LICENSING OF UNIVERSITY SCIENCE: TACITNESS AND THE IMPACT OF INVENTION AND GOVERNANCE CAPABILITY ON CONTRACT TYPE[1]

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ABSTRACT

We study a research site wherein technology and governance capabilities are loosely coupled. This allows us to examine the main effect of governance capability on contract structure. Furthermore, we focus on the tacitness of the invention to argue that it not only predicts contract structure but also moderates the relationships between invention or governance capability and contract structure. We test our predictions using decisions on the choice of fixed versus performance contracts to license 1,049 technologies from a large university. The results illustrate conditions under which, at the same level of invention or governance capability, inventions are commercialized through different contractual structures.

Most knowledge that underlies a rent generating capability tends to be tacit, which makes factor markets inefficient (Barney, 1991), due to the uncertainty over the valuation of tacit technology resources (Dierickx and Cool, 1989). Consequently, when a firm is relatively weak in a technology area, it buys from the market, and when it has strong technology capabilities in an area, it produces internally (Martin and Salomon, 2003a). Recent studies have argued for a nuanced relationship between technology capabilities and the choice of make versus buy decisions (Argyres, 1996; Mayer, 2006; Nickerson and Zenger, 2002; Silverman, 1999). Technological capabilities could be broadly construed to have several component capabilities such including invention, lab development, scaling, production and marketing among others. We constrain ourselves to the narrower condition on inventing as a capability to produce new discoveries that could lead to products and services. Technological capabilities have a primary effect of promoting internal production and a secondary governance effect in reducing certain types of contractual hazard in production outsourcing decisions. These studies depart from the traditional view that firms with superior technological capabilities choose to create products or services within the boundaries of the firm.

Instead, these studies suggest that technology capability may also enable the firms to design more effective contracts and screen vendors to outsource production, which helps avoid the adverse selection problem, monitor project milestones, and mitigate the moral hazard problem (Leiblein and Miller, 2003; Mayer and Salomon, 2006; Vanneste and Puranam, 2010). Consequently, technological capabilities coupled with contracting experience have been suggested to create a 'technology governance' capability (Mayer and Salomon, 2006), which enables firms to monitor outsourced production even in the face of some contractual hazards in imperfect factor markets. In the context of technology licensing, governance capability thus enables a firm to reduce the tacitness of technological knowledge in a transaction by specifying milestones, monitoring, pecuniary clauses, and adherence to strict performance or service delivery standards.

This technology governance capability literature implicitly assumes a tight coupling between the firm's technological capabilities and its attendant governance capabilities in overcoming some contractual hazards. It is conceivable, however, that a firm may have high technological capabilities but possess low governance capabilities; a plausible outcome if the locus of technological and governance capabilities are dispersed, i.e., the capabilities are distributed across engineers, managers and lawyers (Argyres and Mayer, 2007). For example, start-ups with star researchers may have significant invention capabilities, but not necessarily a concomitant governance capability. We turn to a research setting that is a loosely coupled system (Weick, 1976) wherein the invention capabilities and technology governance capabilities are separately housed in different parts of the organization. This allows us to examine the main effect of governance capability on contract structure, which in other settings would be completely subsumed under technology capability. Hence, in settings wherein the inventor and technology governance capabilities are loosely coupled, and could evolve asynchronously, we expect that as a firm gains technology capabilities, the tacitness of the knowledge underling the technological capability increases. Whereas the firm develops a concomitant technology governance capability and gains experience with contracting, the firm's ability to reduce the tacitness underlying the technological capability increases commensurately.

The preceding discussion focuses on the increase (decrease) in tacit knowledge through the accumulation of inventor (governance) capability and its influence on governance modes for transactions. Tacitness, however, can also be determined by the nature of the invention as some firms and scientists work on problems at the frontiers of science, i.e., more tacit areas. Hence the question that arises is, what governance modes are chosen to commercialize inventions when firms work on technologies that expand the frontiers of science? More importantly, how does the variation in tacitness of the knowledge resulting from firms and scientists working at the frontiers of science influence the relationships between inventor capability or governance capability and the choice of governance mode to execute the transaction?

We argue that tacitness of invention can vary exogenously to the level of technology capability or governance capability: some problems are at the frontiers of science whereas others are more incremental. We predict that tacitness of an invention, measured by whether an invention is at the frontier of science, is a critical construct that not only determines contract structure but also moderates the relationships between invention or governance capability and contract structure. By focusing on tacitness of the invention, we are able to illustrate cases, when at the same level of invention or governance capabilities are licensed through different types of contracts.

From a knowledge based lens, we argue that inventions vary based on the stickiness of the knowledge that underlies it (Kogut and Zander, 1992; Polanyi, 1967: Szulanski, 1996; Winter, 1987). Knowledge is inherently "sticky" to the creators of the knowledge, which hinders its evaluation by the market, making the market for knowledge imperfect (Polanyi, 1967; Winter, 1987; Szulanski, 1996). Furthermore, contract theory suggests that when further effort is required from the inventors to ensure commercialization, contracts should be performance based, i.e., make payment contingent on success (Aghion and Tirole, 1994). Conversely, if no further effort is needed from the inventor, it is optimal to offer fixed price or spot market contracts. We contrast inventions by inventor teams that contain a star scientist, i.e., an inventor who is at the cutting edge of science (Zucker and Darby, 1999), with inventor teams without star scientists. We predict that inventions by star scientists, even when they have no prior invention experience, i.e., low accumulated invention capability, result in performance contracts because the knowledge that underlies that invention needs greater effort to codify and transfer. Furthermore, inventions at the frontiers of science are more tacit and hence more difficult to price even when the firm has higher governance capability in the technology domain. This suggests that the nature of the invention may moderate the impact of governance and invention capability on governance choices.

We make two contributions to the extant literature on governance of technology contracts and to the innovation literature. First, by focusing on the tacitness of the invention we are able to predict the variation in the type of contracts chosen for commercializing inventions, for the same level of invention or governance capability. This helps explains why, given a level of governance capability, we would still expect to see different types of licensing contracts. To our knowledge, there is no large sample empirical examination of technology licensing contracts using the invention as the unit of analysis. Jensen and Thursby (2001) conduct a survey of TTO licensing managers in the U.S. and find that performance based contracts are more prevalent due to the fact that most inventions are at an embryonic stage at the time of licensing. Our intent is to examine how the relationship between sticky knowledge and governance contracts is moderated by development of capabilities in the inventing team and at the organizational level. Hence, our work could be viewed as a complement to theoretical models (Aghion and Tirole, 1994; Dushnitsky, 2010) and survey studies in contract theory.

Second, we test the predictions of the theory in the licensing of 1,049 technology inventions made at a large U.S. University between 1980 and 2000, and then trace them in subsequent years till 2007. Our setting allows us to decouple, theoretically and empirically, invention from governance capabilities. Universities are loosely coupled systems, wherein academic scientists have significant freedom to work on research projects of their choice. The university's technology transfer office (TTO) is the sole legal source to which all inventions by the university staff must be disclosed and the TTO is in charge of all licensing at the university. The research site offers a natural setting wherein the invention capability and governance capability are independently organized within the university, but with the common goal of bringing university science to the market.

The study also contributes to the practice of technology licensing which has seen rapid growth in the number of technology licensing deals. We provide a useful framework to investigate settings and industries where there is a division of labor between invention capabilities and commercialization capabilities like that between biotechnology firms' and established pharmaceutical firms (Arora and Gambardella, 1994) where licensing has become widespread. Our results can inform the decision making of lawyers and managers for the governance choices for those licensing contracts. To further this aim, we expand our analysis to include contract clauses that are commonly found in practice. Indeed, contracts embody assignment of complex economic rights that have several interrelated provisions such as: exclusive rights, claw back, and milestones. We show that tacitness of the invention is a good lever to explain the complexity of the contract provisions that influence economic rights of the parties to a technology licensing contract.

HYPOTHESES DEVELOPMENT

Contract Theory: Licensing of Inventions

The efficiency of the market and its ability to price goods and services correctly is a central assumption of economic theory. The logical conclusion from this premise is that transactions between two parties should best be done at arm's length, leaving the buyer as the residual claimant of the good or service sold (Mas-Colell et al, 1995). It is immediately obvious that in reality many transactions are not at arm's length but are governed by contracts or internalized within firms. Contract theory, consequently has some important provisos for technology licensing.

First, contract theory draws attention to the possible need for the inventor's continued involvement to create value for the licensee. For example, at the time of licensing, inventions may require further research effort by the inventor before they can be turned into products and services (Jensen and Thursby, 2001). Research and development (R & D) effort, however, is difficult to measure as it consists of non-routine tasks (Alchian and Demsetz, 1972; Hart and Moore, 1999), the execution and quality of which may be influenced by the technology capability of the inventor. Since effort is costly, the licensee firm is not assured that the inventor will invest the right level and quality of effort required to maximize the project value (Aghion and Tirole, 1994; Lerner and Merges, 1998). The moral hazard literature solves this by linking remuneration to performance, thus creating an incentive to invest in effort in order to increase performance (Holmstrom, 1982). In the contract literature, shirking by the inventor is frequently identified as a reason for performance-based contracts (Amit et al, 1990; Thursby et al, 2009; Jensen and Thursby, 2001; Aghion and Tirole, 1994). Hence, projects that require more effort from the inventors are assigned to performance contracts and projects that need relatively little effort from inventors are assigned to fixed upfront payments, i.e., market contracts.

Second, the market place may be unable to value the good or service because the buyer or the seller has tacit information. In licensing contracts, inventions are subject to significant of technological uncertainty, which makes them challenging to value. If the invention cannot be accurately valued, the market may fail to clear and no transactions occur (Akerlof, 1970). The more innovative a product, the more difficult it is to value: the knowledge it uses may not have been codified, and likely will be sticky to the inventor, which leads to more uncertainty concerning the project value. Asymmetry of information on the project value can be resolved by linking the payment to the realized project value through a performance based contract. This guarantees that the licensee firm, even if it does not have the scientific knowledge to assess the true value of radically innovative projects, pays an amount that is commensurate to the invention's profits.

To summarize, when there are no complicating factors such as moral hazard or tacit information, contract theory confirms the optimality of the market transaction, i.e., fixed upfront payment[2]. The incidence of any of the above mentioned market imperfections may cause the inclusion of performance-based components, either on top or to the exclusion of a fixed payment. Next, we review the knowledge based view to understand when and why knowledge is more tacit and more effort is required from the inventors for the commercialization of inventions.

[2] A third reason to deviate from the market transaction can be risk aversion by the buyer. In the licensing context, the scope and the market of the invention may not be completely determined yet, due to both technological and market risk. If the licensee has to pay the arm's length transaction price, he faces the risk of losing his investment if the project proves to be failure. Thus, the licensee firm may prefer to offer a performance-based contract which ensures that the risk of the project's failure or success is shared between the inventor and the licensee. We seek to control for risk aversion of the licensee firm in the estimations as it does not result from effort and tacit knowledge.

The Knowledge Based View and Technology Transfer

The knowledge based view focuses on the tacitness of knowledge to explain capabilities and boundaries of firms. Polanyi (1967) suggests that individuals know more than they can explain, and this tacit knowledge has been suggested as a source of rents as it may be unique and difficult to imitate. Kogut and Zander (1996) provide a more formal treatment of the role of knowledge in firms and in markets. They suggest that technology know-how is much easier to coordinate within the boundaries of the firm with other complementary resources so that the technology can be commercialized. Firms are viewed as a community in which there exists a body of knowledge regarding how to cooperate and communicate (Kogut and Zander, 1993). Repeated interactions between the employees of the firm lead to a common understanding that helps to transfer knowledge needed for new products and services. The transfer of knowledge across boundaries of firm is slower, due to the lack of common understanding and the need to negotiate for transfer. Thus, firms provide a better milieu for knowledge creation than markets.

The knowledge based view has been extensively evoked to study technology transfer between organizations. The most costly component of technology transfer is the transfer of tacit know-how (Teece, 1977; Contractor, 1981). Work that has focused on describing tacitness in greater detail provides a richer framework to understand why knowledge transfer is slow and expensive (Rogers, 1980; Winter, 1987). Kogut and Zander (1993) pick three dimensions of tacitness and test their influence on technology transfer: codifiability, teachability and complexity. Codifiability is the extent to which the knowledge of the invention is articulated in documents, such as blueprints or recipes. Teachability is the ease with which know-how can be taught to new employees. Complexity is the number of critical interacting elements underlying the invention. We focus on codifiability and teachability dimensions as they have received empirical support in prior work (Kogut and Zander, 1993).

Tacitness and Performance-Based Contracts

We integrate the insights of contract theory and the knowledge-based view of technology transfer together. First, tacitness implies that knowledge is hard to communicate and understand. Incomplete understanding of the invention makes it difficult to appraise and thus creates uncertainty on the invention's value. Contract theory predicts that uncertainty surrounding the invention's value will lead to performance-based contracts: the licensee firm protects its interests by not paying a large amount upfront, and the inventor gets paid commensurately to the ultimate value of the invention.

Second, our two focal dimensions of tacitness, i.e. codifiability and teachability, also relate to the effort needed by the inventor to transfer the knowledge to the licensing firm. The less codified a project and greater the effort to teach, the more tacit the innovation and the more effort is required by the innovator in order to commercialize the innovation and realize its full potential. Contract theory shows that the innovator will only expend costly effort if he is given an incentive. By tying the innovator's income with the invention's revenue, a performance-based contract motivates the innovator to transfer her knowledge to the licensee firm.

Finally, in the face of valuation uncertainty, a performance-based contract can be seen as offering a limitless upside, without the downside. While it is true that a performance-based contract shields the inventor from losses, requesting a performance-based contract carries the opportunity cost of the upfront payment that the inventor could otherwise get. Therefore, a risk-neutral, and to a greater extent risk-averse, inventor should balance the expected revenue from a performance-based contract and its unlimited upside with the market-based transaction price she is likely to obtain. To summarize, we find that tacitness of the knowledge that underlies an invention creates the need for performance-based contracts through two mechanisms identified in contract theory, namely asymmetry of information and moral hazard.

Invention Capability and Performance-Based Contracts

Experience at inventing influences the level of codification and teachability of subsequent projects in two ways. First, knowledge creation is a cumulative process (Cohen and Levinthal, 1990). As individuals and organizations generate more inventions and are exposed to more technologies, they develop deeper understanding of the domain. Experience enables scientists to better understand what combinations in a domain are feasible and also identify dead-ends. Organizational theorists have argued that a firm's competence to increase production output improves with experience because the firm benefits from well-embedded, robust routines derived from prior success and failure experiences (Argote, 1999; George, 2005; Miner et al., 1999). Similarly, as inventor teams accumulate more experience, their tools and techniques to solve problems in a domain increases. These problem solving routines are unique to the inventing teams as they develop a path-dependent, trial and error process to find solutions (Levitt and March, 1988; Dierickx and Cool, 1989). To transfer the know-how behind the projects, the teams have to codify and teach the licensee firms their unique tools and techniques. Martin and Salomon (2003b) present evidence from the semi-conductor industry in support of experiential learning leading to firms working on frontiers of knowledge that makes their inventions more tacit. The authors find that, as semiconductor firms gained more experience with successive product generations, the firms' knowledge became more abstract and difficult to convey. As individuals and teams gain experience in a domain, their tacit knowledge increases. Hence, teams with higher inventing experience require to invest a greater effort in codifying and teaching in order to transfer know-how underlying their inventions.

Second, experienced inventors may also select more promising projects with respect to performance payoffs for their effort. Past invention experience provides insights into promising areas for subsequent work (Shane, 2000). Aghion and Tirole (1994) suggest that stand-alone research units are better off avoiding areas where firms with complementary manufacturing and downstream capabilities focus, implying that research units and academic scientists with experience at inventing should prefer to work on areas of research that are farther away from those favored by operating firms. Therefore, due to the effort needed for codifying and teaching more basic science, firms licensing technologies of experienced inventors are more likely to opt for performance-based contracts to assure themselves of the needed inventor effort to commercialize their inventions.

Inventors with experience could have a better understanding for the need to codify knowledge throughout all the stages of the invention process. As there experience increases, inventors are more likely to codify knowledge early and become better at transfering it to licensee firms. As experience increases inventors are more likely to attempt higher levels of codification, thereby reducing tacitness of the inventions, which should lead to market based contracts. Nonetheless, even with detailed written instructions, individuals and firms fail to replicate the most routine of tasks (Levitt and March, 1988). Thus we expect that replicating new inventions, especially moving the invention from laboratory to industrial scale, requires further effort from inventors. Therefore, we maintain that as invention experience increases, the inventors have to expend greater effort to teach the licensee firms wherein licensee firms secure this assurance through performance-based contracts. Hence we predict that:

> *Hypothesis 1: As invention experience of the team increases, it is more likely that the inventions are licensed through performance-based contracts.*

Governance Capability

Recent work in the resource based view has viewed developing technological capabilities to be a precursor to developing a governance capability (Argyres, 1996; Argyres and Mayer, 2007; Mayer and Salomon, 2006). This literature follows the work on experience with alliances leading to the development of an alliance management capability (Dyer and Singh, 1998). The causal logic is that experience with prior alliances leads to the focal firm learning how to manage inter-firm relationships. Similarly, Mayer and Salomon (2006) suggest that as firms gain technological capabilities, they can better understand relevant technologies, identify suppliers of adequate quality, specify pecuniary clauses that ensure compliance, and monitor supplier effort. Consequently, firms with greater technological capabilities might be better positioned to develop a secondary governance capability.

Argyres and Mayer (2007) point to the subtle distinction in the locus of technology and governance capability. They suggest that engineers, managers, and lawyers have different knowledge useful for the innovation process, implying that as firms gain experience with the market form of governance, lawyers develop routines to write contracts that are effective at managing the outsourcing relationship. Akin to the alliance governance capability that rests in a dedicated alliance management function (Kale, Dyer and Singh, 2002), it is possible that invention evaluation and contracting capabilities may also be developed within the commercialization part of the organization. This implies that even if the inventing capabilities of the firm decrease due to turnover in scientists, a residual capability to commercialize innovation through market forms of governance is retained.

The influence of governance capability is likely to be more pronounced in a loosely coupled system, wherein the invention and governance capabilities reside organized separately. In such a system there may be several inventors with low invention experience but the licensing unit may have high experience from having dealt with several inventions in a technology domain over a period of time. Owen-Smith (2005) conducts an analysis of 157 disclosures by scientists to a university's technology transfer office. He finds that general estimation of the market size to be one of the important factors that is discussed at monthly meetings at the TTO. In technology domains wherein the TTO has more experience it would have better understanding of the technology's market potential. Through contacts with its licensee firms, the licensing unit learns the ultimate performance of its prior licensed inventions. This knowledge and licensing experience enable the licensing unit to refine its estimate of the commercial potential of subsequent focal inventions in the same domain. Following the above arguments, we suggest that as the technology transfer organization develops experience in a technology domain it is more likely to write market-based contracts[3]. Therefore we predict that:

> *Hypothesis 2: The greater the experience of the organization with handling inventions in a particular domain, the more likely that the inventions from that domain are assigned to market-based contracts.*

Inventions at the Frontiers of Science: Star Scientists' Inventions

In this section, we motivate the classification of inventions into two categories based on whether the scientists are working on the frontiers of scientific knowledge, i.e., more tacit inventions. We follow the literature in economics which identifies star scientists as those who work on frontiers of science (Zucker and Darby, 1999). We contrast the inventions by star

[3] The TTO selects which disclosures to patent and then to license, and negotiates on behalf of the university and the scientists. From a contract theory perspective, we cannot ignore the TTO's objective and incentives to maximize its own utility. The TTO receives a share of the licensing revenue, which ensures that the TTO's objective of revenue maximization is aligned with the university's and the inventor's objectives.

scientists and non-star scientists. More importantly, star scientists could have high or low invention experience. Furthermore, the star scientists could be working in domains that the organization has high or low governance capability. This exogenous variation in both the star scientist invention experience and the licensing unit's governance experience in the domains they work allows us to make predictions on the moderation effect of inventions by star scientists on the relationships between invention experience or governance experience and the market or performance-based contract choice.

Knowledge, especially cutting-edge knowledge, is largely tacit (Dosi, 1982). Leading scientists in a domain are typically five to seven years ahead of their colleagues, especially in emergent fields like biotechnology (Zucker and Darby, 1999). According to Zucker and Darby (1999), the mere knowledge of recombinant DNA technique was not sufficient to give scientists an advantage. The real advantage stems from the exceptional ability of the star scientist. They note "*…the knowledge was far more productive when embodied in a scientist with the genius and vision to continuously innovate and define the research frontier and apply the new research techniques in the most promising areas.*" Since the inventions by star scientists lead the field, knowledge needed for these inventions may not be codified and is likely tacit, making it harder for other scientists without first hand exposure to the techniques to use this knowledge. For instance, the tacitness of dealing with human embryonic stem cells was in handling the propagation of the cell lines themselves, rather than the principle or method to derive cells from the embryo. This knowledge diffuses slowly as the knowledge is tacit and complex, making codification difficult, costly, and time consuming; especially if the diffusion of techniques occurs through socialization and working in the laboratory of star scientists (Latour, 1987). Licensee firms may not have the expertise to interpret and absorb the knowledge of discoveries made by star scientists, and depend upon the star scientist investing further effort to transfer her knowledge to the licensee firm. Under conditions wherein further effort is required, contract theory recommends performance-based contracts, as the licensee firm is unable to verify effort in transferring knowledge or further developing the technology till it is commercialized. Furthermore, while innovations by star scientists can also be expected to be more valuable, their inherent tacitness results in considerable uncertainty about future applications and commercialization value. Per contract theory, however, it is the uncertainty in valuation rather than the absolute value of the innovation, which governs the contracting choice[4]. Therefore, we posit that:

Hypothesis 3a: Inventions by teams with star scientists are more likely to be assigned to performance contracts.

As scientists gain invention experience, they learn from prior projects, resulting in an invention capability that allows them to focus on harder problems which could be at the frontiers of science (Martin and Salomon, 2003a; Nelson and Winter, 1982). Hence, the effort needed from experienced scientists to codify and teach the licensee firm would be higher than non experienced inventors who may work on more incremental problems. Star scientists, however, are by definition more likely to be working on the frontiers of science, regardless of their invention experience, and the effort required from them to codify and teach the licensee firm the technology is high. As star scientists gain experience their inventions will continue to be assigned to performance contracts for commercialization. Indeed, both star scientists and invention experience are linked to increased tacitness. Cohen and Levinthal (1989) argue for decreasing returns in the ability to learn from experience with an increase in the stock of

[4] Furthermore, we would expect that the value of star scientist's effort relative to the effort from the licensee firm is higher than a non star scientist's effort relative to the licensee firm effort. This may result in the star scientist getting a higher share of the performance contract. Since it does not change the prediction of the contract being performance-based, we do not explore this further here, but show in a robustness check that this is the case.

knowledge. This further supports our hypothesis that invention experience will be more influential for non-star scientists than for star scientists, who already possess a large stock of tacit knowledge.

Hypothesis 3b: As inventors gain experience there will be a greater increase in the likelihood that inventions by without star scientists will be assigned to performance-based contracts than inventions by teams with star scientists.

The experience of an organization with governance of technology transactions enables it to successfully select and manage market transactions (Mayer and Salomon, 2006). The inventions by star scientists, however, are highly tacit, reducing the ability of commercialization personnel like intellectual property managers and lawyers to truly understand and communicate the tacit knowledge to outsiders. The problem could be due to the tools, techniques, and material that are used in the technology transfer for cutting-edge, radical science being harder to specify ex ante or due to the fact that specifying the time to milestones is harder. To continue with the stem cells example, after its discovery in 1995, it has taken 15 years and several further enabling discoveries for the development of a process to produce stem cells in sufficient commercial scale. Therefore, we expect that as a part of the firm gains experience with governance of technologies, this governance experience has a stronger effect on the type of contracts written for inventions by teams without star scientists teams than inventions by teams with star scientists.

Hypothesis 3c: Presence of star scientists in a team of inventors negatively moderates the relationship between governance experience and fixed price contracts. Specifically, the governance experience of the organization in a particular domain has a more positive effect on the likelihood that an invention will be assigned to market contract for teams without star scientists than teams with star scientists.

RESEARCH SITE AND METHODS

The research site for testing the predictions is the Technology Transfer Office (TTO) of a large US university. The university has one of the oldest technology transfer offices in the US, with an asset base of more than $1.5 billion, making it among the largest of its peers and respected for its patenting and licensing capabilities. From its revenue stream, the TTO supports the university with nearly $50 million allocated annually towards various research initiatives. The data for this study were collected in 2007. The authors regularly visited the TTO and conducted interviews with intellectual property managers, licensing managers, legal counsel and the senior management team to develop a deeper understanding of the TTO and its processes.

The TTO documents all disclosures made by the university faculty. All university employees are obligated to disclose their inventions to the TTO, even if they want to commercialize the invention themselves. Once an inventor approaches the TTO with a claim that she has made an invention that may have commercial value, a file with a unique identifier number is created and an intellectual property manager (IPM) is assigned to the case. The IPM interviews the inventors to elicit detailed information about the invention and its commercial potential. Based on the interviews, the IPM writes a report on whether the TTO should file for IP protection. There is a monthly meeting where all new disclosures are discussed. Usually present at the meeting are all IPMs, licensing managers, legal counsel, and senior management of the TTO. Once the decision on IP protection has been made, the licensing managers are included in detailed discussions with inventors to discuss strategies to effectively market the IP. The legal counsel then prepares the disclosure for patent protection filing in the Patent and Trademark Office in the US or in other countries.

Sample

The sample for this study includes all invention disclosures made to the TTO from 1980 to 2000. We selected 1980 to reflect a dramatic change in institutional environment with the passing of the Bayh-Dole Act. The Act enabled university faculty to benefit from the IP created by government-sponsored research and forced the universities to ensure that such output is transferred as goods and services into the economy. Our sample ends in 2000 to allow a minimum window of seven years (until the end of 2007) to observe if a disclosure has been licensed or not. The starting sampling frame results in 4,577 disclosures made from 1980 to 2000. Out of these 4,577 inventions, 1,049 are licensed, which is the final sample for the analysis. To avoid sample selection issues and to control for unobserved factors that may lead to both an invention to be licensed and to be systematically assigned either to performance or upfront contracts, we run sample selection correction described below.

Estimation Strategy and Dependent Variable

Dependent Variable. The dependent variable for the analysis is a binary variable that takes a value of 1 if the invention is licensed as a performance contract or 0 if it is assigned to upfront fixed price contract. Some contracts have a fixed and a performance component. These contracts are classified as performance for the estimations. We also present robustness results that run multinominal logit which view these categories as independent and ordered logit which runs from pure fixed to hybrid (fixed and performance) and pure performance. Our results support the view of Dechenaux et al. (2009) that hybrid contracts are essentially similar to performance contracts but for the risk aversion of the licensor in asking for some fixed payments.

Sample Selection Estimation. We use a two-stage Heckman sample selection estimation (Heckman, 1976) that controls for unobserved factors leading to an invention being licensed and assigned to a particular type of licensing contract. In the first stage, we estimate if the invention is licensed or not, while in the second stage, we estimate whether it is licensed as a performance contract or market contract, conditional on licensing. To identify the equations, we need one or more variables in the first stage that are not a part of the second stage estimation and that influence only licensing and not the type of contract being written. We elaborate below on the sample selection exclusion variable.

One potential problem is that we end the observation window in 2007. If a disclosure is licensed after this time, it is recorded as not being licensed. A possible method to avoid the right censoring bias is to run time-to-event models. However, these models assume that higher quality inventions are more likely to be licensed faster. This may not be true in our setting as higher quality inventions, such as human therapeutics discoveries, would still have to go through development that may take a long time to license. Furthermore, the time-to-survival models assume that if we follow all observations in a sample to their logical end, the event of interest will occur, e.g., all humans will die eventually. However, in our setting most inventions may never be licensed (Jensen and Thursby, 2001). From our interviews, we discovered that the majority of licensed inventions were licensed within three years post-disclosure. Hence, we follow an alternative strategy and use a minimum of a seven-year window after disclosure for an invention to be licensed. To summarize our estimation strategy: in the first stage we estimate which of 4,577 inventions made from 1980 to 2000 are licensed, and in the second stage, whether performance or upfront payment contracts are written for the 1,049 licensed inventions.

Sample Selection Instrument Variables

A sample selection instrument variable should have the property that it influences whether an invention is licensed but not the type of licensing contract written. We turn to contract theory for a variable that meets this requirement. In contract theory, performance based contracts are written to correct imperfections in the market. The most common imperfections are hidden information, i.e., the information concerning the good or service is not equally known, and hidden action, i.e., an action that influences the total economic value of the good or service can be taken but not verified. If neither hidden information nor hidden action is present, and no other market imperfections exist, the optimal transaction would be to agree to a fixed price for the invention. If hidden action by the inventor is present or if the inventor has hidden information, the contract will be performance based. If we can find a variable that influences the probability of signing a contract, but does not change the information structure of the transaction, we have a valid instrument variable.

We propose that a shared signal, or shared information, about the value of the invention satisfies this requirement. It is intuitive that the higher the signal of the value of the invention, the higher the likelihood of licensing. The important point is whether the value of the signal changes the information structure of the transaction, i.e. the presence of hidden action and/or information. It is easy to see that having a small or a large signal of the value of the invention does not alter the fact that the inventor's action is needed and unverifiable (or not). In order to understand the impact on hidden information, we need to delve deeper into the definition of the signal under different information regimes. If the inventor does not have hidden information, the invention's actual value is known to the licensee and the signal is irrelevant (and equal to the invention value). If the inventor has hidden information, the signal is a noisy representation of the invention value. The TTO estimates the focal invention's value by combining its knowledge of the value of prior inventions in the same domain combined with its understanding of the specific features of the focal invention. Therefore, some uncertainty on the project value will remain and the signal is not perfect. Since there is little reason to assume that the signal systematically over- or under-estimates the invention value, the licensee still faces uncertainty on the economic value of the invention after observing the signal. Hence, the contract structure will not be affected.

Symmetrically known quality-Countries IP Protected. Because there is uncertainty surrounding the economic value of disclosures, evaluating the economic potential of an invention is critical to the likelihood of licensing. One proxy for the invention's economic potential at time of disclosure is the number of countries in which the TTO decides to patent the invention. If the IPMs view the disclosure as having far-reaching economic potential then the TTO allocates substantially more budget for the disclosure and seek IP protection in several countries. In our interviews, managers indicated that the cost of filing for a US patent varied between US$ 10,000 to 20,000, depending on the complexity of the application. Applying for patent protection in Japan and European countries doubled or tripled this cost. Therefore, the TTO is careful to select disclosures for which it has sought worldwide protection based on the disclosures' economic potential. The number of countries in which patent protection is applied for at the time of disclosure is the TTO's best estimate of the economic potential of the invention. The more extensively the TTO seeks protection, the higher its estimation of quality. The number of patent applications is a credible communication and is symmetrically known to the TTO and the licensee. Therefore, we use the number of countries in which the TTO files for patent protection, a proxy for economic valuation, to predict if an invention is licensed. The mean value is .8 and the standard deviation is 0.4.

Explanatory Variables

Invention experience. Inventors' prior experience is defined as the average number of prior inventions that the inventors have worked on before the focal project. Out of the total 4,950 unique inventors in our sample nearly 60% have one invention. We follow other studies in taking the natural log of average number of prior inventions as the returns to experience are non linear and the variable is skewed.

Licensor experience. It is the experience of the TTO in a particular domain. We count the number of prior invention disclosures that the TTO has handled prior to the focal invention in the domain of the focal invention. We use the schools of the first inventor, i.e., the principal investigator, to count the prior experience of the TTO. Since the marginal increase in learning from handling one more invention is unlikely to be constant, we follow prior studies in taking the natural log of the count variable.

Star scientists. Scientists who have published highly cited papers have been referred to as star scientists. Zucker and Darby (1999) identify star scientists as those who have 20 or more articles published on genetic sequence discoveries. Since our sample includes scientists from biotechnology and other disciplines in the university, we have to rely on a more inclusive measure that is applicable across scientific disciplines. We use a proxy that Zucker and Brewer (1998) identified to show that star scientists receive a lot more citation to their work than non-star scientists. We relied on data from ISI's list of the top 250 scientists in 21 subject categories (www.isihighlycited.com). We manually matched this list to each inventor from the licensing data in an effort to determine whether they were considered a star scientist by ISI. There are 4,950 unique inventors in our sample. Out of these inventors we classify 135 inventors as star scientists based on the inclusion of an inventor in the top cited scientists in a subject category.

Given that our unit of observation is projects, we aggregated the individual classification to the project-level by creating a binary indicator. This indicator is set to 1 if at least one of the inventors was a star scientist otherwise the value was set at 0.

Notice that the classification of star scientists is based on the ability of scientists to codify their research such that it gets published in scientific journals and that other scientists build on the star scientists' work. This may imply that star scientists may also be good at codification and hence the level of tacitness of the knowledge on the dimension of codification should reduce for the star scientist inventions. However, Zucker and Brewer (1998) forcibly argue that the tools and techniques used by the star scientists were so far ahead of their field that it took 5 to 7 years for others to catch on, even when the description and results of the star scientists' experiments where published.

Control Variables

Complexity. Work in the technology transfer field has focused on the number of components that interact and distance between these to measure complexity (Zander and Kogut, 1995). Distant combinations of knowledge by inventors from varied disciplines may create more important innovations but the coordination cost between the inventors may be higher (Basalla, 1988; Cummings and Kiesler, 2005; George, Kotha and Zheng, 2008). To capture the need for coordination between scientists and the variation in mutual knowledge we use the departments and schools in which scientists are employed[5]. A simple construction of the variable is if the scientists are employed in the same school, then they are likely engaged in intra-disciplinary

[5] Recent work to capture the knowledge distance between scientists has focused on the patent sub-categories in which their discoveries are classified (Tzabbar, 2009), the intuition being that if two scientists file in the same category, their knowledge bases overlap. The distance between the categories is measured using the citation proportion between all patents in one sub-category with the other patent sub-category. We do not use the patent-based measure but rely on the intuition behind these measures. The reasons we do not use the patent-based measure are: i) some inventions are licensed without needing patent protection; ii) recent evidence suggests that assignment of a patent to sub-classes is done by patent appraisers and the inventors may not see their work as being in a particular category.

research and if employed in different schools they are engaged in inter-disciplinary research. A more complex construction of this variable by weighting the knowledge distance between the scientific departments based on citation pattern produces similar results.

Team continuing project. Inventor teams can work on *de novo* projects or choose to work in the same area of their prior invention. It is common for inventors to work on path-dependent technology trajectories (Dosi, 1982). Inventors working within a paradigm and technology trajectory have rich past history, whereas *de novo* projects are more challenging from a coordination perspective. When a disclosure is filed with the TTO, the IPM systematically asks for and files information on whether the project is *de novo* or a continuation of an existing stream of research. We use an indicator to capture whether the project is continuing.

Citations received. Ziedonis (2007) suggests that the number of citations received by a patent is a good indicator of economic potential of the patent. We include a variable of the count of citations a patent has received, excluding self citations. We count the citation received by the patent that covers the technology up to 2007. The average in our sample is 12.37 with a standard deviation of 19.77.

Incremental invention. Most university disclosures are early stage in the technology commercialization cycle with no commercial prototype or field data (Thursby and Thursby, 2002). Inventions in the early stage of technology development cycle need a lot more effort from the inventors before the invention can be transformed into products and services. We count the number of other patents that the focal patent under the disclosure cites as a measure of its incremental nature, i.e., the more the citations to other work, the more incremental the current invention, consistent with others (e.g., Ziedonis, 2007).

Funded IP. We use an indicator variable to determine whether the IP is funded by a private firm or government agency. Funded projects are likely to be of greater commercial interest to the sponsoring firm.

Size of the inventor team. We include a count variable for the size of the inventor team.

Licensee Control Variables

Licensee relationship history. It is the count of prior inventions a licensee has licensed prior to the focal invention. Licensees with experience may move from an arm's length mode of operation to a more embedded relationship, which may influence the type of governance contract signed (Granovetter, 1985; Corts and Singh, 2004).

Licensee size. We use the public listed company status of the licensee at the date of signing of the contract to proxy for size. We were unable to find systematic information on the licensee of either capital or employees at the date of the contract as most of the licensee firms tend to be private, and this information is not systematically available.

Licensee expertise. We used a combination of two indicators variables to identify a licensee's expertise in a domain. The first variable was if the licensee had any patents filed in the related classes in which the focal invention's patent were filed. Since only a few licensee firms had patent filings prior to the licensing and this was correlated with size of the licensee firm, we read through the contract documents and correspondence between the licensee and the licensor (TTO) to search for information that acknowledge the licensee's expertise in the domain. If the contract documents, i.e., development plan, mentioned that the licensee had expertise in the domain then we coded the variable as one. If either of the two measures was coded as one, we created an indicator variable that took the value of one to indicate that the licensee had expertise in the domain of the focal invention.

Distance of the Licensee from Licensor (TTO). Since most cutting edge knowledge is tacit and the inventors are mostly located near the licensor, we measured the distance in miles between the university and the head quarters of the licensee. For some licensees who had multiple research sites, we checked the correspondence between the licensor and the licensee to see where the commercial development was being conducted by the licensee.

We also employ year fixed effects and category indicators for the industry in which the invention is licensed as control variables.

RESULTS

We report the summary statistics of the variables used in the analysis in Table 1. The number of inventions that were discovered from 1980 to 2000 is 4744 of which 1,049 were licensed. In Table 2, we report the correlations between the variables for the inventions that are licensed. All correlations over .047 are significant at p-value<.05. The highest correlation is .29 between the star scientist indicator variable and the experience of the inventor.

Insert Table 1 and 2 about here

In Table 3, we report the estimations of the probability of an invention being licensed as a performance contract. Models 1 to 5 are logit estimations to account for the dependent variable that takes a value of 0 when the contract is fixed price and 1 otherwise. Model 1 includes the control variables and, in Model 2, we introduce the main effects of invention capability, licensing capability, and presence of star scientists in an inventor team. In Model 3, we introduce the star scientists moderation of invention capability and Model 4 the moderation of star scientists presence on governance capability. Model 5 reports the full model that we use to test the moderation hypotheses.

Insert Table 3 about here

Hypothesis 1 predicts a positive relationship between invention experience and performance contracts. We find support for hypothesis 1 (Model 2; b=.584; p<.001). When the value of experience increases from its mean by one standard deviation, we find that the probability of a performance contract increases from .86 to .92. We find weak support for hypothesis 2 on the negative relationship between licensor experience in a domain and the probability of a performance contract (Model 2; b=-0.248; p<.10). When the licensor experience increases from the mean value by one standard deviation, then the probability that an invention will be licensed through a performance contract decreases from .90 to .87.

Hypotheses 3 (a, b, and c) predict the main effect of the presence of a star scientist in a team and the moderations of the presence of star scientist in a team on inventor and licensor experience. We find support for 3a on the main effect of the presence of star scientist in a team leading to the invention being assigned to a performance contract (Model 2, b=2.048; p<.001). We find that teams without star scientists have a 0.83 probability of being assigned to a performance contract whereas inventions by teams with star scientists have a 0.97 probability of being assigned to a performance contract. The presence of a star scientist is the single largest predictor variable in all our estimations.

Hypotheses 3b and 3c are moderations of the presence of star scientist in a team of inventors on the relationship between inventor experience and governance of contracts and licensor experience and governance of contracts respectively. Since this is a non-linear model with a limited dependent variable, interpretation of the main effects and the moderators is not straightforward because the main effects cannot be interpreted in isolation of the moderator variables. In the literature, several solutions have been offered to test moderations of marginal effects (Ai and Norton, 2003; Norton et al, 2004; Hoetker, 2005). Greene (2010) in a review of the statistical tests of moderation recommends the following: statistical testing of marginal effects is less informative than using a graph and examining the economic consequences of the explanatory variables. Greene recommends that hypotheses testing should be done at the model building stage. Hence, we follow the suggestions in Greene (2010) and graph the moderations to discuss the economic impact of the moderations.

Figure 1 is the graph of the relationship between inventor experience and the probability of performance contract by teams with and without star inventors. When invention experience is one standard deviation below the mean experience, teams without star scientists have a .75 probability of having their inventions licensed as performance contracts, whereas teams with star scientists have a .98 probability of their inventions being licensed as performance contracts. When invention experience is at mean, teams without star scientists and teams with star scientists have .83 and .99 probability of their invention being licensed as performance contract respectively. The increase is much higher for teams without star scientists and it is significant ($p<.05$). When invention experience increases by one standard deviation above the mean teams without star scientists and teams with star scientists have .90 and .99 probability of their invention being licensed as performance contract respectively.

Hypothesis 3c predicts that the influence of TTO experience will be much greater for a team without star scientists than for a team with star scientists (Figure 2). When licensor experience is one standard deviation below its mean value, the probability that an invention will be assigned as performance contract is .85 and .99 for teams without and with star scientists respectively. When licensor experience is at its mean value, this probability changes to .83 and .98 for teams without and with star scientists respectively. Similarly when licensor experience is one standard deviation above its mean value, the probability that an invention will be licensed as a performance contract is .82 and .94 for teams without and with star scientist respectively. This suggests that licensor experience (TTO) plays a limited role in influencing the governance of contracts of inventions by either star scientists or non star scientists.

Robustness Checks

Hybrid contracts. In our estimations, we compared fixed contracts with performance based contracts. Some performance based contracts contain fixed payments as well. We estimate a multinomial logit model that does not make any assumption on the ordering of the fixed, mixed and pure performance based contracts as distinct categories to check if collapsing performance and performance contracts with fixed as one category is appropriate. We find that there is no difference between the coefficients of performance and performance contracts with fixed payments. However fixed contracts are statistically different from pure performance and mixed contracts. This supports our strategy to compare fixed contracts with the other types of contracts (pure performance and mixed) collapsed as one category. We report the results of these estimations in Table 4. The comparison group is fixed upfront payment contracts. In Model 1a we report the results of hybrid contracts and in Model 1b we report results of pure performance contracts; both these results are compared to fixed contracts as baseline. The results of these estimations are essentially similar to estimations in Table 3. In particular, all the main effects for the theory variables are significant in the direction predicted. The results of the interaction terms are also similar. When we compared the coefficients of pure performance and hybrid contracts with each other, we found that there is no statistical difference, supporting the results reported in Table 3.

Insert Tables 4 and 5 about here

Sample selection. We follow the traditional set up of sample selection estimation where the variables in the second stage are a perfect subset of the first stage (p 268; Baum, 2006).We report the first stage and second stage of the sample selection estimations in the Table 5. The key variable to focus on from an identification point of view is the symmetric quality variable, which measures the number of countries in which the TTO has decided to protect the intellectual property that underlies an invention. The symmetric quality variable is positive and a significant predictor of licensing (b=.0982; p<.05). To check the validity of the sample selection variable we enter the symmetric quality variable in estimations predicting the choice of governance contract. We find that the symmetric quality variable is not a significant predictor of type of contract; confirming that the variable meets the empirical requirements for being an instrument variable for sample selection.

Tacitness of star scientist inventions. The results of the estimations we presented are consistent with the view that star scientists inventions are more tacit and hence are assigned to performance contracts. To reinforce our point, we conduct robustness checks to see if we can verify if the inventions by star scientists are more tacit than inventions by non star scientists. We examine the patents that are linked to the inventions by star and non star scientists to verify the difference in level of tacitness of the inventions. The literature on technology spillovers has identified several variables that can be used as proxies for tacitness of inventions: self cites made and self cites received. *Self cites made* is defined as the percentage of prior knowledge that the patent draws from the prior work of the inventors of the focal patent. *Self cites received* is defined as the percentage of citations that a focal patent receives that are by inventors of the focal patent. In Figure 3, we report comparative analyses of star and non-star scientists. We find that inventions by star scientists build more on their prior work. These descriptive statistics suggest that inventions that involve star scientists are more tacit as these inventions build on their prior work more, making the transfer of technology from the inventors to the licensee firm more effort intensive.

Insert Figure 4 about here

Fixed effects. We use invention as the unit of analysis. Multiple licensing of the same invention offers the possibility of using invention-level fixed effects to control for unobservable variables. However, in our sample less than 10% of all inventions are licensed multiple times and hence a fixed effects model would imply significant loss of data. We do account for inventions that are licensed multiple times by clustering the observations on the inventions.

In sum, the results of the estimations and robustness checks support the view that tacitness of knowledge of an invention can explain why at a given level of invention capability or governance capability different choices are made for the governance mode for licensing of university technologies.

DISCUSSION

This study makes two theoretical contributions. First, by focusing on tacitness of the invention, we are able to contrast the difference in contracting choices given the same level of invention and governance capabilities. Consequently, this study proffers evidence that technology and technology governance capabilities may not necessarily be tightly coupled capabilities within organizations. Further, we contribute to the literature on governance modes for technology transfer. One comparison between the market and other forms of coordinating knowledge transfer that has not received much empirical attention is the comparison of upfront payments contracts versus performance based contracts for the development and commercialization of technology. We discuss the implications of our findings below.

Technological and Governance Capabilities

Recent work in the literature on capabilities has called attention to the role of firm capabilities in building a second order governance capability. Since governance capabilities develop from experience with dealing with technology transactions of make versus buy decisions or from inter organizational alliance experiences, usually technology and governance capabilities are synchronous. In multi-party exchanges, however, where inventing and governance capabilities are located with different parties, such as in our empirical setting, it is interesting to note the extent to which technology capability and governance capability jointly influence the licensing of technology, especially when these capabilities are asynchronous and dispersed within the organization. This allows us to detail the separate and opposite effects of technology and governance capabilities. The impact of governance capability, however, is weaker than the impact of the technological capability, which could explain why it is generally subsumed by the latter.

Further, we focused on tacitness of knowledge and relied on two dimensions of tacitness: codification and teachability. Interestingly, in our prediction for inventor experience and for star scientists' impact on governance choices, we anticipated that the level of codification would be higher as experienced inventors and top publishers in scientific journals would be better skilled at codification than inventors without such experience or inventors who were not star scientists. Consequently, this could result in a lower tacitness. We argued, however, that these inventors are also more likely to push the frontiers of science, increasing the effort needed to teach the technology to others. Our predictions and results support the view that codification is almost never complete and hence the dimension that is most important for transfer of technical knowledge is the level of effort needed from the inventors to teach the buyers of the technology. Therefore, in our sample, we find that teachability tends to have higher salience than codifiability.

Our findings have implications for ongoing conversations in the literature on capabilities and contracts. For instance, our work has implications to the literature on inter-organizational alliances. The literature on alliances suggests that there is a continuum of organizational forms that start with markets and progress to alliances, equity alliances, and finally integration of organizations within the boundaries of the firm through mergers as modes of organizing (Mowery, Oxley, and Silverman, 1996). However, the cost of more hierarchical arrangements need to weighted against the benefit of knowledge transfer. One comparison between the market and other forms of coordinating knowledge transfer that has not received empirical attention is the comparison of upfront payments contracts i.e. fixed price upfront payments which resemble markets versus performance-based contracts for the development and commercialization of technology. This omission is especially surprising because performance contracts may have lower cost than the more hierarchical forms of technology transfer like joint ventures and acquisitions. Our work is also related to the licensing of innovations that come from open-source collaborations. The open-source collaboration setting is in line with our empirical context, as the licensor's organizational experience does not influence the choice of projects by inventors, unlike inter-organizational alliances where these preferences are closely matched (Mitsuhashi & Greve, 2009). Consequently, the approach we take in this study to separate the technology capabilities of the inventors and the organization's technology governance capability may have useful implications for the analyzing open source innovation, wherein inventors take-up technology challenges posted online and are open to everyone (Jepessen and Karim, 2009).

Tacitness of knowledge and its implications for contract choices

Would the tacitness of knowledge of an invention influence other important clauses that enhance or restrict the economic rights of the parties to the contract? Here, we explore the relationship between presence or absence of star inventor in a team and heterogeneity in exclusive or restricted rights, claw back clauses, and development plans. Contract and auction theory have been used to explain whether an invention should be licensed to one firm or to several competing firms. The licensor's preference to grant exclusivity has been found to depend on the impact of the invention on the competition. Radical innovations, i.e., innovations that create a natural monopoly, should be licensed exclusively (Kamien and Tauman, 1986; Katz and Shapiro, 1986). Small innovations, on the other hand, can be licensed to multiple competing firms. It is clear, however, that the licensee firm would always prefer to be the exclusive license right holder regardless of the value of the invention. Since the inventions by star scientist are more likely to be drastic in nature and because more effort is needed from the licensee firm to commercialize the more tacit inventions by star scientists, we would expect the invention by star scientists to be assigned to exclusive licensing contracts. We find that 35% of all licensed inventions by star scientists are exclusive licenses whereas 23% of licenses by inventors who are not star scientist are licensed as exclusive contracts (Figure 4).

Insert Figure 4 about here

The literature on innovation licensing recognizes the threat of shelving by the licensee firm, i.e., when the licensee firm acquires the invention under an exclusivity clause without the intention of commercializing. The licensee firm uses her exclusivity to block her competitors' access to the invention (Dechenaux et al. 2009). Therefore, if exclusivity is granted in the contract, the licensor may want to include claw back clauses that give her the right to request the return of the patent if no progress and payments are made. Theoretical models, however, show that the likelihood of shelving depends on the value of the invention, and that radical inventions are less likely to be shelved (Dechenaux et al. 2009). Thus, we find that while radical inventions push the licensor towards exclusivity, which may require the inclusion of claw back clauses in the contract, the high value of those inventions should also reduce the likelihood of shelving by the licensee firm. In our sample, 47% of contracts by star scientists have a claw back clause whereas 42% of contracts by teams without star scientists have a claw back clause (Figure 4).

Finally, development plans can be useful to monitor the development of the invention towards commercialization. A development plan determines milestones and deadlines and can be used to hold either party to its duties in achieving the required development. A development plan aims to ensure the other party's continued involvement in the commercialization of the invention and is mostly required for inventions that still require substantial further development before commercialization. The licensee firm would like to include a development plan if the scientist's effort is needed, i.e., more particularly for highly tacit knowledge transfers by star scientists. The TTO, on the other hand, benefits from a development plan by preventing a licensee firm with exclusive rights from shelving the project. Therefore, we would expect inventions by star scientists to be more likely to include a development plan. In our data, 56% of contracts by star scientists include a development plan, whereas only 42% of contracts by teams without star scientists include a development plan. To summarize, tacitness of knowledge of an invention, for which the presence of star scientists in an inventor team is a proxy, is useful to explain the awarding of economic rights in a technology transfer contract.

Alternative Explanations

Why are some technologies assigned to performance contracts and other technologies to fixed market payments? We focus on the tacitness of the technology that underlies an invention as the key driver of the governance of technology licensing contracts. Specifically, we identified inventions by star scientists as embodying knowledge that is not codified and harder to teach. The results of the estimations are consistent with this line of view. There are two alternative views which would also make a similar prediction. The first is that the tacitness may make valuation of the invention a problem for the licensing firms and licensing firms offer performance contracts to attract high quality inventors. Our analysis is consistent with predictions of the adverse selection models. Notice that the adverse selection prediction does not say much about the effort needed from the inventor. There is a body of literature, however, that suggests that transferring tacit knowledge is expensive and inventor effort is needed. The distinction between moral hazard and adverse selection models is difficult to make, since both are linked to higher tacitness of the invention and both result in performance contracts.

The second and harder to justify view is that individuals with higher ability are also systematically more risk seeking. The raw count of contracts in our sample show that 778 inventions were by teams without star scientists and 271 inventions were by teams with star scientists. The overwhelming majority of inventions by star scientists, however, are assigned to performance contracts. This may suggest that star scientists are more risk seeking than other inventors and hence prefer performance contracts. We do not think that this is a reasonable assumption, but rather that this is an unavoidable result of adverse selection and moral hazard. What at the face of it may appear to be a risk seeking behavior can be explained by the fact that star scientists' inventions are harder to evaluate and need more effort from the star scientists for commercialization, thus prompting the licensing firms to offer, or star scientists to choose, performance contracts.

Another alternative explanation is that star scientists are secure in their academic and research careers that enables them to be risk seeking in their commercialization projects. Since we are unable to measure risk appetite of the inventors we conduct robustness checks to see if there is any difference between the patterns of contracts that star scientists' inventions are assigned to when the star scientists are early in their career versus later in their career. We find that inventions by star scientists have the same propensity to be assigned to performance contracts regardless of whether these inventions are early in their career or later.

Limitations

Our approach of focusing on the tacitness of the invention seeks to complement the theoretical and survey work that has shown that the stage of technology has the most bearing on the licensing of technology. Whereas we have not explicitly measured the stage of technology, we have used several proxies for the critical variable. Some other limitations of the study are that we have used data from licensing data from one university and this may not reflect licensing in general between other universities and firms or between firms. We follow other studies that have used a similar setting from which they have then drawn generalizations that apply to other industries that depend on science and technology (Shane 2000; Ziedonis 2007; Agarwal, 2006). We believe with these authors that in industries and firms which maintain profitability through the generation of new science the importance of the tacitness of knowledge in the technology transfer may hold.

Another limitation is that we do not measure the several dimensions of tacitness of an invention. It is conceivable that we could read the patents that are linked to an invention and score the invention's codification and teachability. But, this would need experts in each of the domains of the invention and also for the experts to retrospectively evaluate tacitness at the time of the invention disclosure. Lacking a direct measure of teachability and codification we conduct robustness checks of the citations of the patent filed by star and non star scientists to show that inventions by star scientists are more tacit. Finally, for our estimation strategy we tried to control for the omitted variable bias by running a two stage sample selection model. We have identified an instrument variable that we argue meets the theoretical and in our results the empirical requirements. However there is no widely used empirical test to categorically access the suitability of a single instrument variable. Hence, we follow Wooldridge (2000) recommendation and rerun out estimations with the same variables in the first stage and in the second stage as a conservative test. We find that the results for the theory variables do not change.

CONCLUSION

Limitations aside, this study builds on recent arguments which suggest that the locus of technology capabilities and governance capabilities could be dispersed in organizations and this could open the possibility that the two capabilities could evolve asynchronously. We find that the choice of market versus performance contracts is driven by the levels of capability that inheres within the organization and the inventor, but that they can be asynchronous in their development. Especially when inventors work at the frontiers of science, this increases the tacitness of knowledge which causes frictions in the evaluation of the invention and transfer of knowledge to the licensee firms. Our study also holds some normative considerations for technology transfer from universities to firms, especially with regard to inventor experience and star scientists and the choice of contracts offered.

REFERENCES

Agarwal, A. 2006. Engaging the Inventor: Exploring Licensing Strategies for University Inventions and the Role of Latent Knowledge. *Strategic Management Journal* **27**(1): 63-79.

Aghion P, Tirole J. 1994. On the management of innovation. *Quarterly Journal of Economics* 109: 1185–1207.

Ai, C. R., E.C. Norton. 2003. Interaction terms in logit and probit models. *Economics Letters* 80(1): 123-129.

Akerlof, G. A. 1970. Market for lemons – Quality uncertainty and the market mechanism. *Quarterly Journal of Economics* 84(3): 488-500.

Alchian, A. A., H. Demsetz. 1972. Production, information, information costs, and economic organization. *American Economic Review* 62(5): 777-795.

Amit, R., Glosten, L., Muller, E. 1990. Entrepreneurial Ability, Venture Investments, and Risk Sharing. *Management Science* 36: 1232–1245

Anand, B.N., T. Khanna. 2000. The Structure of Licensing Contracts. *The Journal of Industrial Economics* 48(1): 103-135.

Argote, L. 1999. Advances in strategic management - Population-level learning and industry change - Preface. In A. S. Miner & P. Anderson (Eds.), Advances in Strategic Management, Vol 16 - 1999 - Population-Level Learning and Industry Change, Vol. 16: XV-XVII.

Argyres, N., K.J. Mayer. 2007. Contract design as a firm capability: An integration of learning and transaction cost perspectives. *Academy of Management Review* 32(4): 1060-1077.

Argyres, N. 1996. Evidence on the role of firm capabilities in vertical integration decisions. *Strategic Management Journal*, 17(2): 129-150.

Barney, J. 1991. Firm resources and sustained competitive advantage. *Journal of Management* 17(1): 99-120.

Basalla, G. 1988. *The evolution of technology*. Cambridge University Press, Cambridge.

Baum, C. 2006. *An introduction to modern econometrics using Stata*. Stata Press.

Cohen, W. M., Levinthal, D.A. 1990. Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly* 35(1) 128-152.

Cohen, W.M., Levinthal, D.A. 1989. Innovation and Learning: The Two Faces of R&D. *The Economic Journal* **99**(397): 569-596.

Conner, K.R., C.K. Prahalad. 1996. A resource-based theory of the firm: Knowledge versus Opportunism. *Organization Science* **7**(5): 477-501.

Contractor, F. J. 1981. The role of licensing in international strategy. *Columbia Journal of World Business* 16(4): 73-83.

Corts, K., Singh, J. 2004. The Effect of Repeated Interactions on Contract Choice: Evidence from Offshore Drilling. *Journal Of Law, Economics & Organization*. 20(1),pp. 230-260.

Dechenaux, E., M.C. Thursby, J.G. Thursby. 2009. Shirking, Sharing Risk, and Shelving: The Role of University License Contracts. *International Journal of Industrial Organization* 27(1):80-91.

Dierickx, I., K. Cool. 1989. Asset stock accumulation and sustainability of competitive advantage. *Management Science* 35(12): 1504-1511.

Dosi, G. 1982. Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. *Research Policy* 11(3) 147-162.

Dushnitsky, G. 2010. Entrepreneurial Optimism in the Market for Technology Inventions. *Organization Science*, 21(1): 150-167

Dyer, J. H., H. Singh. 1998. The relational view: Cooperative strategy and sources of interorganizational competitive advantage. *Academy of Management Review* 23(4): 660-679.

George, G. 2005. Slack resources and the performance of privately held firms. *Academy of Management Journal* 48(4): 661-676.

George G, Kotha R, Zheng YF, 2008. Entry into insular domains: A longitudinal study of knowledge structuration and innovation in biotechnology firms, *Journal of Management Studies*, 45: 1448-1474.

Granovetter, M. 1985. Economic action and social structure: The problem of embeddedness. *American Journal of Sociology* 91(3): 481-510.

Greene. W. 2010 .Testing hypotheses about interaction terms in nonlinear models. *Economics Letters* **107**: 291–296.

Hart, O., J. Moore. 1999. Foundations of incomplete contracts. *Review of Economic Studies* 66 139-151.

Heckman, J. J. 1976. Common structure of statistical models of truncation,sample selection and limited dependent variables and a simple estimator for such models. *Annals of Economic and Social Measurement* 5(4): 475-492.

Hoetker, G. 2005. How much you know versus how well I know you: Selecting a supplier for a technically innovative component. *Strategic Management Journal* 26(1): 75-96.

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

Jeppesen, L.,Karim, L. 2009. Marginality and Problem Solving Effectiveness in Broadcast search. *Organization Science,* forthcoming.

Kale, P., Dyer, J. H., Singh, H. 2002. Alliance capability, stock market response, and long-term alliance success: The role of the alliance function. *Strategic Management Journal* 23(8): 747-767.

Kamien, M.I., Y. Tauman. 1986. Fees versus Royalties and the Private Value of a Patent. *The Quarterly Journal of Economics* 101(3):471-492.

Katz M.L, C. Shapiro. 1986. How to license intangible property. *The Quarterly Journal of Economics* 101(3):567-590.

Kogut, B., U. Zander. 1992. Knowledge of the firm, combinative capabilities and the replication of technology. *Organization Science* 3(3): 383-397.

Kogut B., U. Zander. 1993. Knowledge of the Firm and the Evolutionary Theory of the Multinational Enterprise. *Journal of International Business Studies*, 24 (4):625-645.

Kogut, B., U. Zander. 1996. What firms do? Coordination, identity, and learning. *Organization Science* 7(5): 502-518.

Latour, B. 1987. *Science in action: How to follow scientists and engineers through society*. Cambridge, Mass. Harvard University Press.

Leiblein, M. J., D.J. Miller. 2003. An empirical examination of transaction- and firm-level influences on the vertical boundaries of the firm. *Strategic Management Journal* 24(9): 839-859.

Lerner, J., R.P. Merges. 1998. The Control of Technology Alliances: An Empirical Analysis of the Biotechnology Industry. *The Journal of Industrial Economics* 46(2):125-156.

Levitt, B., J.G. March. 1988. Organizational learning. *Annual Review of Sociology* 14: 319-340.

Martin, X., Salomon, R. 2003a. Knowledge transfer capacity and its implications for the theory of the multinational corporation. *Journal of International Business Studies* 34(4): 356-373.

Martin, X., Salomon, R. 2003b. Tacitness, learning, and international expansion: A study of foreign direct investment in a knowledge-intensive industry. *Organization Science* 14(3): 297-311.

Mas-Colell, A., M.D. Whinston, J.R. Green. 1995. *Microeconomic theory*. Oxford University Press.

Mayer, K. J., Salomon, R. M. 2006. Capabilities, contractual hazards, and governance: Integrating resource-based and transaction cost perspectives. *Academy of Management Journal* 49(5): 942-959.

Mayer, K. J. 2006. Spillovers and governance: An analysis of knowledge and reputational spillovers in information technology. *Academy of Management Journal* 49(1): 69-84.

Miner, A. S., Kim, J. Y., Holzinger, I. W., Haunschild, P. 1999. Fruits of failure: Organizational failure and population-level learning. In A. S. Miner & P. Anderson (Eds.), Advances in Strategic Management, Vol 16 - 1999 - Population-Level Learning and Industry Change, Vol. 16: 187-220.

Mowery, D. C., Oxley, J. E., Silverman, B. S. 1996. Strategic alliances and interfirm knowledge transfer. *Strategic Management Journal* 17: 77-91.

Nelson, R.R., S.G. Winter. 1982. *An evolutionary theory of economic change*. Cambridge, MA: Harvard Univ. Press.

Nickerson, J. A., T.R. Zenger. 2002. Being efficiently fickle: A dynamic theory of organizational choice. *Organization Science* 13(5): 547-566.

Norton, E, Wang, H, and Ai, C.2004. Computing interaction and standard errors in logit and probit models. *Stata Journal.*

Owen-Smith J. 2005. Dockets, deals, and sagas: commensuration and the rationalization of experience in university licensing. *Social Studies of Science*. 35:69–97

Polanyi, M. 1967. *The tacit dimension*. New York: Doubleday Anchor.

Shane, S. 2000. Prior knowledge and the discovery of entrepreneurial opportunities. *Organization Science*. **11**(4) 448-469.

Silverman, B. S. 1999. Technological resources and the direction of corporate diversification: Toward an integration of the resource-based view and transaction cost economics. *Management Science* 45(8): 1109-1124.

Simon, H. 1962. The architecture of complexity. Proceedings of the American Philosophical Society. 106(6) 467-482.

Szulanski, G. 1996. Exploring internal stickiness: Impediments to the transfer of best practice within the firm. *Strategic Management Journal* 17: 27-43.

Teece, D. J. 1977. Technology transfer by multinational firms: resource cost of transferring technological know-how. *Economic Journal* 87(346): 242-261.
Thursby, J. G., Thursby, M. C. 2002. Who is selling the ivory tower? Sources of growth in university licensing. *Management Science*. **48**(1) 90-104.
Vanneste, B. S., Puranam, P. 2010. Repeated Interactions and Contractual Detail: Identifying the Learning Effect. *Organization Science* 21(1): 186-201.
Weick, K. 1976. Educational organizations as loosely coupled systems. *Administrative Science Quarterly*. 21(1) 1-19
Wernerfelt, B. 1984. A resource based view of the firm. *Strategic Management Journal* 5(2): 171-180.
Winter, S. 1987. Knowledge and competence as strategic assets. In the competitive challenge:Strategies for industrial renewal, ed. D.Teece, pp:158-84. Cambridge, MA: Ballinger Publishing.
Wooldridge, J. M. 2000. *Introductory econometrics: A modern approach.* Third Edition. Thomson, South-Western, USA.
Zander, U., Kogut, B. 1995. Knowledge and the speed of transfer and imitation of organizational capabilities – An empirical test. *Organization Science* 6(1): 76-92.
Ziedonis, A. A. 2007. Real options in technology licensing. *Management Science* **53**(10) 1618-1633.
Zucker, L., Darby, M. 1999. California's inventive activity: Patent indicators of quantity, quality, and organizational origins. Sacramento, US: California Council on Science and Technology.
Zucker, M., Brewer, B. 1998. Intellectual human capital and the birth of US biotechnology enterprises. *American Economic Review*. **88**(1) 290-306.

Table 1: Summary Statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
Performance contracts	1049	0.8	0.4	0	1
Inventor experience	1049	1.8	1.0	0	4.1
Licensor experience (TTO)	1049	5.9	1.0	0.7	7.2
Star scientists†	1049	0.3	0.4	0	1
Number of inventors	1049	0.3	0.4	0	1
Complexity	1049	0.6	0.5	0	1
Funded research†	1049	4.0	7.6	0	40
Incremental research	1049	13.8	21.3	0	86
Citations received	1049	0.5	0.5	0	1
Related inventions	1049	1.5	0.9	1	7
Licensee relationship history	1049	0.3	0.5	0	1
Licensee size†	1049	0.5	0.5	0	1
Licensee expertise	1049	6.0	2.1	0	9.2
Distance from TTO	1049	1.1	0.6	1	6
Symmetric quality	1049	0.8	0.4	0	1

† indicator variable

Table 2: Correlations between the Variables in the Second Stage: Performance/Upfront Contracts

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Performance contracts	1													
2	Inventor experience	.21	1												
3	Licensor experience (TTO)	-.09	.15	1											
4	Star scientists†	.24	.29	-.08	1										
5	Number of inventors	-.01	.16	.19	.06	1									
6	Complexity	.12	-.05	-.01	.03	.07	1								
7	Funded research†	-.15	-.08	.12	-.22	-.05	-.11	1							
8	Incremental research	.04	.21	-.17	-.10	-.10	.03	-.13	1						
9	Citations received	.12	.08	-.27	.22	-.14	.21	-.30	.60	1					
10	Related inventions	.22	.09	.02	.04	-.14	.19	-.18	.26	.24	1				
11	Licensee relationship history	.01	.00	.08	-.08	.01	-.10	.12	-.10	-.09	-.16	1			
12	Licensee size†	-.13	.01	-.16	-.03	-.06	-.03	-.06	.05	.10	.06	.01	1		
13	Licensee expertise	.05	.01	.05	.05	.02	.11	-.13	.06	.07	.15	-.12	-.05	1	
14	Distance from TTO	-.21	-.03	.00	.12	-.10	-.05	-.03	-.02	.07	-.02	-.07	.22	-.07	1
15	Symmetric quality	.09	.12	.10	.21	-.07	.00	-.23	.00	.06	.11	-.03	-.04	.03	.01

All correlations greater than .047 are significant at p<.05 level

Table 3: Probit Estimation of the Probability of an Invention being assigned to Performance Contract with Sample Selection Control

	Dependent Variable: Performance Contract									
	Model 1		*Model 2*		*Model 3*		*Model 4*		*Model 5*	
	b	s.e.	b	s.e.	b	s.e.	b	s.e.	b	s.e.
Number of inventors	0.0526	(0.054)	-0.0467	(0.051)	-0.0459	(0.052)	-0.0533	(0.052)	-0.0512	(0.053)
Complexity	0.176	(0.371)	0.193	(0.365)	0.190	(0.364)	0.174	(0.365)	0.143	(0.365)
Funded research	-0.518†	(0.265)	-0.320	(0.253)	-0.316	(0.250)	-0.428†	(0.250)	-0.437†	(0.244)
Incremental research	-0.0447*	(0.020)	-0.0463*	(0.021)	-0.0464*	(0.020)	-0.0392†	(0.021)	-0.0379†	(0.021)
Citations received	0.00825	(0.009)	-0.00557	(0.009)	-0.00527	(0.009)	-0.00750	(0.009)	-0.00774	(0.009)
Related inventions	1.214***	(0.257)	1.234***	(0.260)	1.268***	(0.261)	1.268***	(0.260)	1.332***	(0.265)
Licensee relationship	0.109	(0.151)	0.198	(0.147)	0.200	(0.146)	0.201	(0.146)	0.204	(0.145)
Licensee size	-0.825*	(0.353)	-1.027**	(0.335)	-1.017**	(0.336)	-1.025**	(0.334)	-1.016**	(0.334)
Licensee expertise	-0.0414	(0.327)	0.0992	(0.315)	0.108	(0.315)	0.0631	(0.320)	0.0667	(0.320)
Distance from TTO	-0.335***	(0.068)	-0.362***	(0.066)	-0.363***	(0.066)	-0.354***	(0.065)	-0.353***	(0.065)
Inventor experience			0.584***	(0.145)	0.543***	(0.154)	0.572***	(0.145)	0.502***	(0.152)
Licensor experience (TTO)			-0.248†	(0.150)	-0.241	(0.156)	-0.133	(0.170)	-0.108	(0.170)
Star scientists			2.048***	(0.518)	1.407*	(0.717)	8.304**	(2.725)	8.899**	(3.305)
Invention experience * Star					0.311	(0.320)			0.572	(0.360)
Licensor experience * Star							-1.020*	(0.417)	-1.309*	(0.570)
Constant	3.177**	(0.976)	4.896***	(1.234)	4.895***	(1.242)	4.367***	(1.291)	4.302***	(1.294)
Year fixed effects	included		included		included		included		Included	
Number of observations	1008		1008		1008		1008		1008	
chi2	113.3		163.6		165.9		161.6		160.2	
ll	-407.3		-357.2		-356.8		-354.8		-353.5	

Robust clustered standard errors in parentheses ,† p<.10, * p<.05, ** p<.01, *** p<.001.

Figure 1: Moderation by Star Scientists of the relationship between Inventor Experience and Performance Contracts

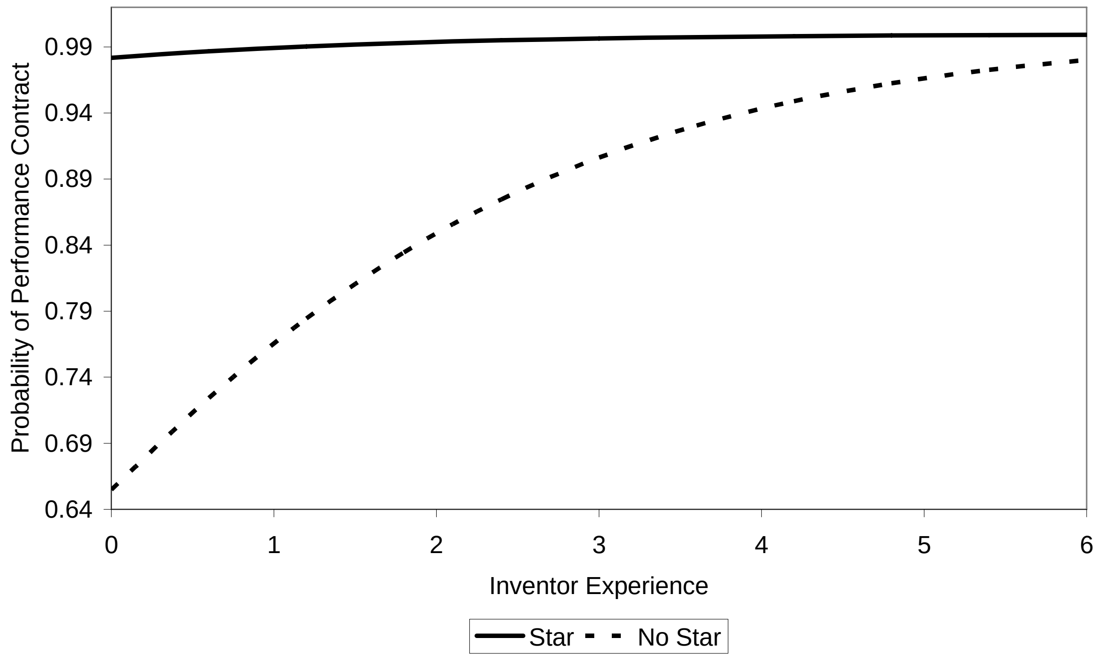

Figure 2: Moderation by Star Scientists of the relationship between Licensor (TTO) Experience and Performance Contracts

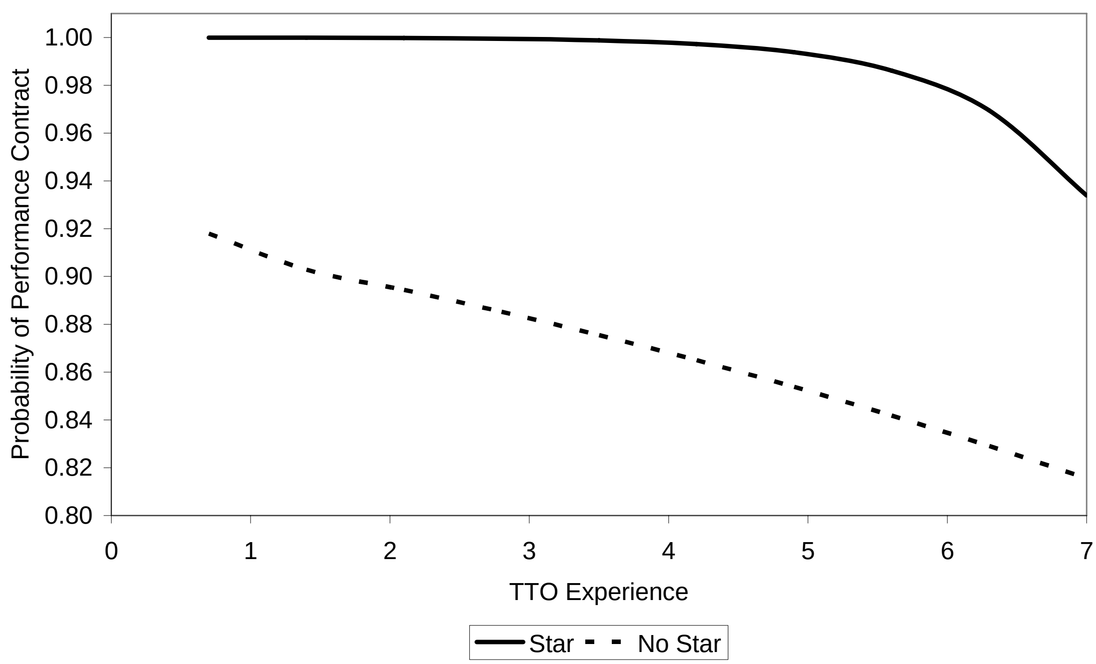

Table 4: Multinomial Logit Estimations of Fixed, Hybrid (fixed and performance) and Pure Performance Contracts

	Multinomial Logit: Comparison is Fixed			
	Model 1a		Model 1b	
	b	s.e.	b	s.e.
Number of inventors	-0.0711	(0.062)	0.00256	(0.057)
Complexity	0.243	(0.372)	-0.333	(0.538)
Funded research†	-0.483†	(0.252)	-0.391	(0.312)
Incremental research	-0.0333	(0.021)	-0.0577	(0.039)
Citations received	-0.00501	(0.009)	-0.0172	(0.012)
Related inventions	1.449***	(0.270)	0.832**	(0.316)
Licensee relationship	0.183	(0.154)	0.290	(0.183)
Licensee size†	-0.914**	(0.350)	-1.353*	(0.615)
Licensee expertise	0.0492	(0.333)	0.183	(0.486)
Distance from TTO	-0.298***	(0.067)	-0.505***	(0.109)
Inventor experience	0.498**	(0.155)	0.470*	(0.214)
Licensor experience (TTO)	0.0656	(0.190)	-0.540*	(0.220)
Star scientists†	9.441**	(3.389)	8.742*	(3.554)
Invention experience * Star	0.613†	(0.370)	0.463	(0.441)
TTO experience * Star	-1.406*	(0.583)	-1.286*	(0.623)
Year fixed effects	Included		Included	
Cut 1				
Cut 2				
chi2	178.72			
Log Likelihood	-715.0			

Standard errors in parentheses ,† p<.10, * p<.05, ** p<.01, *** p<.001.

Table 5: Heckman Sample Selection Estimation of Probability of an Invention being licensed as a Performance Contract conditional on an Invention being Licensed

Dependent Variable	First Stage: Licensing (Yes/No)		Second Stage: Performance Contract (Yes/No)	
	b	s.e.	b	s.e.
Constant	-2.1119***	(0.2796)	0.6732***	(0.1732)
Number of inventors	0.2385***	(0.0171)	0.0077	(0.0081)
Complexity	-0.2294***	(0.0657)	0.0502	(0.0285)
Funded research†	-0.0218	(0.0528)	-0.0395*	(0.0192)
Incremental research	-0.0164**	(0.0054)	-0.0013	(0.0017)
Citations received	0.0396***	(0.0026)	0.0003	(0.0012)
Related inventions	0.5470***	(0.0491)	0.1316***	(0.0274)
Theory variables				
Inventor experience	0.0558*	(0.0253)	0.0813***	(0.0116)
Licensor experience (TTO)	-0.0435†	(0.0289)	-0.0282*	(0.0111)
Star scientists†	0.2599***	(0.0721)	0.1689***	(0.0288)
Instrument variable				
Symmetric quality	0.0982*	(0.0444)		
Year fixed effects	Included			
Rho	0.3			
chi2	1268.12			

Robust clustered standard errors in parentheses ,† p<.10, * p<.05, ** p<.01, *** p<.001.

Figure 3: Analysis of Patents that are linked to Star and Non Star Scientist Inventions

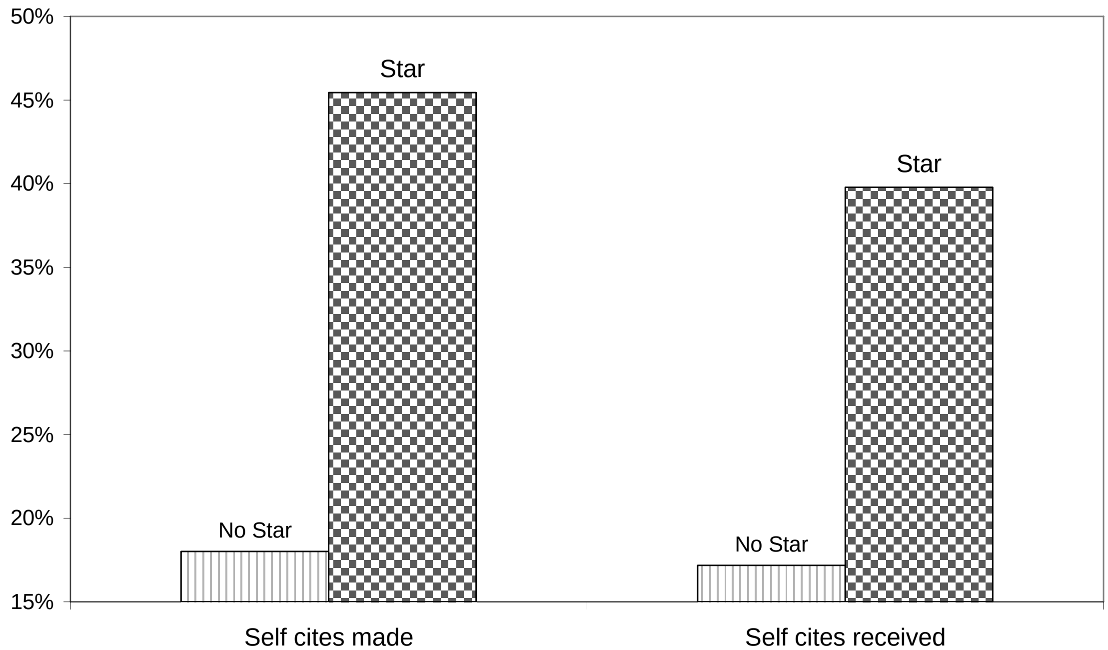

Figure 4: Percentage of Contracts by Inventor Teams with Star and without Star Scientist that contain Excusive, Claw back, and Development Plan clauses