Part of the Ewing Marion Kauffman Foundation’s Emerging Scholars initiative, the Kauffman Dissertation Fellowship Program recognizes exceptional doctoral students and their universities. The annual program awards up to fifteen Dissertation Fellowship grants of $20,000 each to Ph.D., D.B.A., or other doctoral students at accredited U.S. universities to support dissertations in the area of entrepreneurship.

Since its establishment in 2002, this program has helped to launch world-class scholars into the exciting and emerging field of entrepreneurship research, thus laying a foundation for future scientific advancement. The findings generated by this effort will be translated into knowledge with immediate application for policymakers, educators, service providers, and entrepreneurs as well as high-quality academic research.
ABSTRACT

This dissertation examines entrepreneurial activities in the U.S. biotechnology industry. I combine (i) data on founders, scientific advisors and research executives of all U.S. biotechnology firms that have filed IPO prospectuses between 1972 and 2002, and (ii) a random matched sample of 5,000 life scientists drawn from the underlying population, to conduct a large-scale, quantitative analysis of university scientists’ entrepreneurial activities. The first essay investigates how propensity to start or advise a for-profit biotechnology company varies with the social and physical proximity to previous participants in commercial science. The second essay examines gender differences in scientists’ participation in for-profit biotech ventures. The third essay analyzes the publication strategies of young biotech companies to assess how founders’ professional orientation, firms’ technological niches, and the influence of competitors jointly shape firms’ propensity to adopt the open science strategy. The fourth essay explores the diffusion of knowledge in science, especially in the context of the ever increasing exchanges between academia and industry during the past two decades.
Four Essays on the Formation and Evolution of U.S. Biotechnology Companies

Ph.D. Dissertation
Executive Summary

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Highlights

My dissertation is a collection of essays examining entrepreneurial activities in the U.S. biotechnology industry. I combine (i) data on founders, scientific advisors and research executives of all U.S. biotechnology firms that have filed IPO prospectuses between 1972 and 2002, and (ii) a random matched sample of 5,000 life scientists drawn from the population of all U.S. doctoral degree holders in life sciences and related disciplines, to conduct a large-scale, quantitative analysis of university scientists' entrepreneurial activities. My first essay investigates how propensity to start or advise a for-profit biotechnology company varies with the social and physical proximity to previous participants in commercial science. The second essay examines gender differences in scientists' participation in for-profit biotech ventures. The third essay analyzes the publication strategies of young biotech companies to assess how founders' professional orientation, firms' technological niches, and the influence of competitors jointly shape firms' propensity to adopt the open science strategy. The fourth essay explores the diffusion of knowledge in science, especially in the context of the ever increasing exchanges between academia and industry during the past two decades.

Essay One: When Do Scientists Become Entrepreneurs?

What factors lead to a decline in scientists' adherence to professional norms of conduct? Are individual characteristics, organizational contexts, or occupation-wide developments most influential in driving defection from norms of the scientific community? I empirically explore these questions in an examination of academic scientists' decisions to (i) found a biotechnology company, or (ii) join the scientific advisory board of a new biotechnology firm.

In his classic statement of the normative structure of science, Merton (1968) described four norms that together constitute the ethos of science: universalism, communism, disinterestedness, and organized skepticism. Although Merton highlighted plenty of instances of
deviances from the norms in his writings, researchers in the fields of sociology, medicine, and law have concluded that, in recent years, the many commercial endeavors of academicians fundamentally collide with the traditional norms of science (e.g., Eisenberg 1987; Blumenthal et al. 1996; Etzkowitz 1998). Indeed, some believed that the rapid diffusion of commercial activity in academia has led to a revision in the traditional norms to accommodate for-profit science. At least, the now taken-for-granted status of the "academic entrepreneur" has mitigated community-imposed sanctions for scientists’ involvement in private ventures, and reduced the role conflict that might otherwise have vexed faculty members who found, advise, or hold ownership stakes in private-sector firms created to exploit their research discoveries.

In this paper, I seek to uncover the structural conditions that antecedent academic scientists’ transition to the role of entrepreneur. My focus is on three types of mechanisms as determinants of the transition rate: imprinting-type effects engendered by socialization in graduate school, peer influence exerted across social network ties, and spatial clustering of transitions driven by pro-entrepreneurship values in scientists’ workplaces. To clarify the underlying mechanisms, I also examine how these effects interact with a few characteristics of scientists’ work contexts and the broader institutional environment, such as the level of diffusion of entrepreneurial science in the community of academic life scientists. In the most general terms, my aim is to assess whether and to what degree there is evidence of social influence in the transgression of norms.

Using adjusted proportional hazards models, I find evidence that the orientation toward commercial science of individuals’ colleagues and coauthors, and the socialization they received during graduate training, significantly influenced scientists’ hazards of transitioning to for-profit science, and thus the incidence of departures from the norms of science. The key findings of this essay include:

Waverly W. Ding, University of Chicago
Accomplished faculty members (by measures of experience, research productivity, and academic prestige) are more likely to engage in commercial science.

Faculty members were more likely to become entrepreneurs when they worked in university departments that employed other scientists that had previously ventured into the commercial sector.

The effect of working with academic entrepreneurs was largest when those having commercialized their work were prestigious scientists, and it was attenuated for individuals in medical schools and after for-profit science had significantly diffused in the academic community.

Scientists with coauthors who had become academic entrepreneurs were more likely to transition to commercial science.

The influence of commercially oriented coauthors is strongest when an individual’s coauthors were well connected in industry and when the link was established prior to the time that the collaborator had established an affiliation with a private-sector firm.

If a faculty member was trained at a department where entrepreneurial activity was present, he or she is more likely to become entrepreneurs in post-graduation career.

Collectively, the findings suggest that social influences discernible from the evolving connections among scientists contoured the diffusion path of commercial science in academia. In addition, the finding that the most accomplished scientists were also most likely to transgress the norms of science is interesting when viewed in context of the literature on professional norms. As an activity unbefitting a professional, entrepreneurship was often thought to be relegated to low prestige individuals on the fringe of a professional group. My analysis, however, seemingly uncovers the opposite relationship: highly regarded scientists employed at prestigious universities were the likeliest defectors from the Mertonian norms.

Essay Two: Gender Stratification in Academic Entrepreneurship

In the second essay, I study how gender affects scientists’ propensities to participate in commercial science. Understanding the relationships between gender and wage attainment, advancement paths, and other aspects of scientific careers is a topic that has elicited the interest of sociologists for many years. Much of the empirical work on this subject has examined sex

Waverly W. Ding, University of Chicago
differences in three outcome variables: appointment to positions in prestigious departments, rates of advancement in rank, and research productivity. Although debate remains about underlying mechanisms, the existing research, with few exceptions, concludes that female scientists who are otherwise comparable to males experience less successful careers by the standard metrics of attainment (NRC 1994; Long and Fox 1995). There are, however, indications that the gender gap in performance in scientific careers is beginning to close, especially in the life sciences.

This essay investigates a new arena in which ascriptive characteristics appear to stratify attainment levels in scientific careers: participation rates of university faculty members in commercial science. My key empirical findings are as follows:

- Female life scientists are far less likely to be assigned patents, start, or advise biotech companies. Specifically, male scientists are more than twice as likely as women to found or advise private biomedical companies.
- The gender gap in participation rates persists even after accounting for scientists' productivity and prestige.
- The gender-commercial science relationship is, however, shaped by a number of employer and individual level factors. Specifically, the gender gap is (a) smaller among faculty at institutions that strongly support commercial science, (b) smaller among scientists possessing significant amounts of human and social capital, and (c) larger among scientists employed in high status academic departments.

The above outlined differences between male and female scientists' rate of participating in private biotech ventures have significant implications. During the past 20 years, academic scientists have started and advised literally thousands of for-profit companies, a great many of which were explicitly established to capitalize academic research. Often, universities earn significant revenues from licenses of faculty-invented intellectual property (for example, according to the Association of University Technology Managers, at least 344 companies based on university discoveries were formed with faculty participation in 1999, and universities collected $821 million from licenses executed on university technology in that year alone). Because universities share royalties from licensed science with the relevant faculty members and

Waverly W. Ding, University of Chicago
company founders and scientific advisors receive stock in the firms with which they affiliate, commercial science has become a significant source of supplemental income for many scientists. Thus, the distribution of opportunities for extracurricular work of this nature informs the degree of inequality in earnings attainment among scientists.

Essay Three: Why Do For-Profit Firms Adopt Open Science?

In recent studies, scholars have noted that some for-profit firms organize their research in ways that mimic the practices found at universities or publicly funded research organizations (Rosenberg 1990; Gambardella 1992; Dasgupta and David 1994; Cockburn and Henderson 1996). In particular, open science,\(^1\) which is traditionally institutionalized at universities and non-profit research organizations, has been adopted by major pharmaceutical companies in the U.S. Biotechnology firms have also been found to rely heavily on collaboration with academic scientists to improve research productivity (Zucker and Darby 1996).

These findings challenge the traditional understanding of the distinction between public and private science. Private sector research was thought to be different from its public sector counterpart both in research foci and dissemination methods. Because for-profit firms are concerned with appropriability of knowledge, they tend to avoid investing in research that belongs to the basic science arena, leaving such topics to researchers employed at public institutions. In addition, intellectual property protection mechanisms such as patents and trade secrets are often invoked in the private sector. These mechanisms are important in providing for-

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\(^1\) Traditionally, "open science" is conceptualized to describe the types of research conducted at universities and non-profit research organizations that are supported by state funding or the patronage of private foundations with the pursuit of public knowledge as the primary objective. A distinctive set of norms and institutions have emerged with open science and are thought to govern scientists' behaviors: intellectual findings belong to the scientific community and reward in the form of peer recognition is directed to those who first communicate the scientific discoveries to the public. Though the increasing instances of commercial involvement by public sector scientists have led some to question whether the norm of open science has been revised, researchers in general believe that open science has been institutionalized successfully at U.S. academic institutions.

Waverly W. Ding, University of Chicago
profit firms incentives to invest in corporate research. Though appropriability, secrecy and property rights remain important concerns in the world of private science, the increasing evidence of for-profit firms' engagement in public science necessitates a reevaluation of costs and benefits of instituting open science in the for-profit sector.

In this essay, I focus on the social antecedents that have motivated for-profit firms' adoption. Specifically, I analyze three types of forces underlying firms' adoption decisions. First, I examine whether firms have any intrinsic propensity to over-or-undervalue the virtues of open science depending on the composition of their founding teams. Since open science has its roots in academic institutions, I postulate that founders who have been exposed to the norm of openness during their graduate education increase firms' propensity to adopt the strategy. Second, the risk of open science—the potential knowledge spillover that may benefit competitors—varies with a firm's structural position in an industry. For firms occupying a position where there is a high degree of crowding around its technological niches, open science is more costly due to the risk of spillover. Thus, I trace firms' technological niches and examine how the rate of adoption differs across niche structures. Third, drawing upon studies of social contagion and competitive influence, I model a focal firm's propensity to adopt open science as contingent upon the adoption decision of its rival firms occupying similar structural positions.

Key findings from the Probit analysis of firms' probability to adopt open science (which is defined as allowing their research staff to publish their research in academic journals) are as follows:

- When Ph.D. scientists have participated in the venture founding process of a biotechnology firm, there is a higher probability that the firm would institute a pro-open-science policy.

- Ph.D.-founded firms react differently to situations where open science is costly. Compared to non-Ph.D.-founded firms, firms with academically trained scientists involved in venture founding (hence are more bound by academic norms) are significantly less sensitive to the increase in the risk of open science (e.g., propriety research could be used by competitors to enhance their technological capability).
- The adoption by structurally comparable rivals effectively promotes the adoption of open science by the focal firm.

**Essay Four: Does Science Chase Money?**

Public trust in modern scientific institution is due, to a large extent, to the “complex of values and norms which is held to be binding on the man of science” (Merton 1968, p.605). Among them, the norm of disinterestedness, a control mechanism that helps reign in a wide range of motives of individual scientists to present a collective image of science as an independent and autonomous institution (Merton 1968), contributes greatly to the certification of and the public trust in scientific knowledge.

However, social scientists have long challenged the characterization of science as an autonomous entity. Many believed that the speed and direction of scientific development are affected considerably by social, economic and technical factors originating outside the scientific research community (Mulkay 1979). Despite the attention to the problem of external influence on science, there are surprisingly few systematic evidences that show the extent of such influence.

In this paper, I rely on archival, research publication records of a random, stratified sample of 5,000 university scientists to empirically assess the extent to which external forces have influenced the direction of scientific research. More specifically, I focused on the influence of the biotechnology industry on the research direction of university life scientists. To this end, I used the research papers published by university scientists and distilled 15,000 scientific research topics most frequently used in these publications. I traced the growth of these research topics in terms of the number of papers published on them and the number of university scientists and firms publishing papers on them between 1976 and 2000. The growth trajectory of each of these scientific research topics is analyzed as a function of corporate community’s involvement in these topics. The key findings include:

*Waverly W. Ding, University of Chicago*
- The more industry involvement in research on a topic, the higher growth rate the research topic enjoys in a future period.

- There is mixed evidence regarding whether the interest of financially well-performing companies had any impact on the rate of utilization growth of the topic in a future period—a research topic's commercial appeal to academic scientists is likely to be represented by a couple of top-performing companies that have been working on the topic.

- Moreover, the industry impact was stronger on research topics that were also supported by federal funding, suggesting that the influences of government and industry reinforce rather than complement each other in shaping the research interests of academic scientists.

The findings of essay shed light on whether the institutional norms of science (e.g., disinterestedness) had remained intact when confronted with industry participation in scientific research, which endorses a set of values largely contravening those cherished by the scientific community. The evidences suggest an attenuation of scientific norms in guiding university scientists' choice of research foci and to certain extent, the convergence in public and private sector research interests.

References


