licensing agreements hypothetically promise substantial rent, in practice, a predominant or disproportionate pursuit of such licensing strategy would frequently be suboptimal. Earlier research and theory also suggest that semiautomatic pursuits of cash licensing tend to overestimate the maturity and applicability of discoveries and de-contextualize the resource–capability mix needed for licensees to utilize these inventions (Markman et al., 2005a).

To add theoretical context, consider a TLO's commercialization strategy as either planned or emergent (Mintzberg, 1990). A planned strategy does not mean the absence of change, but it is characteristically stable and repeatable, downplaying needed adjustments due to variations in an innovation's maturity and market demand. In contrast, emergent strategy is shaped by an iterative process of experimentation, learning, and adjustments. Because commercialization strategies are inherently forward-looking pursuits, it stands to reason that they would actually *emerge* according to the idiosyncratic nature of each discovery. Hence, we suspect that commercialization strategies would fare particularly well when TLOs customize their strategy to each technology. Put slightly differently, an ongoing pursuit of a licensing-for-cash strategy without regard to context (e.g. technology readiness or the resource–capability mix of firms and university) and inconsideration of competing strategies (e.g. sponsored research and equity agreements), will be counterproductive. Overemphasis on licensing and near-term returns will crowd out experimentation, learning and capability development that are vital to a TLO's long-term engagement in innovation sourcing.

With this theoretical background in mind, it is important to note that we do not suggest that TLOs pursuing planned strategies will always under-perform TLOs that follow emergent strategies. What we do stress, however, is that a predominant or disproportionate pursuit of any one strategy, to the exclusion of others, would set a TLO up for failure and that because most university IP is unsuitable for deployment in product markets, an ongoing pursuit of a licensing-for-cash strategy would be an impediment. Thus, we have what appears to be a paradoxical situation: a TLO's most attractive strategy (i.e. cash licensing) is frequently inapplicable, particularly when it is used on a regular basis. This logic leads to the following prediction:

Hypothesis 2: A disproportional or ongoing use of licensing-for-cash strategies is negatively related to commercialization outcomes.

Structural Autonomy

Because large organizations are complex and require division of labour, the choice of structure has implications for work coordination and resource allocation. Studies show that by virtue of their extensive education, training, and specialized knowledge, professional personnel (e.g. academics) enjoy substantial discretion to manage their own work, frequently beyond the oversight of their central administration (cf. Young et al., 2004). Researchers also note that decentralized organizations enjoy greater autonomy to act entrepreneurially, while centralized organizations lack this autonomy because they are designed to maximize process efficiency (Christensen and Bower, 1996; Levinthal and March, 1993). While efficiency increases product reliability and reduces waste, tight coupling of centralization with routinization and inflexible processes result in organizational rigidity (Leonard-Barton, 1992). The choice of organizational form, then, poses a managerial dilemma: centralization promotes strong, reliable processes, but restricts strategic agility, managerial discretion, and operational flexibility. Given this background, we explain below why autonomous TLOs would source out more discoveries than TLOs that are deeply embedded within and controlled by their parent institutions.

In general, units that are effectively separated from their parent institutions (e.g. spin-offs; Lockett et al., 2005) enjoy greater operational independence and strategic discretion. This explains why highly autonomous TLOs forge independent ties with industry and local business communities, but at the risk of incomplete oversight by the parent university. Naturally, concerns about conflicting cultures, mores, and traditions motivate some universities to maintain stronger oversight and control over their TLOs (Lam, 2007). This is understandable; universities are traditionally critical of mixing science and commerce, having historically promoted the free dissemination of research. In contrast, TLOs are profit centres as well as knowledge brokers, so potential conflicts are apt to emerge. Still, the reality is that some TLOs are highly autonomous and can negotiate agreements based on market dynamics and technological idiosyncrasies whereas others operate under constraining supervision by centralized university policies (DiGregorio and Shane, 2003). This variability in autonomy levels has budgetary and strategic implications: when TLOs are highly embedded in and dependent upon their parent university, their budget and growth are also more volatile because each year these

TLOs compete with other institutional units, including legacy programmes and non-economic groups that create no direct surplus. Limited autonomy or excess centralization also means that TLOs are unauthorized to craft or readjust commercialization contracts and strategies in response to market dynamics, therefore standing to lose some contracts.

Naturally, the risk of undue autonomy is that TLOs may craft contracts that fail to maximize licensing revenues. Such hazards should not be underestimated, but given the transparent deliverables expected of TLOs, we take the position that – at least in the current environment – the benefits of autonomy outweigh the risks of centralization (Lam, 2007). Consistent with open innovation theory (cf. Chesbrough, 2006), commercializing discoveries requires a great deal of speed in analysing technology trends, as well as a deep understanding of industry shifts and firm behaviours. In addition, because autonomous TLOs require less coordination with university-wide administrators, turnaround time to identify industry partners is substantially shorter than that of less autonomous TLOs (Markman et al., 2005a). To echo Hill and Rothaermel (2003), loosely coupled units are highly adaptive and sensitive to environmental changes. The above logic suggests that to enhance innovation sourcing, TLOs must seek faster experimentation and creative processes that facilitate exploratory learning (Child and McGrath, 2001; McGrath, 1999). Given the irregular nature of technology licensing activity, we predict that decentralized or more autonomous TLOs will experience higher rates of innovation sourcing than centralized TLOs. Thus, we make the following prediction:

> *Hypothesis 3:* An autonomous, or decentralized organizational structure is positively related to commercialization outcomes.

Creating Alignment

In this section we redirect attention to mechanisms that universities use to stimulate innovation sourcing. This theoretical focus is important because it sheds light on why information asymmetry can undermine innovation sourcing despite apparent congruency of goals in agency relationships. Agency theory provides clear prescriptions regarding the roles of information and monitoring and their impact on agency relations (Jacobides and Croson, 2001). When principals have accurate information regarding the actions of agents, the former can pay the latter based on the effort actually exerted. When such information is lacking, however, it becomes difficult to define adequate contracts between parties; information asymmetry and unobservability induce moral hazard, enabling agents to pursue undesirable actions (Holmstrom and Milgrom, 1991). For example, scientists may license their best inventions privately to the market, essentially diverting critical discoveries away from their TLOs (Markman et al., 2008a). Thus, incomplete information can redistribute surplus from principals to agents. If moral hazard increases under information asymmetry, what kind of employment contracts can principals use to mitigate agency costs? The following subsections theorize on the types of pay contracts universities offer faculty, departments, and TLO officers.

Contracts with inventors. Despite the passage of the Bayh–Dole Act in 1980, almost 30 years ago, challenges persist with regard to inducing faculty to disclose discoveries, professionalizing TLOs, and developing competencies in commercialization. Agency theory suggests that in the absence of monitoring or transparency regarding agents' work, universities will seek to enhance commercialization through tighter goal congruence in the form of increased royalty share to faculty. The theory also holds that universities with limited commercialization experience will use particularly generous royalty contracts as a means to counteract years of strong anti-commerce culture.

We suspect that generous royalty contracts also aim to reverse a lingering asymmetry in motivation. A sturdy publish-or-perish culture can conflict with innovation sourcing, patent statutes, and licensees' desire for exclusivity. First, once a discovery is published, it is less likely to be patented because inventors are allowed only one year after public disclosure to file a patent. Second, many licensing contracts include 'delay-of-publication' clauses, which give certain faculty members (e.g. untenured) little incentive to support commercialization. A third issue relates to how some scientists opt to source some of their discoveries privately, essentially bypassing their respective TLOs (Link et al., 2007; Markman et al., 2008a). The private diversion of discoveries to the market explains, at least in part, why many of the discoveries that *are* disclosed to TLOs are of lower quality (Jensen et al., 2004; Markman et al., 2008a).

Despite conflicting findings (DiGregorio and Shane, 2003; Lockett et al., 2003), we suggest that the generous royalty contracts offered to scientists by their universities are motivated by the following goals: develop commercialization competencies; increase revenues from basic research; uproot an obstinate anti-commerce culture; and harness faculty support. Deficient monitoring of scientists and a history of poor technology-licensing performance contribute to these generous contract terms also. Thus, consistent with agency theory, we expect positive relationships between generous pay contracts to faculty and innovation sourcing:

Hypothesis 4: The greater the royalty share universities allocate to inventors, the greater the commercialization outcomes.

Contracts with departments. Several factors support the view that a central administration will be better able to monitor academic departments than individual faculty members. First, there are fewer bureaucratic layers between a university's central administration and academic departments than there are between the former and scientists. A typical research university may have thousands of scientists working in various labs but a significantly smaller number of departments; this disparity in group size makes direct monitoring of departments less problematic than overseeing each faculty member. Second, costs of gauging department routines and collective performance are appreciably lower than those associated with individual scientists; departments are stable entities whereas their faculty members, particularly the top scientists, are highly mobile. In fact, because a university's central administration is unable to monitor faculty research directly, departments become instrumental as dual agents – agents to a university but principals to faculty. For example, universities steeped in innovation sourcing tend to support generous contracts with departments, which in turn use the proceeds to reward faculty who support commercialization (Markman et al., 2008a). Generous royalty contracts with departments give rise to cultural norms that shore up and motivate commercialization (Owen-Smith and Powell, 2003). Thus:

Hypothesis 5: Generous royalty sharing between universities and departments is associated with greater commercialization outcomes.

Pay to TLO officers. Innovation sourcing requires TLO licensing officers to have a diverse set of competencies including technical aptitude, thorough understanding of IP law, negotiating skills, industry knowledge, business planning, and an extensive professional network that includes angel investors, venture capitalists, and corporate investors (Jensen and Thursby, 2001). Technologists, IP lawyers, and MBAs who possess such qualifications are difficult to find and very costly to retain (Lockett and Wright, 2005). To overcome this challenge, universities employ incentive systems that signal to their TLO officers the value of commercializing technologies. For example, unlike semi-automated, routinized jobs, the uniqueness of each commercialization task and agreement call for complex skill sets and highly changeable – at times even unpredictable – work processes. Higher pay, then, should motivate TLO officers to allocate additional time (and creativity) to build out their network of industry representatives and convince them to invest in discoveries emanating from universities' labs. High compensation is also needed to attract and retain high-quality licensing officers, thus improving the potential of innovation sourcing. Further, the more TLO officers are paid, the greater their incentive to work more collaboratively with the broader constellation of inventors, IP law firms, and industry players to produce better overall commercialization outcomes. Presumably, greater compensation also reduces the likelihood that TLO officers might transfer to another university or be recruited by industry-based TLOs. Thus:

Hypothesis 6: Higher pay for TLO officers is positively related to greater commercialization outcomes.

METHODS

As we noted earlier, we advance the view that innovation increasingly emanates from loosely-coupled players and inter-organizational processes. As such, this study focuses on TLOs in research universities as industry's suppliers of innovation. In the autumn of 2002, we conducted structured phone interviews with directors from 128 of the 139 TLOs depicted in the AUTM (1999) population, representing a 92 per cent response rate. These TLOs embody universities responsible for over 60 per cent of federal and industry research support, over 70 per cent of licences executed, and over 85 per cent of US patents issued to universities (AUTM, 1999). Thus, the sample is a close approximation of the broader population of major research universities in the USA.[5]

Measures

To avoid common method bias and improve triangulation, we collected data from several sources: AUTM (1999, 2002) Licensing Surveys; formal policies and statistics from the websites of TLOs and parent universities; and patent count data from the US Patent and Trademark Office (USPTO). The only non-verifiable data points were pay levels to TLO officers in private institutions and the ratios of commercialization strategies, which we obtained only from the interviews. We acquired data on pay contracts from interviewees and validated these data by analysing the contents of documents culled from TLO websites that explain incentive policies to scientists and their academic departments.

Dependent variables. To operationalize the *innovation sourcing* construct, we used financial and non-financial measures of commercialization outcomes. The financial measure was average annual revenues that accrue to universities as a result of commercializing IP (1999–2000). The non-financial measure was the average number of yearly spinouts from technology transfer activities (1998–2001). The economic impact of firms founded to exploit university-assigned IP is impressive. For instance, start-ups that exploit university-assigned IP enjoy a high survival rate (about 70 per cent of the 2578 TLO start-ups since 1980 remained in business in 1998 according to AUTM (1999)). Similarly, some well-known companies had their origins in university labs, including Akamai (MIT), Genentech (UCSF), and Google (Stanford University). These are extreme but instructive examples that illustrate how exploiting university technology through licensing to new ventures advances local economic development and agglomeration (DiGregorio and Shane, 2003; Zucker et al., 1998). Data on these two variables were first obtained from the AUTM survey, then validated through interviews and searches of TLO websites. In order to abate non-linearity and non-normality, these variables were log-transformed.

Commercialization agreements. TLOs exploit discoveries through a multitude of agreements, including licensing in exchange for sponsored research, equity, and cash. We asked TLO directors to describe the frequency distribution of their office licensing strategy (i.e. 'What percentage of the time does the office commercialize IP through sponsored research, equity, and cash?'). For instance, the distribution of agreements at one northwestern university was 40 per cent for sponsored research, 10 per cent for equity, and 50 per cent for cash; whereas agreements of a southwestern university were entirely for cash (i.e. this university chose not to pursue sponsored research and equity agreements). As we noted earlier, equity agreements rarely yield instant cash, so for the sake of divergent validity, our analyses focuses on sponsored-research and cash agreements.

Structural autonomy. To measure autonomy we inquired about the various TLO structures. We asked interviewees, 'Where does your university house its TLO?'. The question hinges on the fact that there are three TLO archetypes, each reflecting a different level of autonomy vis-à-vis the parent university. Going from low- to high-autonomy: the *traditional structure* reflected 67 TLOs (52 per cent) housed within their university structure, usually in the Office of Provost for Research. A *non-profit research foundation [501(c)3]* was characterized by 52 TLOs (41 per cent) housed in a Research Foundation, a separate legal entity. Finally, a *for-profit private extension* included 9 TLOs (7 per cent), which focused on broad economic developments, including licensing and new venture creation. Interviews confirmed that the latter enjoyed the highest level of operational and strategic autonomy, whereas the traditional TLO structure was least autonomous.[6] An institution's website authenticated these structural configurations and helped to confirm construct validity, divergent validity between structures, and convergent validity with data from interviewees. We used two contrast codes to compare the three configurations (Tabachnick and Fidell, 1996). First, we contrasted the traditional TLO structure against the non-profit foundation and for-profit extension. Second, we compared the for-profit structure with the first two using a similar coding logic. These two contrast codes were labelled, respectively, *low*- and *high-autonomy structures*.

Pay contracts. We analysed three pay contracts: (1) percentage incentive payment from licensing revenues given to inventors; (2) percentage incentive payment from licensing revenues given to inventors' departments; and (3) average annual salary of TLO officers (in thousands of dollars). We obtained data on these variables from our interviews with TLO directors, and the first two measures were corroborated through web searches. It is important to note that payment to scientists and their departments is usually based on a model of net revenue sharing. The net revenue, calculated as a percentage, is defined as gross university revenues from licensing activity minus all out-of-pocket costs incurred in protecting and licensing the technology (e.g. patenting cost as well as costs related to contract enforceability).

Control variables. There are several factors that could impact the exploitation of discoveries, including TLO age, size, affiliation with a private or public university, and the presence of an institution-based business incubator. For example, consistent with arguments based on absorptive capacity and learning theory, older and larger TLOs may have developed competencies in licensing, tighter ties with industry, and more efficient protocols than their younger counterparts (Cohen and Levinthal, 1990). Private–public designation is important because private universities generally have higher endowments as well as greater flexibility in terms of mission, stakeholder mandates and overall market orientation. The presence of incubators can accelerate the formation, growth and success rates of start-ups. Hence, we controlled for these factors by operationalizing *TLO age* as years of operation; *size* by the number of licensing officers (support staff were excluded); *private–public* as a dummy variable (private = 0; public = 1); and the *presence of affiliated incubator* as a dummy variable (yes = 1; no = 0).

Because the quality of discoveries is related to the quality of inventors, we included a faculty quality index (Bercovitz and Feldman, 2008; Lach and Schankerman, 2005). This index was obtained from the 1995 National Survey of Graduate Faculty (National Research Council, 1995) and is based on assessments of about 8000 faculty members engaged in university doctoral programmes. The faculty quality index ranges from a low of 1.0 (poor) to 5.0 (distinguished). The index represents an average score across three domains particularly relevant to commercialization – biological sciences, engineering, and physical sciences and mathematics. For universities with two or more campuses (e.g. California, New York–SUNY, etc), we averaged their quality measures across the campuses. We also tested alternative variables, which are omitted from further analyses because they were insignificant or because they were highly correlated with other variables. We present these and other variables as well as robustness tests in Appendices A and B.

RESULTS

Two hierarchical regressions were performed: one predicting licensing revenues and the other predicting the number of new start-ups using university IP. Table I summarizes the descriptive statistics and the correlation matrix of variables used in the analyses. The yearly mean revenues from exploitation of IP and number of start-ups in the sample were \$5.10 million and 2.05, respectively. The average TLO had 15 years of experience (age) and enjoyed the expertise of 3 licensing professionals (size). On average, inventors and their departments could earn, respectively, 40 and 26 per cent of net revenues from licensed technologies, whereas the average gross salary of TLO officers was slightly over \$78,000 a year.

Table II summarizes the regression analyses on licensing revenues and the number of firms created. Model 1 shows that larger TLOs and high-quality faculty are associated with greater licensing revenues. Model 3 suggests that TLO age and size, as well as quality of faculty and presence of incubators, are related to firm creation. These models account for 45 per cent of the variance in licensing revenues and 55 per cent of the variance in firm creation, respectively.

The full models (2 and 4) show that sponsored research agreements are significantly and negatively related to licensing revenues but unrelated to firm creation, thus providing some support for Hypothesis 1. Hypothesis 2 also received some support: a disproportionate pursuit of licensing agreements is inversely related to revenues but unrelated to firm creation. The low-autonomy structure is negatively related to licensing revenues and unrelated to firm creation, while high-autonomy structure is significantly and positively related to firm creation but not to revenues. Thus, Hypothesis 3 was partially supported. The contingency pay contracts with inventors and their departments are significantly but negatively related to commercialization outcomes. Thus Hypothesis 4 is contradicted: we found a negative association between a generous pay contract with inventors and licensing revenues and firm creation. Hypothesis 5, which predicted a positive relationship between department compensation and commercialization, received moderate support: generous pay contracts with departments are positively related to licensing revenues, but not to firm formation. Finally, amount paid to TLO officers was significantly and positively related to firm creation but not to licensing revenues, thus providing some support for Hypothesis 6. The predictors explained an additional 13 per cent ($p < 0.01$) of the variance in revenues and 7 per cent ($p < 0.05$) of the variance in firm creation, to a total of 58 and 62 per cent of the variance, respectively.

DISCUSSION

Our study focused on structural, policy, and human resource factors to analyse how TLOs in American universities commercialize their basic research, but the conceptual

Table I. Means, standard deviations, and correlation matrix

	Mean	*s.d.*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
1. Licence income	5.10	13.24													
2. Start-ups	2.05	4.23	0.60												
3. TLO age	1986	11.45	−0.40	−0.47											
4. TLO size	3.15	3.86	0.56	0.57	−0.30										
5. Public/private (1/0)	0.74	0.44	−0.28	−0.21	0.18	−0.10									
6. Faculty quality index	2.76	0.79	0.63	0.62	−0.32	0.55	−0.33								
7. Incubator (yes = 1; no = 0)	0.64	0.48	−0.03	0.10	−0.07	0.06	0.38	−0.02							
8. Sponsored research	10.49	10.15	−0.30	−0.33	0.17	−0.26	−0.11	−0.31	−0.19						
9. Licensing agreements	72.10	12.80	−0.03	0.04	−0.07	0.02	0.07	−0.03	−0.08	−0.57					
10. Low autonomy	0.55	0.50	−0.18	−0.09	0.21	0.08	−0.21	0.01	−0.23	0.14	0.03				
11. High autonomy	0.05	0.23	0.07	0.20	−0.09	0.00	−0.20	0.06	0.12	−0.08	−0.18	−0.26			
12. Contracts (inventors)	0.39	0.08	−0.36	−0.34	0.34	−0.21	−0.01	−0.29	0.02	0.11	−0.04	0.09	−0.04		
13. Contracts (department)	0.25	0.13	0.27	0.15	−0.06	0.09	−0.22	0.17	−0.28	0.01	0.07	0.20	−0.16	−0.12	
14. TLO salary	78.26	14.27	0.19	0.36	−0.18	0.27	−0.38	0.33	−0.15	−0.10	−0.02	0.15	−0.01	−0.05	0.06

Notes: Correlations between 0.17 and 0.25 are significant at the 0.05 level.
Correlations of 0.26 and greater are significant at the 0.01 level.

Table II. Results of hierarchical regression analysis on commercialization activity

Variable:	*Commercialization outcomes*			
	Licensing revenues (log)		*Firm creation (log)*	
Model:	1	2	3	4
TLO age	–0.13	–0.05	–0.18**	–0.12*
TLO size	0.31**	0.34**	0.30**	0.26**
Public/private (1/0)	–0.08	–0.19*	–0.04	0.04
Faculty quality index	0.38**	0.21**	0.44**	0.38**
Incubator (yes = 1; no = 0)	0.03	–0.05	0.16*	0.14*
Sponsored research		–0.26**		–0.06
Licensing agreements		–0.23**		–0.02
Low-autonomy structure		–0.27**		–0.03
High-autonomy structure		–0.08		0.16*
Pay contracts with inventors		–0.14*		–0.14*
Pay contracts with departments		0.19**		0.10
TLO salary		–0.09		0.19**
Adj. R^2	0.45	0.58	0.55	0.62
Δ Adj. R^2		0.13**		0.07**
F	20.08**	14.19**	28.57**	15.63**

Notes: Values are standardized regression coefficients (n = 128); given the nature of our dependent variables, we also run negative binomial regression. The results were virtually the same.
* Significant at the 0.05 level.
** Significant at the 0.01 level.

contribution redirects attention to opening innovation processes. In contrast to existing paradigms, where innovation is shaped by a single firm through a tightly-coupled protocol (Levinthal and March, 1993), through alliances and networks (Salaman and Storey, 2002), or via an M&A strategy (e.g. Cisco's M&A strategy (White and Vara, 2008)), we propose a framework that depicts innovation as a decoupled process that hinges on inter-organizational transactions in technology. We employed real options theory to explain why firms source in discoveries made elsewhere, and we demonstrated how TLOs that relied too heavily on licensing-for-cash agreements saw their revenues actually shrink. We also found that commercialization of technology is enhanced when a TLO enjoys greater autonomy. Using agency theory, we showed that the absence of transparency undermines principal–agent alignment. We also sought to extend innovation research by focusing on organizations whose *raison d'être* is to do basic research, yet part of their TLOs' mission is to commercialize inventions. We found that in research institutions, exploitation of discoveries is often influenced not only by size, resource availability, or experience – as confirmed by theory and research (Wright et al., 2006) – but also by commercialization strategies, TLO autonomy, and pay contracts. Though we used a US sample, increasingly, universities across the globe face similar issues (Siegel et al., 2007). These and other findings – including some theoretical and practical implications for opening up the innovation process – are discussed in greater detail in the remaining sections.

Commercialization Agreements

As predicted, *sponsored research agreements* are negatively related to commercialization, which suggests that universities wishing to exploit discoveries primarily by collecting *research orders* from industry players actually lose revenues without improving firm creation. This finding is important, as the primary objectives of many TLOs are to maximize the transfer of IP *and* to earn rents (Siegel et al., 2003). This suggests that TLOs unwilling or unable to free themselves from the allure of sponsored research funds will continue to underperform their peers.

TLOs that employ primarily a *licensing-for-cash* strategy secure less revenue than those that pursue a more balanced licensing strategy, but there was no significant effect on firm creation. Fully explaining this finding requires additional research, but follow-up interviews provide some clues. Many TLO directors noted that regardless of the IP in question or interest from new ventures, cash licensing agreements comprise their most desired strategy. However, university inventions are usually rudimentary, or as one TLO director told us, 'Only one disclosure in a hundred yields licensing royalty.' As scientists disclose primarily nascent inventions suitable for start-ups (Owen-Smith et al., 2002), TLOs' pursuit of cash licensing agreements with large firms seems counterproductive. Indeed, data culled from interviewees indicate that over 72 per cent of the time, TLOs pursued such agreements although the basic state of the discovery called for either sponsored research agreements with mature firms or equity agreements with start-ups. A predominant pursuit of *cash* agreements may seem to lie with inexperienced licensing officers; however, interviewees noted that a bias for cash-licensing also stems from high expectations placed on TLOs by central administration to become self-sustaining and turn into a profit centre. The pressure to generate cash and inattention to technology–market fit are consistent with the view that a de-contextualized strategy can be counterproductive and costly. Still, additional research is needed before we can fully explain the disproportionate focus of TLOs on cash licensing.

TLO Autonomy

We found that less autonomous TLOs generate less licensing revenue, while more autonomous TLOs spur more ventures. These finding are striking, but could they also raise concerns about the possibility that licensing agreements shift universities' resources from basic to applied research? Maintaining the focus on basic research is obviously important, but evidence suggests that TLOs exert little influence on scientists' work. For example, many academic entrepreneurs have little respect for TLO officers (Mosey and Wright, 2007). Moreover, TLOs are agents of their university; they have no authority or clout to influence the allocation of research capital or dictate research agendas in laboratories. In fact, TLOs depend on scientists to provide a steady inflow of scientific discoveries and work with licensees; whereas scientists depend, to a lesser extent, on the expertise of TLOs to attract industry interest. Thus, both parties understand that coercive relations would decelerate and even derail technology commercialization. Also, research institutions enjoy a culture that values discovery and creation of knowledge, and evidence shows that universities remain focused on basic research (Colyvas et al., 2002).

Finally, the decline in average proportion of basic research to total research expenditures between 1977–80 and 1994–98 was only 0.005 per cent (Thursby and Thursby, 2002). Interestingly, there is evidence that TLOs make occasional concessions, and even exceptions to their basic policy, to accommodate star scientists who wish to form a new venture, especially when the scientists threaten to go elsewhere (Lockett et al., 2005). On balance, however, the current level of focus on licensing agreements does not appear to be having an adverse impact on basic research at universities.

Incentive Contracts

Our focus on incentive contracts differs from past research on technology commercialization in the following ways. First, we measure three types of pay contracts: those involving faculty; academic units; and TLO officers. Second, we expand on past research by linking incentive contracts with both licensing revenues and new venture formation. In addition, we explicitly assessed the adverse impact of information asymmetry on agency contracts. Specifically, we studied the rates of royalty sharing given to faculty members and – contrary to agency prediction – found them to be negatively related to licensing revenues. There are several explanations for this seemingly counterintuitive finding. First, the negative associations do not indicate that pay undermines commercialization, but rather that scores of underperforming institutions, many of which are new AUTM members, inflate the average contracts to reverse a poor licensing track record in hopes of creating a culture that embraces commercialization (Lach and Schankerman, 2005).[7] Second, tenure and promotion policies are geared towards scholarly work, which might suppress the proclivity to disclose inventions and to support commercialization activities, especially from junior faculty (Bercovitz and Feldman, 2008). The high ratio of publications to patents (about 8 : 1 in mechanical and electrical engineering departments) hints that commercialization is still marginal to a professor's career (Agrawal and Henderson, 2002). As a TLO director told us, 'Our faculty sees commercialization as their night-job, and many see it as an annoyance.' Finally, as we noted earlier, some faculty members bypass their TLOs and license their best discoveries privately. Markman et al. (2008a) explain that scientists are first to appreciate the intrinsic value and market implications of their discoveries, and that TLOs usually rely on these scientists to identify suitable licensees. They conclude that this combination of *first mover* and *information asymmetry* misalign even what appears to be attractive licence-sharing fees a university can pay its scientists. DiGregorio and Shane (2003) explain that faculty members forgo new venture creation because they could earn more for the same effort by focusing on publishing their research. We suspect, however, that the moral hazard problem is due to neither unattractive royalty contracts nor pay raises for high-end publications, but rather to the fact that scientists can almost always earn more by taking their best discoveries directly to the market (and face very limited reprisal).

The second type of pay contracts we studied involved faculty department and the results show that royalty contracts with scientists' departments are positively related to licensing revenues but not to firm creation. Allocating licensing fees to departments enlists department heads to encourage faculty to support commercialization through rent-generating transfer activities (Bercovitz and Feldman, 2008). Indeed, in many universities, resource-sharing arrangements between scientists and departments are the norm; typical research grants are distributed in a similar manner.

Lastly, we found that pay to TLO officers is significantly and positively related to firm creation, but not to licensing revenues. Follow-up interviews attribute this to an inherent asymmetry between discoveries disclosed by faculty and the preference of TLOs to exploit through license for cash. That is, embryonic technology tends to have greater utility to start-ups and small markets, but because start-ups are cash-poor, TLOs prefer to license IP to larger and more resourceful corporations. Once a discovery is rejected by the more matured market players, TLOs turn their attention to start-ups, many of which are located in nearby incubators or technology parks. The early stages of technology along with proximity factors that allow entrepreneurs to interact with faculty members who made the discovery, make such transfers increasingly more promising. Indeed, interviewees suggested that TLOs are now seeking officers that are versed not only in technology, but also in the formation of start-ups. Thus, the bond between pay and exploitation is quite robust, but the nature of the link is complex, and evolving.

Limitations and Suggestions for Future Research

This study is not without shortfalls. Research institutions source innovation and exploit knowledge through a myriad of channels including, but not limited to, student mentoring, outreach programmes, basic and applied research, conference presentations, publications in refereed and non-refereed journals, and patenting. Thus, it is important to acknowledge that commercialization of IP represents only a small proportion of the knowledge and science explored and exported by academia (Agrawal and Henderson, 2002). We started our theory by focusing on a single construct (commercialization outcomes), but in reality innovation sourcing can have different outcomes. To mitigate this conceptual shortcut, the empirical portion of our study emphasized two such outcomes; revenues and firm creation. The fact that some predictors correlated with revenues whereas others were tied to firm creation supports the view that innovation is a multi-dimensional process producing diverse results. Also, it is unclear whether our findings might be generalized to different types of research institutions or other nations (Owen-Smith et al., 2002). As noted earlier, there are thousands of research institutions, with millions of employees, generating billions of dollars annually. The number of corporations seeking to procure external innovation is also increasing.[8] The growth and proliferation of research institutions coupled with the fact that firms are increasingly abandoning the view that they can outcompete rivals by focusing on intra-firm R&D alone, suggest that the role of research institutions in this growing value chain of innovation deserves greater scrutiny.

The focus on commercialization and autonomy may raise questions about interaction effects. To this end, we tested interaction terms (e.g. between TLO autonomy and commercialization; between faculty quality and pay contracts; and between TLO age and pay contracts) but none were significant. This is consistent with the main-effect view of structural contingency theory (Burns and Stalker, 1961) and suggests that, in this context, exploitation is not a function of the relationship between licensing agreements and TLO autonomy.

We documented that universities supply discoveries to firms, but an exciting opportunity exists for future research to assess more specifically how such discoveries accelerate a firm's ongoing innovation effort, compress learning, generate better offerings, or lock out rivals from gaining access to key technology corridors. Put differently, we still know relatively little about how firms integrate innovations sourced from external players. Another unanswered question concerns whether firms source discoveries as part of their forays into areas outside their expertise, where both costs and revenues can be volatile. Another possibility is that firms source university discoveries not only to complement existing R&D projects, but also to stimulate and accelerate the creation of new ones; in fact, they are using universities to spur truly 'exploratory' research. Clearly, these are important questions that await future research.

To recap, this study contributes to open innovation theory in several ways. First, an open market for invention implies that the development of basic research and the utility of embryonic discoveries are increasing through co-creation, with the burden and excitement of developing new technologies spread across many scientists throughout diverse organizations. If wealth creation shifts in favour of those who use, augment, and exploit diverse sets of external discoveries – as open innovation theory suggests – then a second implication is that research universities capable of reducing transaction and search costs related to technology commercialization would outperform universities that lack this ability. We also add credence to a central tenet of innovation sourcing: As knowledge becomes more distributed (e.g. the internet is a powerful leveller), companies cannot rely entirely on internal R&D and market research. Rather, they should hone sourcing competencies – buying, licensing, and trading processes and discoveries from other entities, including customers and even non-market players. Firms should also sell, license, and spin off internal inventions that are not being fully exploited. For example, Boeing builds aircraft, but suppliers own the IP in many of Boeing's planes; HP's computers and Apple's iPod pack hundreds of parts invented and manufactured by diverse companies; and Lego pays customers for inventing new marketable models. Put differently, in the past, firms controlled their entire innovation value chain – they were simultaneously explorers and exploiters – and that reality created formidable barriers to entry. Our message, however, is that now the value chain of innovation is populated by a constellation of diverse players, including suppliers, customers, and non-market players who together co-create new offerings. This distributed co-creation reduces barriers to participation, thus opening incredible windows of opportunities to smaller players and budding entrepreneurs. This trend also offers exciting research opportunities because the extant literature does not adequately address this topic.

CONCLUSION

Focusing on universities as supply-side innovators, the current study proposes that rudimentary discoveries made in one organization evolve into deployable innovations in another. Real options logic explains why firms import discoveries, and our study demonstrates that a disproportionate pursuit of a cash-licensing strategy can be counterproductive. We also show that more autonomous TLOs facilitate the commercialization of discoveries. Finally, we illustrate how pay contracts are related to different commercialization outcomes. Open innovation and the role of universities as suppliers in this ecosystem are still emerging phenomena (West, 2008), but our study shows that it is not too early to examine the processes underlying distributed co-creation.

To place this study in a broader context, we wish to highlight the fact that in the past, innovators did most of their R&D work inside their laboratories, through what we call tightly coupled and highly proprietary processes. Internally-generated innovations became a critical competitive advantage, but due to their scope, they were limited to big, resourceful, and usually vertically-integrated firms that could recruit talented scientists and provide enough capital and equipment. This model of innovation is *the* dominant paradigm, but it is not the only one; many organizations, including multinational corporations and start-ups, create new wealth by creating and enhancing markets for innovations. This trend suggests that at least part of the innovation process can be de-coupled. There are several reasons for this change. First, as product complexity increases, firms must deploy R&D capital into a wider portfolio of technologies than they can possibly manage single-handedly. As the Merck and Procter and Gamble examples illustrate, technological breakthroughs hinge on a wide range of very diverse scientific disciplines and personnel. Naturally, no single firm can control all possible combinations of scientific knowledge and engineering capability. Second, companies are increasingly willing to move away from vertical integration and into collaborative agreements as a way to uncover new ideas, convert inventions into product faster, fend off competition, compensate for technology lockouts, and adapt to swift market changes. Consequently, some R&D initiatives are decoupled and outsourced. Finally, people, capital, and IP have grown more mobile. Scientists may move from one research lab to another depending on where the most exciting opportunities are, while VCs are making it possible for start-ups to pursue costly research projects. Given the multi-dimensional nature of innovation, we hope this study will motivate additional research on innovation as a decoupled process and universities and other research-focused entities as supply-side innovators.

ACKNOWLEDGMENTS

The authors thank Mike Wright and two anonymous reviewers for their insightful comments.

NOTES

[1] Many firms also utilize TLOs (e.g. in 2000, DuPont's revenues from licensing its patents were $300 million).

[2] Research universities in Europe face similar issues (cf. Siegel et al., 2007).

[3] Examples of successful equity agreements include Akamai Technologies (MIT) and Medarex Corp (Dartmouth College). Unfortunately, most ventures fail as exemplified by the experience of Boston University during the 1990s, when it poured a fifth of its endowment – more than $85 million – into Seragen, but eventually lost 90 per cent of its investment.

[4] For example, an undergraduate student at the University of South Florida (USF), who invented a reusable cleanser to remove ammonia from wastewater (US Patent No. 5,082,813), was incarcerated after he refused to sign over his patent and used his notebook outside USF's lab.

[5] To determine non-response bias, we compared respondents to non-respondents on a variety of variables (e.g. licensing revenues, number of start-ups, patenting, TLO age, and number of professional schools). We found no statistically significant differences, so the risk of a non-response bias is minimal.

[6] A detailed description and comparison of TLO structures is available upon request from the authors.

[7] For example, contingency pay to faculty at Harvard, MIT, and Stanford University ranges from 25 to 33 per cent, whereas the University of Northern Iowa, University of Hawaii, University of Tennessee, and Creighton University pay a minimum of 50 per cent.

[8] As we noted earlier, Procter & Gamble's chairman, A. G. Lafley, challenged his company to increase sourcing in of externally-generated innovations from 20 per cent currently to 50 per cent.

APPENDIX A: ADDITIONAL DATA

To increase certainty regarding the findings and rule out alternative explanations, we collected additional data and tested other models. However, the following variables were not presented in the study because they were non-significant or failed to improve existing models:

(1) Number of Professional Schools: A log transformation of the count of professional schools – engineering, medical, and hard science.
(2) Medical School: A dummy variable (1 = medical school; 0 = no medical school).
(3) R&D Budget: Data on university budget for research (AUTM, 1999, 2002).
(4) University Quality: A Carnegie I Designation denotes whether a university is considered to be a *Doctoral/Research University* according to the 2000 Carnegie Classification edition. The Carnegie designation is important because it represents the scope and quality of the university's inventive capacity. A dummy variable (1 = if Carnegie Designation; 0 = if not).
(5) Research Agglomeration: *Number of Carnegie Schools within 50 and 100 Miles*. A measure of number of Carnegie Designated schools within a 50 and 100 mile radius of a sample university. Following the literature (cf. Mansfield, 1991, 1995), this measure represents a proxy for the inventive capacity of the region in which a university is located.
(6) High-Tech Agglomeration: The *Milken Tech-Pole Composite Index* proxies high-tech infrastructure, research capacity, and entrepreneurial activity. These measures represent national high-tech real output, and the concentration of high-tech industries – or location quotient – for each metropolitan statistical area (MSA). Following Friedman and Silberman (2003), we used data culled from the Milken Institute report, *America's High-Tech Economy* (DeVol, 1999).
(7) Cost of Living Index: Measures of the cost of living in city and state where a university is located. Data were collected from ACCRA's annual index (Council for Community and Economic Research, 2000). The index was used to control for differences in cost of living across university municipalities, especially for the measure of TLO officers pay.
(8) Local VC Activity: Similar to the other variables representing regional agglomeration, this measure represented financial and entrepreneurial capacity of immediate regions for each university. The measure represents an aggregate dollar amount of venture capital activity in various regions across the USA. Data are from the MoneyTree™ Survey conducted jointly by Price Waterhouse Coopers, Thomson Venture Formation, and the National Venture Capital Association (2002). To control for the effects of the capital markets 'bubble' of the late 1990s, we used a three-year average for the years 1998–2000.

(9) Patents: Data on the number of patents assigned to a university were collected from the USPTO website. These data were verified against several university websites, which reported the individual patenting activities of each university for the years 1998–2000.

(10) Equity Licensing Strategy: Data on this variable were collected during interviews.

APPENDIX B: ROBUSTNESS CHECKS

To verify the robustness of our theoretical model, we conducted a series of tests with alternative predictors, control variables, and different analyses. Specifically:

- The number of patents was deleted from the analysis because of its multicollinearity with TLO size ($r = 0.84$). To test for *institutional effects* we included measures of professional schools, presence of a medical school, and Carnegie Designation. To test for *environmental effects* we included measures of number of Carnegie schools within 50 miles, the number of Carnegie schools within 100 miles, ACCRA cost of living index, the *Milken Tech–Pole Composite Index*, and the *MoneyTree™ Survey*. We found that after the inclusion of the predictor variables, none of these variables were significant with either of the outcome variables. We then tested models that included both *institutional* and *environmental effects*, and again found no statistically significant linkages between these control variables and our predictor variables or our outcome variables.

We also explored the possibility of sample bias. University-based technology transfer has two distinguishing features: (1) there are a few high-performing TLOs and many low-performing TLOs, vis-à-vis revenues and start-ups; and (2) licensing revenues hinge on very few, but very powerful patents. Thus, we tested alternative models that adjusted for these skewed distributions in the sample. Following Lach and Schankerman (2005), we ran a regression that excluded the top performing TLOs (i.e. the potential outliers) – the California System, Columbia, Stanford, Harvard, and MIT. With the exception of royalties paid to inventors' departments (which was now non-significant), we found no major adjustment to our model.

The California System TLO represents nine Carnegie doctoral/research universities (UC–Berkeley, UC–Davis, UC–Irvine, UC–Los Angeles, UC–Riverside, UC–Santa Barbara, UC–Santa Cruz, UC–San Francisco, and UC–San Diego). Hence, we checked whether the inclusion of the largest TLO was influencing the findings. We collected additional data on all nine universities and used these institutions as a replacement for the single TLO of the California System. Again, this model did not significantly deviate from the original model (i.e. when the California System was included as one item).

Finally, given the nature of the dependent variables in this study, we also tested our models with negative binomial regressions. The results of these regressions were virtually the same.

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