Academic Stars and Licensing Experience in University Technology Commercialization*

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Research Summary: We examine the process by which university technology transfer offices (TTOs) allocate internal resources, which provides insight into technologies offered for commercialization to the private sector. Using detailed administrative records of patenting decisions and outcomes by one prominent U.S. research-based university's TTO over a 30-year period, we analyze the performance of invention disclosures by academic stars and by inventors with prior licensing experience. We find that the lead inventor's academic prominence (but not licensing experience) predicts patent application filing, while licensing experience (but not academic prominence) predicts patent impact and commercialization success. We supplement this descriptive analysis with follow-up interviews and empirical evaluation of possible mechanisms for this seemingly outsized role of academic stars.

Managerial Summary: Increasingly prevalent hybrid organizations are expected to fulfill multiple objectives. University technology transfer offices (TTOs) are an example of a hybrid organization and are charged with disseminating academia-originated technology for the public good as well as for economic benefit. We study how one TTO allocates internal resources, using comprehensive in-house administrative data over a 30-year span. We find that while the TTO tends to put resources behind inventions by academic stars, the commercial returns from licensing inventions from such individuals are no different than inventions by non-stars. By contrast, inventors' prior licensing experience highly predicts commercial returns. These results illustrate the challenges inherent in internal resource allocation inside a complex hybrid organization.

Running Head: Academic Stars and Licensing Experience

Keywords: University technology commercialization; patents; academic stars; licensing experience; administrative data.

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1. INTRODUCTION

Universities are an important part of the entrepreneurship and innovation ecosystem, both in their training and research activities (e.g., Nelson, 1993; Furman et al. 2002). The knowledge they generate is also directly and indirectly important for industrial managers in their product and service development (e.g., Mansfield, 1991; Cohen, et al. 2002). This reliance on university science, often federally funded (Fleming et al. 2019), is likely exacerbated by the secular decline in research (as opposed to development) efforts in U.S. corporations over the past 40 years (Arora et al. 2018).

While academia-industry knowledge linkages can occur in various ways, university technology licensing and commercialization efforts are particularly important.[1] Moreover, some studies have suggested that universities are disproportionately responsible for *breakthrough* commercial technologies (Colyvas, et al. 2002). Although prior work examines the university technology commercialization process (e.g., Rosenberg & Nelson, 1994; Mowery et al., 2004; Etzkowitz & Zhou, 2017), scholars often treat university technologies as exogenous (e.g., Nerkar & Shane, 2007). Since university missions increasingly include economic development and commercial translation (e.g., Sanberg, et al. 2013), such treatment obscures internal organizational resource decision-making underpinning the commercialization process.[2]

We focus on the technology transfer office (TTO) managers who must allocate resources to pursue patent applications on inventions disclosed by intellectual property (IP) producers (i.e., academic scientists). Patent protection is often a prerequisite to attracting potential technology licensees, which is a necessary step to commercialization success (and associated licensing revenues). The patenting process is costly, however, requiring TTO managers to decide not only whether to file a patent application, but also whether to continue to invest in its prosecution and post-grant renewal. Such investment entails foregone opportunity costs of other activities which could also help fulfill the TTO's mission.

[1] In 2018 alone, over 17,000 patent applications were filed, over 7,600 patents were granted, 828 new products were created, and over 1,000 start-ups were formed at U.S. and Canadian universities (as reported by the Association of University Technology Managers).
[2] An important exception is recent work by Cohen, Sauermann, and Stephan (2020), who examine how scientists' motives to engage in commercial activity vary across technological fields.

To better understand university technology commercialization, we examine the internal resource-allocation decisions of one TTO that we will call PRU (prominent research university), over a 30-year period. This new dataset includes both patenting decisions (starting from invention disclosures) and commercial outcomes (including patents *not* yielding commercial value). We examine two forces under which TTO mangers, faced with uncertain and embryonic technology, may be making their decisions in furtherance of their dual scientific/commercialization mission: IP producers' (1) scientific and academic eminence (the traditional currency of merit) and (2) prior licensing/commercialization experience. Given the dearth of prior work and the lack of established theory, we refrain from forming specific hypotheses, but end the article with discussing possible mechanisms, implications, and directions for future work.

We find that the inventor's academic prominence (but not licensing experience) predicts patent application filing, while licensing experience (but not academic prominence) predicts patent impact and commercialization success. Although our aim is primarily descriptive, we follow our analysis with in-depth interviews with PRU's TTO officers and empirical tests of mechanisms that may lead to these findings. We rule out many economic reasons for this pattern, and conclude that TTO decisions are driven in part by non-economic factors. For example, the relatively high performance but limited influence on decision making of academics with commercialization experience seems to suggest that either the TTO's dual mission may dampen commercialization efforts (by allocating resources away from higher performing academics with past commercialization experience to commercially lower performing stars) or that TTO decisions may be subject to some unconscious biases. For this reason, although our results support various explanations, they suggest that, from a strictly economic perspective, the PRU may allocate disproportionate resources to academic stars.

2. BACKGROUND & LITERATURE

2.1 Historical background of TTO evolution. The period after the US Civil War was crucial for U.S. research universities. For example, Goldin and Katz (1999, p. 45) note: "For most of the 19th century, American institutions of higher education were centers of learning, not research. That began to change in the late 19th century with the founding of Johns Hopkins University (1876), the first dedicated research center in the US." One policy trigger was the 1862 and 1890 Morrill Acts, in which the US government transferred land to states to endow colleges and universities specializing in practical sciences such as agriculture and mechanical arts. Some 432 colleges and universities were established in the US between 1860-1899, whereas only 289 such institutions had been formed in the US in the preceding 222 years.

While the US federal government helped establish these "land grant" universities, it provided almost no university research funding prior to World War II, a pattern which was reversed after 1945 (Gross & Sampat, 2020). This change, along with the 1980 Bayh-Dole Act (Public Law 96-517, 1980) accelerated university efforts in establishing technology transfer and licensing offices by granting universities intellectual property rights to federally funded research (Henderson et al. 1998). Both qualitative (Murray, 2010) and quantitative (Owen-Smith, 2003) accounts find a period of ferment following the Act in which norms associated with traditional research and academia began intersecting and sometimes clashing with commercial interests.[3] For example, universities often exhibit close ties with industry (Mowery, et al., 2004) and often serve local economic interests (Rosenberg & Nelson, 1994), leading to a "triple-helix" among universities, governments, and industry (Etzkowitz & Zhou, 2017).

2.2 Institutional context of modern university technology transfer operations. In the modern era, TTO managers are charged with supporting a mission of both societal benefit (i.e., knowledge transfer and use) and commercial return (i.e., licensing revenue) associated with university-owned IP.[4] However, the historical context, complexity, and public/private mission of research universities sets them apart from most other hybrid organizations. Scholars have investigated contracting policies such as royalty revenue splits and ownership between the various stakeholders (Jensen & Thursby, 2001; Lach & Schankerman, 2008; Hvide & Jones, 2018), but apart from two exploratory studies, the literature on university TTOs has paid little attention to other aspects of internal organizational decision making (Bercovitz, et al., 2001; Siegel et al. 2003). Bercovitz et al. (2001) discuss variation in the way TTOs are organized (e.g., decentralized, centralized, cross-functional)

[3] For example, Harvard's "oncomouse" patent was exclusively licensed to DuPont in 1984, which imposed commercial norms (such as corporate review prior to scientific publication) that led to conflict with academic researchers (Murray, 2010). During this period, academic norms were challenged but slowly became more accepting of commercial science (Merton, 1968; Stuart & Ding, 2006).
[4] Most university TTOs seek to promote both the public good and private value. For example, the MIT TTOs mission is "to move innovations and discoveries from the lab to the marketplace for the benefit of the public and to amplify MIT's global impact." Similarly, Stanford's mission is to "promote the transfer of Stanford technology for society's use and benefit while generating unrestricted income to support research and education."

as an explanatory variable for patenting and licensing behavior across three university TTOs. Such differences in organizational structure shape information processing and coordination capacity and incentive alignment. Siegel et al. (2003) use survey-based responses about internal TTO operations and how university actors interact with external potential licensees to convey academic culture and develop mutual understanding.

Given the limited literature on internal TTO organization decision-making, we suggest that scientific eminence, which in a traditional academic environment provides a status ordering (Merton, 1957; Stephan, 1996), may be an important predictor of TTO managers' resource allocation calculus.[5] For TTO managers, the effect of star academics approaching the licensing office may come in two forms: first, their (perceived or actual) scientific merit may be higher than average and so may form the basis of differentiated technical advance which may translate into enhanced patentability and/or the potential for broader and more valuable IP. A second effect, however, may be that the TTO officer may have a harder time declining requests by high academic status individuals. Therefore, while we expect academic status to correlate with resource allocation, the net commercial effect is ambiguous.

Although our primary focus is on inventors' academic prominence, we also consider inventors' prior licensing experience, which may signal to TTO managers the presence of skills, experience, or knowledge helpful in technology commercialization. For instance, prior licensing experience may indicate knowledge of not only marketplace demand for technology, but also possible familiarity with potential licensees, understanding of industry demand conditions, and ability to facilitate knowledge transfer.

2.3 Academic Scientists and Technology Commercialization. Academic and commercialization success are often in tension, and individuals who succeed at one may be less likely to succeed at the other (Gittelman, 2007). Conceptually, there are time budget constraints and attention-based tradeoffs in producing academic scholarship versus pursuing commercial aims. However, the empirical literature largely does not find empirical evidence for a substitution effect (e.g., Fabrizio & Di Mini, 2008; Fini, et al. 2022), particularly when commercial experience is defined as patenting.[6] Instead, the empirical literature finds academics engaging in

[5] Tenure and promotion decisions at research universities are often tied to scientific accomplishments (Siouw, 1998).
[6] The evidence is more equivocal when commercial activity and experience is defined as spinoff involvement (e.g., Buenstorf, 2009).

commercial activities are associated with more productive academic output, perhaps by exposing the researcher to new ideas (e.g., Zucker & Darby, 1996; Fini, et al. 2022). More generally, the literature on academic technology transfer typically studies individual *academic* outcomes for those engaging in patenting, as just discussed. In contrast, our study reverses this focus by examining the *commercial* performance of academics based on their academic performance and prior licensing/commercialization experience.[7]

3. DATA

3.1 Institutional context of PRU's patent data. Our key data source is from internal invention disclosure and patenting data from PRU's TTO. In addition to gaining access to this TTO's archival data, we conducted post-hoc interviews with all of the senior officers of the organization (including the chief executive), several of whom have worked for PRU's TTO for over 20 years.

PRU's TTO is among the most-established in the U.S. and enjoys a resource-munificent environment, which allows it to give its IP managers wide latitude in resource allocation. The TTO officers feel they have the ability to invest in risky technologies which may have substantial upside, due to either a large addressable market or the potential for being a technological game changer. Nevertheless, each patent application represents a significant commitment of resources since the TTO (not the academic) pays for application preparation, examination, and potentially patent renewal and commercialization efforts. This TTO in the recent past moved forward with patenting for about half of its invention disclosures (down from about 70% a decade ago) through a consultative process with internal and external experts to assess potential patentability and commercial interest. Our informants told us that each resource decision from patent filing to renewal is "considered" rather than "rubber stamped."[8] Thus, despite the PRU TTO's experience and resources, it faces challenges common to most U.S. TTOs, including the need to make many resource allocation decisions across a broad range of often embryonic technology in service of a multi-dimensional organizational mission.

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[7] The literature on this perspective is much more limited. Marx & Hsu (2022) examine a particular form of academic knowledge translation to commercial practice, forming startups. They find that commercial stars (defined as in the upper quartile of founding experience), rather than academic stars, is predictive of entrepreneurial commercialization in their sample of "twin" discoveries across a wide range of industries.
[8] Much like other TTOs, this one devotes effort to educating academics across its university about the patenting and commercialization process. The TTO pays the fees associated with the due diligence and patenting processes (and if necessary, litigation and patent enforcement). Licensees pay upfront fees, together with milestone and royalty fees, and revenues are split between the TTO, the inventor's school/department, and the inventor herself.

3.2 Data sources. Our data stem from several sources: (1) internal data from PRU's TTO, as just discussed; (2) the publicly available Microsoft Academic Graph (MAG); and (3) publicly available bibliographic patent data provided by the United States Patent and Trademark Office (USPTO). We also conducted extensive inventor disambiguation and matching to link inventors across the datasets.

The PRU data identify invention disclosures submitted to and patent applications filed by PRU TTO over a 30-year period (starting in 1985), as well as the names of the inventors. Analysis of patent data is typically limited to granted patents, since data on pending and abandoned patent applications is either quite limited or not publicly available. Because the PRU administrative records include data on invention disclosures as well as pending and abandoned patent applications, they provide a unique perspective on PRU patenting activity. Importantly, the PRU data also include technology and transaction-level licensing information such as whether a patent application was licensed and its lifetime licensing revenue. The commercialization information is particularly noteworthy as it is rare to observe prices in the market for technology, and especially in a way which is not severely selected (e.g., litigated patents).

We rely on the Microsoft Academic Graph (MAG) dataset as redistributed by Marx and Fuegi (2020) for information on inventors' publication records. The MAG dataset identifies bibliographic information such as dates, journals, and authors for more than 160 million academic publications. MAG provides significantly higher coverage than the Google Scholar and Web of Science databases (Hug & Brändle, 2017). We employ the USPTO PatentsView dataset to identify bibliographic information such as patent application filing date, patent grant date, patent citations, and inventors.

3.3 Sample selection. Our sample period extends to disclosures submitted from 1985 to 2015. We start by identifying a total of 8,846 patent disclosures submitted during this period. We uniquely identify all 6,183 inventors who are listed on any of these patent applications and who are affiliated with PRU in the MAG data. We then parse the PRU records to restrict our analysis to the first patent application in each U.S. patent family or patent license. The decision to pursue follow-on applications is often a consequence of commercialization prospects, and is not necessarily indicative of distinct and independent invention.

Accordingly, limiting our analysis to the initial patent application for each U.S. patent family[9] and each license is a conservative approach that helps to avoid double counting decisions and outcomes.

3.4 Variable definitions and summary statistics. Table 1 provides summary statistics. Pairwise correlations suggest that multicollinearity is not a problem for any of the regression models. We believe that aside from invention quality there are two factors which may guide TTO managers' resource allocation decisions: (1) academic status, and (2) licensing/commercial experience. To the first factor, the variable *Publications* is a standardized count of the inventor's academic publications. We first weight each publication by its journal impact factor (JIF), following Azoulay et al. (2010). To account for career length, we then run an OLS regression predicting each inventor's JIF-weighted publication count in a calendar year (P_{iy}) as a function of years since the inventor's first academic publication (C_{iy}), controlling for calendar year (Y). As shown in Equation (1), an inventor's year-specific *Publications* count is then determined by ranking from zero to one all inventors in a calendar year by the regression residual—the difference between an inventor's actual and predicted JIF-weighted publication count. We designate the inventor having the highest raw JIF-weighted publication count as the lead inventor for a given patent disclosure, and we label an inventor in the top 10% of *Publications* in a given year as a "star" academic.[10]

$$(1) \qquad P_{iy} = C_{iy} + C_{iy}^2 + Y, \qquad\qquad Publications_{iy} = rank_y\left(P_{iy} - \widehat{P_{iy}}\right)$$

To measure inventors' commercial experience, *Prior License?* identifies whether the inventor was listed on a patent licensed in the past – 16% of disclosures were submitted by inventors with previous licensing. We also count the inventor's prior patent applications (*Prior applications*) and patents (*Prior patents*). *Is filed*, *Is issued*, and *Is licensed* indicate whether the invention disclosure led to a patent application, issued patent, or license agreement. We find that about 30% of invention disclosures led to at least one patent application, 14% led to at least one issued patent, and 2% led to at least one license. Finally, we determine whether all of the renewal

[9] Patents in the same family share inventors, descriptive material, and an effective filing date, and therefore should not be treated as independent observations in empirical analysis. Instead, the earliest patent in a family indicates the genesis of the ideas, while later patents indicate an effort to provide more effective and comprehensive exclusive rights.

[10] Our results are robust to other thresholds, though. Many prior measures of academic prominence rely on context-specific, detailed data (e.g., Zucker and Darby, 1996; Azoulay et al., 2010). Our measure, although coarser, is both calculable and interpretable for scientists drawn from a range of fields across a 30-year time period. However, due to data limitations, we do not correct for any field-level differences in JIF-weighted publication counts.

fees were paid for each eligible issued patent (*Renewed*), and count the forward patent citations received by each issued patent (*Citations*).

4. EMPIRICAL RESULTS

4.1 TTO resource allocation. Table 2 presents the results of regression models of patent application filing and issuance at the invention disclosure and patent application levels. All models include year fixed effects. Columns 1-4 suggest that the PRU TTO is more likely to file patent applications as an inventor's academic prominence increases – an invention disclosure by an academic star is 6.5 percentage points ($p<0.001$) more likely to be filed in column 1. In column 2, a 10 percentage point increase in *Publications* is associated with a 0.93 percentage point ($p<0.001$) increase in the probability of filing. However, across all models, prior commercialization experience is not positively linked with patent application filing. Columns 5-8 suggest that patent applications by prominent academics are less likely to be granted. In column 5, a patent application filed by a star academic is 10.2 percentage points ($p<0.01$) less likely to issue than a patent application filed by a non-star, although the effect disappears for stars with prior commercialization experience (this interaction effect is easier to interpret in the OLS model than the logit model). Otherwise, we find no evidence that prior commercialization experience is linked with patent application issuance.

----- Insert Tables 1-3 here -----

Collectively these results raise additional questions: if academic prominence negatively predicts patent application issuance, then why does it strongly predict patent application filing? Further, why should past licensing experience not be linked to future patent application filings? To investigate these issues, we examine the significance and commercial performance of the issued patents that result from the process.

4.2 Commercial outcomes. One explanation for the above results is commercialization experience may not predict future commercialization performance. At the same time, academic prominence may not predict patentability but may positively predict commercial performance. That is, whether an idea submitted by any academic is patentable may be unclear at the outset, but TTO managers may know that patents on ideas submitted by prominent academics may prove more commercially impactful if granted, on average, than patents by less prominent academics. To test this possibility, Table 3 presents the results of regression models of various indicators of patent impact. All models include year fixed effects.

In columns 1 and 3, we find that patents by academic stars are no more likely to be licensed and generate no more revenue, on average, than patents by other academics. Similarly, in columns 2 and 4, academic prominence predicts neither the presence of a licensing agreement for a granted patent nor the lifetime revenue accrued by that patent. Patents by academic stars fare even worse when considering outcomes the literature has related to economic value. In column 6, a 10 percentage point increase in *Publications* is associated with a 2.3 percentage point decrease ($p<0.01$) in the probability that a patent is renewed to its full term.[11] Patents by academic stars also receive fewer citations, with a 10 percentage point increase in *Publications* corresponding to a 2.3 percent ($p<0.05$) decrease in citations in column 8.

Although academic prominence is associated with more negative outcomes overall, the reverse is true for licensing experience. In columns 1 and 3, a patent by an inventor who has previously licensed a different patent is 18.8 percentage points ($p<0.001$) more likely to be licensed and generates 190 percent ($p<0.001$) more revenue on average than a patent by an inventor without such experience. In columns 5 and 7, we find that patents by lead inventors who have licensed other patents are 28.1 percentage points ($p<0.001$) more likely to be renewed to full term and receive 29.3 percent ($p<0.001$) more citations than patents by other inventors. As shown in columns 1, 3, 5, and 7 of Table 3, the positive effect of licensing experience is eliminated for academic stars who also have licensing experience, as evidenced by the statistically significant and negative interaction terms.

Collectively these results suggest that academic prominence is not only a negative predictor of application issuance, but also a poor predictor of the commercial success of an issued patent and a negative predictor of the patent's private value and impact. Conversely, while prior licensing experience does not predict patent application filing, it strongly predicts the probability a granted patent will be licensed and renewed, as well as its expected licensing revenue and citations.

[11] In unreported results, we find a similar outcome if we confine analysis to the second renewal fee (a particularly consequential one).

4.3 Possible mechanisms. We discuss several possible mechanisms in this section for the main empirical relationship, that academic stars seem to receive more TTO resources, yet are less successful commercially (with the opposite pattern for those with licensing experience). First, inventions from academic stars may be substantively different, for instance having a longer gestation period or higher commercial outcome variance. Similarly, those with licensing experience may have shorter incubation periods prior to commercialization, with their inventions yielding a more compressed distribution of licensing returns. Second, academic stars may enjoy differential treatment, for instance because PRU decision making takes into account non-economic objectives or because PRU TTO officers mistakenly believe that academic stars are more likely to generate commercially successful patents. These mechanisms are non-exclusive, and several factors are likely to be at play. Nevertheless, to bolster our ability to identify and distinguish between possible mechanisms, we briefed the executive team with our findings and asked them for the most likely explanations.

4.3.1 Substantive Differences. It could be the case that inventions from academic stars are substantively different. For instance, they may have a higher variance of commercial outcomes, which may be more important in the TTO context since a small number of inventions are typically disproportionately responsible for the lion's share of overall commercial returns. Alternatively, they may have a longer gestation period before being ripe for commercialization, perhaps by virtue of relating to different types of technology than patents by other inventors. Next, academic stars may tend to work in different areas of technology than non-stars. As still another possibility, academic stars may be more inclined to submit invention disclosures to the TTO, even when they are of relatively low commercial quality. We discuss each explanation in turn using both quantitative information (based on archival data) and qualitative insights garnered via our interviews with the senior executive officer team at PRU's TTO.

Differences in licensing outcomes may reflect differences not only in means, but also variance. Our data is consistent with prior literature suggesting that the majority of licensing revenue generated by universities is attributable to a small portion of their inventions (Scherer & Harhoff, 2000, Mowery et al., 2001). Azoulay et. al (2011) argue that scientists working at the frontier pursue more risky research leading to both more breakthroughs and more failures, while Ziedonis (2007) found that licensees of university technology were more likely to license technologies exhibiting greater uncertainty under an option contract. To compare the variance of commercialization outcomes as it relates to academic prominence and licensing experience, Figure 1(a) plots the density of logged lifetime revenue for PRU patents for both star scientists and other academics. Across the highly skewed distribution, patents by non-star scientists are associated with somewhat less revenue, although as noted with respect to Table 3, the difference is not statistically significant. We thus find no evidence that academic stars generate a disproportionate share of PRU's commercialization "home runs."

We next address whether the result of licensing experience is associated with an increased likelihood of future licenses. For example, inventors with commercialization experience may be better at identifying interested licensees (our PRU executive officer informants also mention this as an important channel in targeting prospective licensees). Although we were careful in our empirical analysis to account for multi-patent license agreements and interrelated families of patents (so the empirical results are less likely to mechanically hold), subsequent inventions and licenses may also build cumulatively upon earlier licenses. Finally, successful commercializers may experience a "publicity effect" that could draw the interest of potential licensees for future patents (e.g., Lanjouw & Schankerman, 2001). For these reasons, we found it surprising that a proven track record of licensing is not associated with the rate of patent application filing. However, our PRU informants explained that decision makers strive to consider each technology on its merits in an effort to provide equal opportunities to unproven inventors. Figure 1(b) plots the density of logged lifetime revenue for PRU patents for scientists both with and without licensing experience. We find no evidence that outliers in lifetime revenue are driven by serial licensors, although our regression results suggest that patents by serial licensors generate higher revenue on average, perhaps due to an increased probability of being licensed.

----- Insert Figures 1 and 2 here -----

To compare variance in commercialization timing, Figure 2 plots the density of time in years from patent application filing to license execution date for both star scientists and other academics. Licenses to patents by star scientists are executed longer after patent application filing, on average, compared to licenses to patents by others. However, this difference may be due to a selection effect rather than to technology differences (considered below). A less prominent scientist may exert more effort to identifying a commercial opportunity before approaching the TTO, and/or PRU TTO officers may be more inclined to demand evidence of commercial potential for patent disclosures submitted by less prominent academics. In contrast to the relative delay in licensing patents issued to star scientists, patents issued to scientists with previous licensing experience are typically licensed much faster than those issued to other scientists, perhaps reflecting greater familiarity with the licensing process and/or closer ties to industry.

Prominent academics may also conduct research in different areas of technology than less prominent academics. Technological classifications are necessarily coarse and therefore fail to capture the full range of technological heterogeneity. However, in unreported results, we find that the effects we observe are robust to including fixed effects for internal PRU classification categories or for United States Patent Classification (USPC) patent main classes. Thus, although we are unable to conclusively dismiss this explanation, we found no evidence that technology-level differences drive the results.[12]

In universities, scientists tend to initiate interactions with TTOs, and an academic's prestige may influence both the costs and benefits of disclosure (Owen-Smith & Powell, 2001). We therefore discuss the salience of invention disclosure differences in driving the empirical results. As background, our PRU informants noted that star principal investigators typically have the most resources because publishing success typically breeds more success in securing research grants for R&D. In turn, these resources attract and can fund more experiments and more post-doctoral fellows to conduct research, in keeping with the findings of Owen-Smith & Powell (2001). This results in more developed technology and perhaps better links with industry, which perhaps could be of more interest to industry licensees. The same statement could be said of research by inventors with licensing experience. However, our informants also suggested that typical inventors at PRU are unfamiliar with the market, and are simply optimizing their efforts to succeed in the federal government grant-making process for research and development. Nevertheless, we are unable to empirically evaluate whether academic stars and/or those with licensing experience are more inclined than other academics to approach the TTO since we cannot observe unsubmitted disclosures. However, we find no

[12] Due to data limitations, we lack a comprehensive measure of technology – information on patent class is available only for published patent applications and granted patents, while internal PRU records omit technological classification for many records.

evidence that academic stars submit disclosures that are of higher quality than non-stars in terms of licensing, revenue, renewal, or citations, either on average or among the outliers. By contrast, disclosures submitted by academics with prior licensing experience seem no worse than, and better on some metrics, than disclosures submitted by those without such experience.

4.3.2 Differential Treatment. A second possible explanation for the main empirical finding is that non-stars are treated differently than stars at the front-end of the commercialization process in areas such as due diligence, perhaps due in part to political considerations. Although one of our PRU informants noted that "[licensing officers] treat all inventors the same, regardless of prior licensing experience," another reported: "Stars have a lot of political clout. . . . We're just not going to turn them down, and we don't imagine anyone else would do so." At least some differential treatment seems likely given the institutional context of capturing political or symbolic capital associated with academic stars, who hold the currency traditionally valued in an academic environment.

Despite the considerable experience and resources enjoyed by the PRU TTO, we also cannot entirely discount the possibility that PRU's TTO decision making may sometimes be subject to implicit bias toward star academics. Our informants reported that PRU's TTO had never conducted a thorough empirical analysis of its performance despite having a lengthy history and comprehensive internal data. PRU's decisions and procedures thus seem to have been driven by implicit learning over time. Through this channel, PRU's TTO officers might in theory learn to optimize decision making over time (Mowery et al., 2002). However, commercial success even for a large and successful TTO such as PRU's is a relatively rare event, limiting the ability to draw unbiased conclusions in the absence of formal analysis.

5. DISCUSSION

With the decline in corporate investments in basic science (Arora et al., 2018), university technology is likely playing an increasingly important role in the U.S. innovation ecosystem. We investigate the organizational process resulting in technologies available for licensing and commercialization by taking a deep dive into a single prominent research university's experience in technology transfer operations over a 30-year period. Given the historic importance of academic status in this context, perhaps it is not surprising that there is a significant association between academic prominence and patent application filings at PRU. However, when we examine correlates of commercialization success, academic prominence is *negatively* associated with patent grants and uncorrelated with lifetime revenues, even for those with previous licensing experience. The opposite pattern holds for inventors with prior licensing experience, as such experience is uncorrelated with patent application filing and issuance, but positively related to commercialization success.

Although our results are consistent with prior work that finds a highly skewed value distribution for university patents (e.g., Scherer & Harhoff, 2000, Mowery et al., 2001), surprisingly these outliers are not driven by academic stars. Indeed, our findings contrast with prior work finding a substantial impact of academic stars on commercialization efforts. For example, Zucker et al. (1998) found that the presence of academic stars in a geographic area positively predicts the formation of new biotechnology firms in that area. While the outcome variable of that study differs from the ones examined here, these studies collectively suggest that the influence of academic stars on startup formation may be somewhat indirect (or perhaps differentially relevant depending on technological life cycle stage). Future research would ideally examine the role of academic stars along these lines more intensively.

Because we can identify no economic reasons to explain the set of empirical patterns we identified, we conclude that non-economic motivations are likely at play. We suspect that each explanation discussed in the prior section is at least partially true, and perhaps exacerbated by the advanced nature of PRU's technology. Our informants told us that most PRU technology is quite embryonic, thus limiting their ability to conduct due diligence.[13] For this reason, in contrast to prior studies which found that TTOs often seek out a license before investing in a patent (e.g., Mowery et al., 2004), our PRU informants disavowed any such requirements. The disparity in correlates of patent application filing and commercialization outcomes may thus reflect the subjectivity inherent in the PRU TTO's willingness to invest in embryonic technology. Nevertheless, the relatively high performance but low influence (in decision making) of academics with commercialization

[13] Given PRU's TTO unique policy of rendering a patenting decision in short order following an invention disclosure, we are skeptical that most firm commitments from industry could take place in this narrow time window. PRU's process may be different from the TTOs described by Mowery, et al. (2004) in that their patenting decision were characterized as depending, at least in part, on ex ante commitments by licensees. Our PRU informants told us that common reasons not to proceed on a patent application include patentability concerns or a general sense that it may not be worth the investment.

experience seems to suggest that either the dual mission may dampen commercialization efforts (by allocating resources away from higher performing commercializers to lower performing academic stars) or that some unconscious bias may be at play.

Our results are consistent with prior research suggesting a possible mismatch between participants' objectives. Jensen and Thursby (2001) report that 71% of surveyed TTO officers (but only 41% of faculty) stated that royalties and license fees are "extremely important" measure of licensing success, while 73% of faculty (but only 34% of TTO officers) said "sponsored research funds" is an extremely important measure of licensing success. One PRU informant echoed this finding, reporting that many inventors view patenting as an important part of the process of securing grants and other forms of research funding. The disparity in correlates of patent application and commercialization outcomes may thus reflect PRU TTO's efforts to balance its dual missions of revenue generation and supporting academic research.

Our study, while broadening the work in the internal management and resource decision-making of university technology transfer organizations, also points to several areas ripe for future study. Among the highest priority domains is a better understanding of how potential licensees factor into internal TTO resource allocation decisions. A second area relates to the generalizability of our findings, particularly as they pertain to possibly divergent objectives of key stakeholders (Bercovitz & Feldman, 2006; Siegel et al., 2003), an issue that has thus far not received much attention in the literature despite the increasing prevalence of dual-mission organizations (e.g., social and/or environmental responsibility along with commercial returns). For example, would we see the same findings in a hybrid, for-profit organization such as a B-Corporation (see, e.g., Battilana & Dorado, 2010)? Or the case of corporate venture capitalists, who invest in companies for both strategic and financial return reasons? Regardless of context, we suspect that paying close attention to the specific institutional background and environment will be important. There is much work ahead in this domain; we hope this initial effort spurs others to better understand the organization and management of increasingly-prevalent dual-mission organizations.

References

Arora, A., Belenzon, S., & Patacconi, A. (2018). "The decline of science in corporate R&D," *Strategic Management Journal*, *39*(1), 3-32.

Azoulay, Graff Zivin, and Manso (2011). "Incentives and creativity: evidence from the academic life sciences," *RAND Journal of Economics* 42(3): 527-554

Azoulay, P., Graff Zivin, J.S. Wang, J. (2010). "Superstar extinction," *The Quarterly Journal of Economics*, 125(2), pp.549-589.

Battilana, J., Dorado, S. (2010). "Building sustainable hybrid organizations: the case of commercial microfinance organizations," *Academy of Management Journal*, 53(6): 1419-1440.

Bercovitz, J., Feldman, M., Feller, I., Burton, R. (2001). "Organizational structure as a determinant of academic patent and licensing behavior: an exploratory study of Duke, Johns Hopkins, and Pennsylvania State Universities," *Journal of Technology Transfer*, 26(1-2): 21-35.

Bercovitz, J., & Feldman, M. (2006). "Entrepreneurial universities and technology transfer: A conceptual framework for understanding knowledge-based economic development.," *The Journal of Technology Transfer*, 31(1), 175-188.

Buenstorf, G. (2009). "Is commercialization good or bad for science? Individual-level evidence from the Max Planck Society," *Research Policy*, 38(2), 281-292.

Cohen, WM., Nelson, RR. and Walsh, JP. (2002). "Links and impacts: the influence of public research on industrial R&D," *Management Science*, 48(1): 1-23.

Cohen, WM., Sauermann, H., & Stephan, P. (2020). "Not in the job description: The commercial activities of academic scientists and engineers," *Management Science*, 66(9), 4108-4117.

Colyvas, J., Crow, M., Gelijns, A., Mazzoleni, R., Nelson, RR., Rosenberg, N., & Sampat, BN. (2002). "How do university inventions get into practice?" *Management Science*, *48*(1), 61-72.

Etzkowitz, H., & Zhou, C. (2017). <u>The triple helix: university–industry–government innovation and entrepreneurship</u>. Routledge.

Fabrizio, KR, A. Di Minin. (2008). "Commercializing the laboratory: faculty patenting and the open science environment," *Research Policy,* 37: 914-931.

Fleming, L., Greene, H., Li, G., Marx, M., & Yao, D. (2019). "Government-funded research increasingly fuels innovation," *Science*, *364*(6446), 1139-1141.

Furman, JL., Porter, ME., and Stern, S. (2002). "The determinants of national innovative capacity," *Research Policy*, 31(6): 899-933.

Gittelman, M. (2007). "Does geography matter for science-based firms? Epistemic communities and the geography of research and patenting in biotechnology," *Organization Science* 4: 724-741.

Goldin, C., Katz, LF. (1999). "The shaping of higher education: the formative years in the United States, 1890-1940." *Journal of Economic Perspectives*, 13(1): 37-62.

Gross, DP., Sampat, BN. (2020). "Inventing the endless frontier: the effects of the World War II research effort on post-war innovation*," Harvard Business School working paper 20-126*.

Henderson, R., Jaffe, AB., Trajtenberg, M. (1998). "Universities as a source of commercial technology: a detailed analysis of university patenting, 1965-1988," *Review of Economics and Statistics*, 80(1): 119-127.

Hug, SE., Brändle, MP. (2017). "The coverage of Microsoft Academic: analyzing the publication output of a university," *Scientometrics*, 113(3), 1551-1571.

Hvide, HK. & Jones, BF. (2018). "University innovation and the professor's privilege," *American Economic Review*, 108(7), 1860-1898.

Jensen, R., Thursby, MC. (2001). "Proofs and prototypes for sale: the licensing of university inventions," *American Economic Review*, 91(1): 240-259.

Lach, S., Schankerman, M. (2008). "Incentives and invention in universities," *RAND Journal of Economics*, 39(2): 403-433.

Lanjouw, J.O., and M. Schankerman (2001). "Characteristics of patent litigation: a window on competition," *RAND Journal of Economics* 32(1): 129-151.

Mansfield, E. (1991). "Academic research and industrial innovation." *Research Policy*, 20(1): 1-12.

Marx, M., Fuegi, A. (2020). "Reliance on science: Worldwide front-page patent citations to scientific articles," *Strategic Management Journal*, 41(9): 1572-1594.

Marx, M., Hsu, D.H. (2022). "Revisiting the entrepreneurial commercialization of academic science: Evidece from 'twin' discoveries," *Management Science*, 48(2): 1330-1352.

Merton, RK. (1968). Social theory and social structure. New York: Free Press.

Mowery, D. C., Nelson, R. R., Sampat, B. N., & Ziedonis, A. A. (2001). "The growth of patenting and licensing by US universities: an assessment of the effects of the Bayh–Dole act of 1980," *Research Policy*, 30(1), 99-119.

Mowery, D. C., Sampat, B. N., & Ziedonis, A. A. (2002). "Learning to patent: Institutional experience, learning, and the characteristics of US university patents after the Bayh-Dole Act, 1981-1992," *Management Science*, 48(1), 73-89.

Murray, F. (2010). "The oncomouse that roared: hybrid exchange strategies as a source of distinction at the boundary of overlapping institutions," *American Journal of Sociology*, 116(2): 341-388.

Nelson, RR. (Ed.), (1993). National innovation systems: a comparative analysis. Oxford University Press, New York.

Nerkar, A., Shane, S. (2007). "Determinants of invention commercialization: An empirical examination of academically sourced inventions," *Strategic Management Journal*, 28(11): 1155-1166.

Owen-Smith, J. (2003). "From separate systems to a hybrid order: accumulative advantage across public and private science at Research One universities," *Research Policy*, 30: 1081-1104.

Owen-Smith, J. & Powell, W. (2001). "To patent or not: faculty decisions and institutional success at technology transfer," *Journal of Technology Transfer*, 26: 99-114.

Rosenberg, N., & Nelson, R. R. (1994). "American universities and technical advance in industry." *Research Policy*, 23(3), 323-348.

Sanberg, PR. et al. (2013). "Changing the academic culture: valuing patents and commercialization toward tenure and career advancement," *Proceedings of the National Academy of Sciences*, 111(18): 6542-6547.

Scherer, F.M., and D. Harhoff. (2000). "Technology policy for a world of skew-distributed outcomes," *Research Policy* 29(4-5): 559-566.

Siegel, DS., Waldman, D., Link, A. (2003). "Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study," *Research Policy*, 32(1): 27-48.

Siow, A. (1998). "Tenure and other unusual personnel practices in academia," *Journal of Law, Economics and Organization*, 14(1): 152-173.

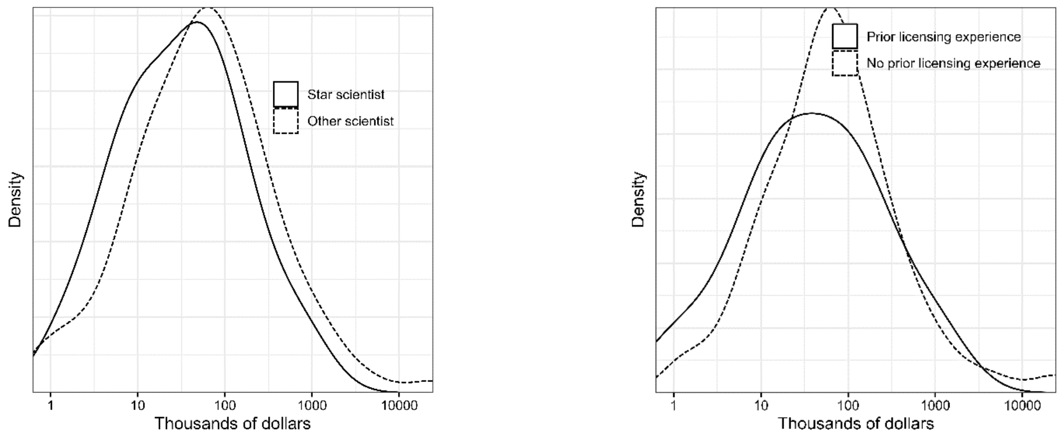
Stuart, TE., Ding, WW. (2006). "When do scientists become entrepreneurs? The social structural antecedents of commercial activity in the academic life sciences," *American Journal of Sociology*, 112(1): 97-144.

Thursby, JG., Jensen, R., Thursby, MC. (2001). "Objectives, characteristics, and outcomes of university licensing: A survey of major U.S. universities," *Journal of Technology Transfer*, 26(1-2): 59-72.

Ziedonis, A.A. (2007). "Real options and technology licensing," *Management Science* 58(10): 1633-1648.

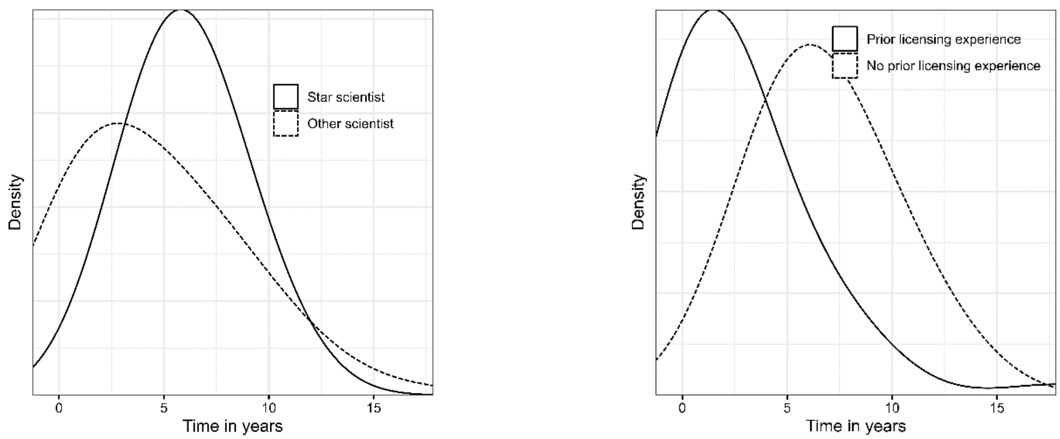
Zucker, LG., & Darby, MR. (1996). "Star scientists and institutional transformation: Patterns of invention and innovation in the formation of the biotechnology industry," *Proceedings of the National Academy of Sciences*, 93(23), 12709-12716.

Zucker, L. G., Darby, M. R., & Brewer, M. B. (1998). "Intellectual capital and the birth of US biotechnology enterprises," *American Economic Review*, 88(1): 290-306.



(a) By star scientist status (b) By prior licensing experience

Figure 1. Density of lifetime licensing revenue (logged scale) for PRU patents[14]



(a) By star scientist status (b) By prior licensing experience

Figure 2. Density of time between patent filing and license execution

Table 1. Summary Statistics

	Variable	Mean	S.D.	Correlations									
1	Publications	0.52	0.31	1									
2	Career length	12.61	8.41	-0.07	1								
3	Has licensed	0.16	0.37	0.1	0.33	1							
4	Prior applications	7.97	23.03	-0.14	0.3	0.25	1						
5	Prior patents	4.74	16.22	-0.17	0.28	0.18	0.98	1					
6	Citations	4.73	12.47	0.01	0.05	0.19	-0.04	-0.04	1				
7	Renewed	0.40	0.49	-0.11	0.11	0.12	0.00	0.00	0.18	1			
8	Is licensed	0.02	0.12	0.00	0.01	0.00	-0.01	-0.01	0.07	0.35	1		
9	Lifetime revenue	5.46	268.45	0.01	0.00	-0.01	0.00	0.00	-0.01	0.07	0.16	1	
10	Is filed	0.30	0.46	0.04	-0.01	0.01	0.02	0.02			0.19	0.03	1
11	Is issued	0.14	0.35	0.01	0.03	0.02	0.02	0.02			0.27	0.05	0.61

[14] Figure 1 omits the many unfiled patent disclosures, unissued patent applications, and unlicensed patents, which in our data each receive zero licensing revenue

Table 2. Predictors of patent application filing and issuance.

	Application filing				Application issuance			
	OLS		*logistic*		*OLS*		*logistic*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Is star	0.065		0.322		-0.102		-0.476	
	(0.016)		(0.079)		(0.031)		(0.143)	
Publications		0.093		0.471		-0.083		-0.382
		(0.015)		(0.078)		(0.030)		(0.138)
Has licensed	-0.014	-0.012	-0.057	-0.059	-0.036	0.012	-0.171	0.048
	(0.017)	(0.015)	(0.086)	(0.077)	(0.031)	(0.028)	(0.142)	(0.126)
Prior applications	0.061	0.060	0.303	0.300	0.009	0.013	0.043	0.061
	(0.010)	(0.010)	(0.051)	(0.051)	(0.026)	(0.026)	(0.118)	(0.118)
Prior patents	-0.044	-0.040	-0.219	-0.202	0.025	0.021	0.115	0.096
	(0.011)	(0.011)	(0.055)	(0.055)	(0.022)	(0.022)	(0.102)	(0.102)
Career length	0.0002	0.001	0.001	0.007	-0.0003	-0.002	-0.001	-0.008
	(0.001)	(0.001)	(0.004)	(0.004)	(0.002)	(0.001)	(0.007)	(0.007)
Is star * Has licensed	0.035		0.134		0.155		0.728	
	(0.031)		(0.151)		(0.055)		(0.255)	
Constant	0.642	0.598	0.571	0.347	0.395	0.425	-0.496	-0.333
	(0.060)	(0.061)	(0.296)	(0.299)	(0.133)	(0.134)	(0.576)	(0.578)
Observations	8,846	8,846	8,846	8,846	2,618	2,618	2,618	2,618
R^2	0.074	0.075			0.129	0.127		
Adjusted R^2	0.070	0.071			0.116	0.115		
Log Likelihood			-5,124	-5,119			-1,627	-1,626

The unit of analysis is the invention disclosure for models 1-4 and the patent application for models 5-8. Models 1-4 include disclosure year fixed effects and models 5-8 include application filing year fixed effects. *Publication record*, *Career length*, *Has licensed*, *Prior applications*, and *Prior patents* are measured for the lead inventor by *Publication record*. Standard errors in parentheses.

Table 3. Predictors of post-grant outcomes for issued patents.

	Is Licensed		Lifetime Revenue		Renewed		Citations	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Is star	0.057		0.500		0.008		-0.076	
	(0.034)		(0.366)		(0.073)		(0.114)	
Publications		-0.038		-0.406		-0.228		-0.233
		(0.029)		(0.306)		(0.068)		(0.101)
Has licensed	0.188	0.154	1.904	1.606	0.281	0.219	0.293	0.252
	(0.024)	(0.244)	(0.263)	(0.058)	(0.062)	(0.080)	(0.087)	(0.080)
Prior applications	0.030	0.034	0.413	0.447	0.067	0.067	-0.011	-0.001
	(0.026)	(0.282)	(0.281)	(0.064)	(0.063)	(0.096)	(0.096)	(0.096)
Prior patents	-0.072	-0.082	-0.911	-1.016	-0.063	-0.075	0.057	0.029
	(0.028)	(0.296)	(0.296)	(0.068)	(0.067)	(0.101)	(0.101)	(0.102)
Career length	0.001	0.001	0.014	0.015	-0.003	-0.006	-0.012	-0.014
	(0.001)	(0.014)	(0.014)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)
Is star * Has licensed	-0.186		-1.681		-0.399		-0.254	
	(0.050)		(0.535)		(0.133)		(0.178)	
Constant	0.048	0.071	0.557	0.794	0.340	0.462	0.038	0.169
	(0.164)	(1.775)	(1.768)	(0.274)	(0.272)	(0.487)	(0.487)	(0.489)
Observations	1,132	1,132	1,132	1,132	592	592	814	814
R^2	0.108	0.097	0.112	0.105	0.139	0.138	0.506	0.506
Adjusted R^2	0.078	0.068	0.082	0.075	0.095	0.095	0.484	0.485

The unit of analysis is an invention disclosure for models 1-4 and a patent application for models 5-8. Models 1-4 include disclosure year fixed effects and models 5-8 include application filing year fixed effects. *Lifetime revenue* and *Citations* are zero-inflated and logged. Standard errors in parentheses.