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ABSTRACT

Essays on Institutions and Innovation

by

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Doctor of Philosophy in Business Administration
University of California, Berkeley
Spring, 2010

The three chapters of this dissertation analyze the influence of three institutions – markets, law, and politics – on the generation and commercialization of new ideas (innovation). Chapter 1 examines how license contracts between startup inventors and developers deal with adverse selection and moral hazard problems in the market for biomedical inventions. The empirical findings are consistent with contract design theories that propose mitigating the information problems with two-part payments consisting of upfront fees and output-based royalty rates. Chapter 2 investigates political influence in the allocation of public funds for the generation of ideas and shows that although U.S. Congressional appropriators do not earmark federal funds for biomedical research performers, they support allocations for those research fields that are most likely to benefit performers in their constituencies. Chapter 3 exploits the Y1995 change in U.S. patent law to understand differences in the patent prosecution strategies of start-up inventors and established firms.

EXECUTIVE SUMMARY

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New ideas, or innovations, drive modern businesses and economies. The value of new ideas however is known by a few, typically its inventors, or revealed only after costly investment in their development. This imperfect information aspect of new ideas poses distinct challenges to their finance, organization, and commercialization. The three chapters of my dissertation analyze the influence of three fundamental institutions – market mechanism, political organization, and legal framework – on these challenges.

Chapter 1: Imperfect information and contracts in the market for ideas: evidence from the licensing of biomedical inventions

The first chapter studies the market for ideas. The market for ideas is characterized by imperfect information. The inventors of a new idea and those who seek to develop it may have different expectations regarding the idea's quality; yet credible demonstration of quality risks the idea's expropriation by potential buyers. This *hidden quality* problem poses difficulties for the two parties to agree upfront on a price for the idea. Even if they agree on a price, the parties may differ in their incentives to invest *unobservable effort* required to develop the idea. "Arm's-length" trades in the market for ideas hence are hard to achieve, and numerous theoretical studies consider the design of "optimal" contracts to mitigate imperfect information problems.

The study asks: how do arm's-length contracts between real world sellers and buyers of new ideas deal with imperfect information problems? Agency theory recommends mitigating the problems – adverse selection (hidden quality) and moral hazard (unobservable effort) – with simple two-part payment schemes consisting of upfront fees and revenue-based royalty rates.[1,2] The prescriptions of theory notwithstanding, we do not yet know how real world contracts between inventors and developers of new ideas deal with the information hazards. One obstacle has been the lack of contract-level data. The goal of this chapter thus is to gather a large sample of contracts between inventors and developers, and test whether the contractual payment schemes are consistent with the predictions of two-sided hidden quality and unobservable effort theories.

For this purpose, I assemble and exploit a sample of 505 licenses between inventors and developers of biomedical inventions negotiated during the years 1995-2008. The license contracts were reported as "material" by public corporations in their U.S. Securities and Exchange Commission (SEC) filings, and represent high value transactions (the sample mean upfront payment to inventors is $1.5 Million). I construct contract-level proxies for the private information of inventors and developers, the hidden quality of inventions revealed after the agreement, and the two parties' unobservable effort, and link the proxies to cross-sectional variation in contractual payment terms. Although contract design theory focuses on upfront fees and royalty rates as primary payment terms, my empirical analysis also examines the minimum royalty payments and milestone payments found in licenses for biomedical inventions.

My analysis finds that unobservable inventor effort is significantly correlated with higher royalty rates, and unobservable developer effort with higher upfront payments. These *ceteris paribus* results are consistent with two-sided moral hazard models that predict revenue-sharing to address the contracting parties' unobservable effort concerns. Next, contracts between inventors informed of the value of their high quality inventions and developers specify higher minimum royalty payments – a finding broadly consistent with the prediction

[1] The intuition is that because royalty rates are expressed as a percentage of revenues and revenues reveal the true quality of an idea, an inventor informed of her ideas' superior quality separates herself from inferior inventors by accepting royalty rate payments instead of upfront fees thus relieving the hidden quality problem. Similarly royalty rates tie the inventor's income to revenues that increase with inventor effort thus addressing the unobservale effort problem.

of inventor adverse selection models. Minimum royalty payments are *contingent* on inventions' successful commercialization, but unlike revenue-based royalty rate payments, do not incur the costs of verifying developers' revenues. Finally, inventions' quality *hidden to both parties* at agreement date is positively related to milestone payments, suggesting that such payments deal with uncertainty about the viability of early-stage inventions.

Overall, licenses for biomedical inventions include provisions to address the hazards posed by: the unobservable efforts of inventors and developers, inventors' private information about hidden quality, and uncertainty associated with the development of novel inventions. The provisions are broadly consistent with the prescriptions of agency theory, but their variety also suggests a need for further modeling and empirical research.

The analysis in this chapter focuses on high-value transactions among sophisticated parties likely to adopt contractual safeguards to mitigate the information hazards. The findings hence suggest contractual "best practices" for inventors and developers, particularly start-up entrepreneurs, who lack alternative means such as reputation and complementary assets to mitigate the hazards. The insights from this study can be extended to a variety of contexts where parties trade ideas under imperfect information; for example, in the book publishing, movie production, and consulting industries.

Chapter 2: Political influence behind the veil of peer review: an analysis of public biomedical research funding in the U.S.

The second chapter probes political influence in the allocation of public funds for the generation of ideas. It asks: how do politicians concentrate federal benefits in their constituencies when reputational concerns constrain them from making direct transfers to their constituents? This study addresses the above question by analyzing federal funding for biomedical research in the U.S., which amounted to $28.7 billion for fiscal 2008.[3] The National Institutes of Health (NIH), the agency responsible for biomedical research, supports half of all federal nondefense R&D and over 60% of federal R&D in U.S.

[3] NIH accounts for 20% of all federal R&D which in FY2008 was estimated to be 1% of GDP (AAAS 2009).

universities (AAAS 2009). The NIH allocates funds among research performers by a mechanism based on "peer review" of the scientific merit of performers' research proposals and is considered an exemplar research agency because of its avoidance of politically mandated performer-specific earmarks (AAAS 2008).

Congressional appropriations bills and committee meeting reports reveal that although committee members do not earmark allocations to biomedical research performers, they frequently support specific biomedical research fields and projects. I argue that members seeking to favor their constituents transfer federal resources to those biomedical fields that are most likely to reach research performers in their constituencies. Such indirect transfers to members' constituencies, couched in the form of patronage for particular research topics, are more palatable to the scientific community and the public than direct transfers to performers that bypass the peer review procedure for distributing research funds.

I test whether research performers in the states of appropriations committee members receive a higher level of peer-reviewed biomedical research funds by using data on all grants awarded by the NIH to 8,310 external research performers between the years 1984 and 2003 – a period during which federal support for the agency grew from $8.4 billion to $30.2 billion (Constant FY2008 Dollars, see AAAS 2009). I exploit the panel structure of the data to control for the unobservable characteristics of biomedical research performers (or states) that may be correlated with both their receipts of federal research funds and representation in appropriations committees.

I find each additional member on the House subcommittee that deals with NIH appropriations (the Labor, Health and Human Services, Education, and Related Agencies or the "LHHE" subcommittee of the House Appropriations Committee) is associated with a 5.9% increase in NIH research funding for represented institutions. State universities, which receive the largest share of federal biomedical research funds (41.5% of all NIH extramural awards in FY2003), and small businesses are especially benefitted by House-LHHE representation, receiving increases of 8.8% and 10.3% per House-LHHE member respectively. Representation on the House and Senate appropriations committees is associated with transfers of 2.9 to 6.7% of total NIH extramural research grants for the period of this study. $0.9 billion of the $20 billion worth of peer-reviewed extramural

awards made by the NIH in the year 2003 can be attributed to the constituency interests of HAC LHHE representatives.

Does political representation favor R&D performers in those fields of research in which they are relatively "strong," or fields in which performers receive relatively lower funds? I find that research performers in the lowest two quartiles of grant recipients in any biomedical field average a 3.6% - 6.4% increase for research in those fields from House LHHE representation. Research fields in which represented performers are strong do not receive larger allocations than otherwise comparable, but unrepresented performers. Peer review that is not moderated by political representation concentrates funding in the top-quartile research fields of performers. These findings highlight a tension between the distributive effects of merit-driven allocations and politically motivated transfers – a topic of debate in U.S. science policy at least since Vannevar Bush's 1945 proposal for a politically insulated public R&D system.

Chapter 3: Pioneering inventors or thicket-builders: which U.S. firms use continuations in patenting?

The third chapter (coauthored with David C. Mowery and Stuart J. H. Graham) analyzes the use of "continuations" – a procedure intended by the U.S. patent law to strengthen the intellectual property rights of inventors of pioneering ideas. Continuation applications permit firms to restart the examination of their patent applications while retaining the filing date of a previous application that discloses the same invention. Inventors can use continuations to revise the claims submitted in their initial application or to pursue claims that have been disallowed after initial examination with new arguments and evidence. According to some corporate IP managers and patent attorneys, continuations are filed by "pioneering inventors" to "obtain adequate protection of inventions that often take a relatively long time to reach the marketplace" (see for example, comments by the Biotechnology Industry Organization, 2006). In this view, inventors use continuations to modify the claims in their patent applications to reflect developments in their inventions that occur after they have filed a patent application.

A very different characterization of the use of continuations argues that patentees file continuing applications to acquire patents with weak claims of dubious quality that were rejected by the examiner during initial prosecution (see Quillen & Webster 2001). These lower-quality patents can be valuable to patentholders seeking to accumulate a thicket of patents for "defensive" purposes and/or to improve their bargaining position in patent cross-licensing negotiations. Additionally, according to Lemley & Moore (2004), inventors may use the continuations procedure to increase uncertainty for rivals' R&D investment decisions, or to acquire so-called "submarine patents."

The continuations procedure is unique to the U.S. patent system and introduces significant delay in the prosecution process: for patents issuing from applications with continuations, the median grant lag (the time between an initial patent application and its final grant) is 44 months, substantially exceeding the median prosecution time of 23 months for patents that are not continued. The procedure is used by a significant number of patent applicants – 29% of the nearly one million patents applied for between 1981 and 2000 and granted to U.S. firms during 1981-2004 are from continuing applications, and the procedure imposes a significant burden on USPTO resources.[4] Whether continuations are filed by firms to protect their pioneering inventions, or as part of defensive patenting strategies that are considered to be of dubious social value, is the subject of recent policy debates over the benefits and costs of the procedure.

Despite the prominence of continuations in firms' IP strategies and patent policy debates, the arguments over the motives for their use by applicants have been subject to little empirical analysis.[5] This study links the characteristics of patents and attributes of their publicly listed U.S. owners to these applicants' use of the three major types of continuations in order to test the validity of competing explanations for continuations usage in the patenting strategies of firms. We also examine the effects of the 1995 change in patent term

[4] During 2005, about 30% of the U.S. Patent Office's patent examining resources were applied to examining continued examination filings that involved revisions of previous applications, in contrast to examining new applications (Federal Register 2006, p 50).

[5] The USPTO proposed limiting the number of continuations as a matter of right to two per application starting in November 2007 – see Federal Register (August 21, 2007) for further details. These rules were rejected by the United States District Court for the Eastern District of Virginia in 2008 as substantive rather than procedural, and therefore exceeding the rulemaking authority of the USPTO (in Tafas v. Dudas *et al.* and Smithkline Beacham Corp. *et al.* v. Dudas *et al.*, April 01, 2008).

on the incidence of continuations and the characteristics of the corporate users of the procedure.

Our primary finding is that firms use different types of continuations as part of different patenting strategies. One class of continuations, the "Continuation in Part" (CIP) appears to be filed disproportionately by R&D-intensive firms that patent heavily and is more common in chemical and biological technologies. Firms also employ CIPs to cover technologically valuable inventions, and the use of CIPs appears to be consistent with a strategy of protecting "pioneering inventions." Two other types of continuations, the "Continuation Application" and the "Division" (the following sections discus the different types of continuations in greater detail), are associated with less valuable patents and used more intensively by capital-intensive firms that patent intensively. This pattern is particularly strong in electronics and computers patents after the 1995 change in patent term, and we suggest that CAPs and Divisions are an important part of firms' defensive patenting strategies in these and similar industries. In addition to providing the first empirical analysis of the strategic use of continuations by corporate assignees and differences in the three types of continuing applications, the findings of our study inform policy debates over continuations reform.

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