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Divergent paths to commercial science: A comparison of scientists' founding and advising activities

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ABSTRACT

This paper investigates the difference in the profiles of university scientists who have founded or advised companies. We analyzed the commercial activities of a sample of 6138 university life scientists and found that the profiles of scientists who become academic entrepreneurs are different from those who become companies' scientific advisors. Founding activity occurs earlier during a scientist's career than advising. Factors such as gender, research productivity, social networks and employer characteristics also differ in their effects on the propensity for founding and advising. In addition, regression analysis shows that being a company's scientific advisor decreases the probability of becoming an academic founder. Overall, evidence from our analysis suggests that founding and advising are two divergent paths for commercially oriented university scientists.

1. Introduction

Scholars of university–industry relations have revealed multiple channels through which university scientists may be involved with commercializing research. At a minimum, scientists may disclose their research to the technology transfer (licensing) office at their universities, which then negotiates with industrial firms that wish to license the research discovery (Jensen et al., 2003; Bercovitz and Feldman, 2008). Over the past decades, universities have increased the number of licensing deals with technology firms and often the scientist inventors are actively involved in the process (Thursby and Thursby, 2002, 2004). Researchers have also studied the patenting behavior of university scientists (Henderson et al., 1998; Owen-Smith and Powell, 2001b; Agrawal and Henderson, 2002; Balconi et al., 2004; Fabrizio and DiMinin, 2008; Stephan et al., 2004; Azoulay et al., 2007a,b, 2009). Alternatively, some university scientists engage in collaborative research with industrial firms in the form of contract research (Blumenthal et al., 1986, 1996), consulting (Jensen et al., 2006) or joint R&D projects (Lam, 2007). In the life sciences, there are a significant number of scientists who are members of scientific advisory boards in biotechnology firms (Stephan et al., 2005; Ding et al., 2007; Murray and Graham, 2007; Stuart and Ding, 2006). Finally, academic scientists may start their own company to commercialize their discoveries. Over the past few decades, there have been an increasing number of university scientists who have founded for-profit firms to develop their scientific breakthroughs (Etzkowitz, 1983; Shane and Khurana, 2003; Stuart and Ding, 2006).

The majority of existing investigations on the commercialization of university knowledge each focuses on only one of the possible routes to commercialization, e.g., disclosure, patenting, licensing, advising or forming companies. With regard to the few studies that have investigated more than one route to commercial involvement, there are significant limitations. For example, Louis et al. (1989) investigated five types of commercial activities in their survey of 1594 scientists from 40 top universities, which included engaging in externally funded research, earning supplemental income, gaining industry support for university research, patenting, and forming and holding equity in private companies. While their study examined factors associated with these different types of commercial activities, the cross-sectional survey design did not allow one to identify the determinants of commercial activities. In addition, commercialization activities have been much more intense since their survey, which was conducted in 1985. Audretsch and Stephan (1996) studied 445 university scientists in 54 biotechnology firms that went through an initial public offering (IPO) between 1990 and 1992. Though they distinguished between the role of university scientists as a founder, scientific advisory board member, scientific advisory board chair, or major equity holder, their focus was limited to explaining the geographical link between scientists and firms. A more recent study by Stuart and Ding (2006) about the social structural determinants of academic activities included both founding and scientific advising of young biotechnology firms that went through an IPO over the past three decades. However, the authors did not dif-

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ferentiate between the activities in their study; hence, they also overlooked identifying different determinants of commercialization activities.

We believe that a more integrated approach that identifies when and why university scientists embark on different commercialization routes is important. First, activities such as disclosure, patenting, advising and founding companies call for different amounts of time and effort, and can have different impacts on scientists' productivities and career trajectories. A comparative analysis of the profiles of scientists who have engaged in various types of activities would help to understand who are inclined to engage in which type of activity and at what stage of their career. Second, each of these activities requires different financial and social resources. For example, disclosure and patenting might require scientists to simply have research that is worth reporting and seeking patent protection. In comparison, advising and founding probably calls for more human and social capital. It is therefore necessary to carry out a comparative analysis of how individual and social contextual factors (e.g., research productivity, status and social networks) affect the likelihood of pursuing different commercial activities. Third, an integrated approach is instrumental in revealing the relationship among the activities. For example, does relatively "light" commercial involvement such as patenting and consulting trigger the more intensive ones such as founding a company, or is it the case that scientists sort themselves into different camps—i.e., those who are more entrepreneurially oriented versus those who are only willing to devote a fraction of their time to commercial activities?

With above interest in mind, we provide in this paper a comparative analysis of two types of commercial activities by life science researchers—participation in a firm's scientific advisory board (SAB) versus founding a company to commercially develop a discovery. We choose to focus on these two activities for three reasons. First, compared to patenting, subsidized research and ad hoc consulting arrangements, advisory and entrepreneurial roles require scientists to be more intensively involved with a firm's operation on a regular basis. In these roles, scientists have more control over the commercialization process in a firm. Hence, SAB members and academic entrepreneurs may exert more impact on the relevant industries than scientists who merely patent or consult for industries. Second, existing theoretical models offer inconclusive predictions of who will become an advisor or founder of a company and when either transition happens in a scientist's career. For example, while role identity theory predicts that the entrepreneurship transition would happen early in a scientist's career, the scientific life-cycle model suggests that it would occur at the mid-to-late stage of a scientist's career. It is worthwhile to empirically assess the relative strength of the various theoretical models in explaining the similarity and differences between advisors and founders. Lastly, the choice is also driven by empirical constraints. While it is always possible to survey current scientists' activities and opinions of the various commercial activities, systematic longitudinal data are hard to find on the various types of activities discussed above. Advising and founding activities, however, are customarily reported in firms' public documents. From these documents, historical data can be reconstructed to trace the histories of scientists who advise and form companies.

We have assembled a data archive with career histories of approximately 6100 life scientists who have various degrees of involvement in commercial science, ranging from no significant commercial involvement, to patenting, advising and founding companies. Because the number of scientists participating in advising and founding activities is small, we employed a sampling procedure known as the "case cohort" design. We analyzed the propensity that a scientist embarks on either advising or founding activities using event history models, correcting for possible bias caused by our sampling design.

We found that the timing of advisory and entrepreneurial activities differ in a scientist's career cycle. The hazard of first-time involvement in founding activity peaks much earlier than that of advising activity in a scientist's life-cycle. This pattern holds true for male and female, older and younger cohort of scientists, and for scientists employed at universities with different ranking. Second, we also identified differences in antecedents of the two activities including gender, research productivity, social network and employer influence. Lastly, in a Cox regression analysis of whether prior advising activity increases the likelihood of a scientist's transition to entrepreneurship, we find no evidence supporting a sequential engagement argument. In fact, our analysis indicates that being an advisor to a firm decreases the likelihood of transitions into entrepreneurship.

2. Comparing scientists' advising and founding activities

Academic entrepreneurship is a process in which a university professor starts a new firm to turn his[1] breakthrough scientific discovery into commercially viable products.[2] The form and function of firms' scientific advisory boards and the responsibilities and benefits of the members of these boards, however, receive much less research attention. SABs have neither fiduciary responsibility nor a formal place in a firm's governance structure. Nevertheless, they have become a quite common organizational feature in technology-intensive industries. Typically these boards are formed by the founding scientist(s) very early in the development of the firm. The founders will identify key scientific areas in which the firm will need to seek expert advice and then invite university scientists who have the required expertise and (ideally) some commercial experience. The boards usually have between five and ten members. Board members are compensated with stock grants and consulting fees.

Below we outline some extant theories and empirical investigations that help explain the factors underlying a scientist's transition to entrepreneurship or the advisory role. We break down our review of the theories and empirical evidence into demand-side explanations, which is related to the opportunity structure for scientists' commercial engagement and supply-side explanations, which is related to the motivation and intention of scientists. Key predictions of advisor and founder profiles based on the explanations are summarized in Table 1.

2.1. Demand side explanations

We start from the demand side explanations for scientists' transition to SAB. Little theory exists that help predict demand side factors influencing the process of transition to an advisory role. We rely on existing empirical investigations of SABs (Audretsch and Stephan, 1996; Stephan and Everhart, 1998; Murray and Graham, 2007; Ding et al., 2007) to understand how opportunity structure shapes scientists' transition to becoming members of SABs.

What types of scientists are sought by companies to join their scientific advisory boards? Audretsch and Stephan (1996) postulated that university scientists facilitate three key functions: to transfer knowledge from universities to firm R&D labs, to give signals to external stakeholders about the quality of the firm, and to

[1] The male pronoun is used to reflect the gender distribution of the scientist-turned advisors and founders.

[2] The concept of academic entrepreneurship is sometimes used broadly in the commercialization literature to refer to various types of commercial activities including patenting, consulting, sponsored research and formation of companies (Franzoni and Lissoni, 2009). In this paper, we use the term of academic entrepreneur to refer to those who have founded companies.

Table 1
Predictions of advisor and founder profiles.

	Advisor	Founder	Profiles converge or diverge
Demand-side explanations	Advanced career stage, well-networked, prestigious affiliations; more hurdle for women to break in	Mixed; young scientists might be favored because of productivity and state-of-the-art knowledge; but some empirical evidence suggests more experienced and networked scientists are more likely to get the resources for venture founding	?
Supply-side explanations			
Social psychological approach	Compared to founder profile, less desire for autonomy, research to have an impact in the real world, and wealth	Have a specific psychological profile: more desire for autonomy, desire for his research to have an impact in the real world, desire for wealth	Diverge
Role Identity change	Advisors are more likely to be older in professional age	Founders are more likely younger in professional age; social structural influence will have stronger effect on founding than on advising	Diverge
Academic life-cycle approach	Both founding and advising activities occur at a later career stage, after a scientist has reached milestones (e.g., tenure)		Converge
Status perspective	Advisors occupy a high status position	Academic entrepreneurs occupy either high or low status in the academic hierarchy	Diverge

help chart the scientific direction of the firm. In two more recent investigations of SAB scientists, Murray and Graham (2007) and Ding et al. (2007) conducted in-depth interviews of about 50 scientists who have either joined SABs or are in fields that are often invited to such boards. Their interviews provide direct evidence of the role of SAB members. Broadly speaking, SABs perform three primary functions for companies. First, technology-intensive firms rely on these scientific advisors for their expertise, ranging from very specific tacit knowledge to general advice on broad scientific strategy and experimental design. SAB members support the firm's internal research activities; during board meetings, scientists assess and critique experiments designed by the firm's internal researchers and debate the direction of the next series of experiments. In general, advisors often have a combination of deep scientific expertise and a basic understanding of business issues. Second, SAB members are also chosen to signal scientific quality to external investors. In the interviews, some scientists who have served on SABs likened their advisory role to "window dressing". In effect, prestigious academic scientists lend their reputations to the early stage firms they advise, which is thought to aid firms in the process of attracting resources (Stephan et al., 2005). Third, advisors bridge the firm to their academic networks (Stuart et al., 2007). Advisors, through their collaborations, assist in identifying other academics who might be a critical resource for the firm, and they locate suitable students to be hired by the firm.

The above findings suggest a certain profile of a scientific advisor in demand by industrial firms. Given the time needed to build up scientific expertise and reputation about the expertise, one would expect that scientists at an advanced career stage are most likely to appear on the firms' radar screens. In addition to the age profile, the status profile would most likely be scientists who command a great deal of prestige in his field. He will be more likely affiliated with prestigious institutions, and in possession of an extensive network in academia. Ding et al.'s (2007) study also suggests that SAB members will be predominantly male. The study found that the invitation-based process of SAB selection presents hurdles for women scientists. Because of the documented gender gap in scientific productivity and eminence, and women scientists' lack of comparable networks to their male colleagues, women scientists lag behind in the rate of joining SAB.

What types of scientists found a company? Scientists' transition to entrepreneurship can also be shaped by the opportunity structure around them, as they need to obtain resources from investors and other stakeholders to start a firm. What will be the common expectations for an academic entrepreneur? The most important consideration perhaps is that university-scientist-founded firms are supposed to exploit cutting edge knowledge generated from universities, often by the scientific founder himself. This suggests that successful entrepreneurs are likely to be those who have high productivity and possess cutting edge scientific breakthroughs. Given the documented academic productivity curve (Levin and Stephan, 1991), the typical academic entrepreneur is likely to be younger and at an early-to-mid-career stage. In contrast, a study by Shane and Khurana (2003) about inventions patented and commercialized from MIT between 1980 and 1996 showed that a scientist's past commercialization experience and his academic rank is positively related to the probability that a firm will be formed to exploit his invention. Shane and Stuart's (2002) study also suggested that scientists who are well-networked are more likely to have a successful venture. Such evidence depicts a profile of academic entrepreneurs that is similar to the profile of scientific advisors.

To summarize, empirically based demand-side explanations for SAB participation and entrepreneurial transition do not offer clear predictions of whether advisors and founders share similar profiles. While the perceived standard for an ideal SAB member is one who is more established, occupying high status in academe, well-networked, and most likely male, the standard for an ideal founder is mixed. On the one hand, younger scientists may be preferred by investors and external stakeholders because of their high level of productivity and close proximity to the most cutting edge scientific development. On the other hand, older scientists may be preferred because they are more experienced (both in terms of their academic rank and commercial involvement).

2.2. *Supply side explanations*

Below we review four different theories that inform scientists' motivation for engaging in commercial science. Though some of the theories were developed explicitly for explaining entrepreneurship, to some extent they also apply to the explanation of participation in SAB. While some theories suggest that academic entrepreneurs should have a different profile and be motivated by different factors from advisors, other theories and empirical evidence find commonalities between founders and advisors.

Social psychological research on entrepreneurship suggests that entrepreneurs display more unique traits than the general population. For example, Schere (1982) and Sexton and Bowman (1985) found that entrepreneurs have a higher tolerance for ambiguity. They also found that entrepreneurs generally have a higher need for autonomy, dominance and independence, and a lower need for support and conformity. Shane's (2004) study of university-scientist-turned entrepreneurs confirms some of these findings among the academic entrepreneur population. He found that those scientists who have managed to transition to entrepreneurship have a stronger desire for wealth, a desire to bring the technological breakthroughs into practice, and a desire for independence and autonomy. The psychological perspective on entrepreneurship thus will suggest that academic founders have different social psychological and behavioral patterns than the advisors.

A scientist's transition to entrepreneurship can also be understood from the perspective of role identity change (Ibarra, 1999). University scientists have acquired strong professional identity given the duration and intensity of their academic training and the prevailing norms in most academic institutions. The transition to commercial activity is not likely a smooth process because of the role contradictions (Owen-Smith and Powell, 2001a). Jain et al. (2009) analyzed the cognitive micro-processes of academic entrepreneurs' transition to entrepreneurship using a combination of both qualitative and quantitative data. They found that scientists engage in a sense-making process of recognizing and internalizing their new commercial role identity. During the process, scientists are motivated by a desire for wealth, yet they are concerned with how they will be perceived in their new role as an entrepreneur and the level of collegial and institutional support from the environment. Assuming that a university scientist's identification with his role of an academician strengthens with the duration and intensity of the socialization process in academia, scientists who have stayed in academia for a long duration will have a more difficult time making the transition to entrepreneurship. These scientists have internalized the ethos of the public science more deeply than their junior colleagues. Hence, they face greater impediments during the transitional process. This assumption suggests that scientists who have successfully made the transition to entrepreneurship are likely to be at an early stage of their career, and have internalized the academic value system to a lesser extent. Given the documented effect of social context on an individual's role identity change (Ebaugh, 1988; Ibarra, 1999), one would expect social structural factors such as association with peers, attitudes of collaborators and institutional support to affect the transition to founder and advisor roles differently. Academic entrepreneurship, the more radical transition compared to becoming an advisor, is probably more subject to the influence of social structural factors. According to this perspective, scientists who are more established in their careers are less likely to transition to entrepreneurship.

A third perspective on the academic-entrepreneur transition is Stephan and Levin's (1996) academic life-cycle model. The authors proposed a model that accounts for university scientists' development of human capital and allocation of time and attention throughout their career cycle. In this model, academic scientists invest the early part of their career in accumulating human capital both for creating an area of expertise and for achieving important milestones (e.g., attaining tenure). This suggests that most university scientists devote the bulk of their attention to basic science research early on in their career. Once these career goals have been reached, scientists then have more opportunities to embark on activities that help gain financial returns on their human capital, among them is the creation of ventures to commercialize their research. Some empirical evidence lends support to this model (Audretsch, 2000; Klofsten and Jones-Evans, 2000). From this perspective, we would expect that scientists at a later career stage and have more established reputation in their research areas to become academic entrepreneurs. Such a profile contradicts the prediction based on role identity theory and is more consistent with the profile of a scientific advisor.

A fourth perspective that offers insight into the academic-entrepreneur transition is from the research on status. It indicates that individuals occupying the middle range of a status hierarchy are less likely to engage in activities that do not conform to external expectations. This is because individuals in a high status position are likely to have adequate resources to withstand the risks associated with any deviant behavior. At the same time, individuals in a low status position have little to lose if they deviate from the prescribed norms, hence have more tolerance of the risks associated with novel practices (Phillips and Zuckerman, 2001). During the past few decades, venture creation was a controversial behavior for most academicians (Bok, 2003). Under such circumstances, one might expect that scientists who engage in entrepreneurial activities occupy either the high or the low end of the academic status hierarchy, both in terms of their academic reputation and prestige of their employers. This perspective, again, suggests a profile of academic entrepreneurs that is different from that of academic advisors along the dimensions of experience, human capital, prestige and affiliation.

To summarize, several theories predict that academic advisors and founders should differ in their profiles even though they share some commonalities. While advisors are more likely to come from the pool of senior, established scientists, there are reasons for expecting founders to emerge from both the senior, established scientists and the younger, less established ones. Academic entrepreneurs are expected to be more tolerant of risks and uncertainties than those who engage only in advising companies. While advisors' roles are to offer expertise, prestige and academic networks to the firms they serve, founders are eager to exploit opportunities to turn their technologies into practice. Indeed, to what extent do these two types of scientists differ from each other is an empirical question to be answered by the data.

3. Data, estimator and variables

3.1. Data and sample characteristics

We assembled a data archive with career histories of approximately 6100 life scientists to empirically examine the determinants, timing and rate of SAB versus founding activities. Because these commercial activities are rare in the population of university scientists, we employed a sampling procedure known as the "case cohort" design. This method was developed by biostatisticians and was often used to analyze events that are rare in general populations (Prentice, 1986; Prentice and Self, 1988).

To construct our dataset, we first collected information about *all* Ph.D. scientific advisors and founders at *every* biotechnology firm that has filed an IPO prospectus (form S1, SB2, or S-18) with the U.S. Securities and Exchange Commission.[3] A total of 533 U.S.-headquartered biotech firms have filed papers to go public between 1972 (when the first biotechnology firm went public) and January, 2002. From these companies, we identified 821 unique members of scientific advisory boards with Ph.D.s (which constitute our advising event set) and 174 founders with Ph.D.s (which constitute our founding event set).[4]

We then drew a stratified, random sample of 13,564 doctoral degree holders listed in the UMI Proquest Digital Dissertation

[3] For companies that filed papers to go public after 1995, IPO prospectuses are conveniently available in the SEC's EDGAR database (http://www.sec.gov/edgar.shtml). We acquired the remaining S-1 forms at the SEC's reading room in Washington, DC. Not every S-1 provided detailed information about founders and advisors; we were only able to obtain this information for approximately 70% of the companies.

[4] A disadvantage of this design is that we missed the university researchers who have advised and founded firms that have never initiated an IPO procedure. Systematic data about university scientists involved in founding and advising private biotech companies over the past three decades are very difficult to collect. Hence, the advising and founding activities we analyzed in this paper are limited to relatively more successful biotech companies.

Table 2
Top 15 scientific disciplines spawning biotechnology company founders and scientific advisors.

UMI subject code	UMI subject description	Match sample frequency	
487; 303	Biochemistry	1,161	(22.5%)
306	Biology, General	608	(11.8%)
410	Biology, Microbiology	503	(9.7%)
369	Biology, Genetics	301	(5.8%)
419	Health Sciences, Pharmacology	298	(5.8%)
490	Chemistry, Organic	288	(5.6%)
433	Biology, Animal Physiology	253	(4.9%)
786	Biophysics, General	234	(4.5%)
301	Bacteriology	192	(3.7%)
982	Health Sciences, Immunology	181	(3.5%)
307	Biology, Molecular	114	(2.2%)
485	Chemistry, General	98	(1.9%)
472	Biology, Zoology	74	(1.4%)
494	Chemistry, Physical	71	(1.4%)
571	Health Sciences, Pathology	71	(1.4%)

The table reports the 15 disciplines that produced the most biotechnology company founders and SAB members. The table also reports the number of scientists (and proportions of the overall total) in our random sample. The proportions are set to match the disciplinary composition of the SAB members.

database, matching the disciplinary composition and Ph.D. year distribution with our event set (e.g., 15% of biotechnology firms' advisors are biochemistry Ph.D.s earned in 1975, so the random sample also contains 15% biochemistry Ph.D.s earned in 1975).[5] Thus, the randomly drawn sub-cohort of scientists resembles the event set scientists in the distribution of subject fields and degree years. The majority of scientists in our sample are in the life sciences and Table 2 reports the top 15 subjects in the sample. The members of this sample are then prospectively followed from the time they earned a Ph.D. degree. We created publication histories for all scientists in our database and used the affiliations listed on papers to identify each scientist's employer and, assuming frequent enough publications, to track job changes. After deleting from the original sample those who were not employed by academic institutions, the final matched sample contains 5143 scientists in the randomly drawn sub-cohort, augmented by the 995 event cases (i.e., founders and SAB members).

3.2. The estimator

We modeled the hazard rate of scientists' advising or founding biotech startups with an adjusted Cox model that employs a pseudo-likelihood estimator (Barlow, 1994) to account for over-representation of the event observations. Each scientist is considered at risk of engaging in commercial science at the later of: (i) the time the individual is issued a Ph.D. degree, or (ii) the year 1961, when the first biotechnology company was established.[6] We used an adjusted Cox model because the standard model will produce biased estimates if applied to case-cohort data. This occurs because including all events in a population and a randomly drawn sub-cohort of (mostly) censored cases causes the proportion of events in the dataset to over-represent the proportion of events in the actual population. This in turn results in an incorrect computation of the event cases' contribution to the Cox score function. To address this problem, we use a pseudo-likelihood estimator proposed by biostatisticians (Barlow, 1994). A weight is assigned to each observation in the model to adjust for the observation's contribution to the score function in our estimation. With the application of different weights, the contribution of the event and matched sample observations are more in line with the (true) underlying population. More details of the adjusted Cox model for case-cohort data can be found in Stuart and Ding (2006).

3.3. Variables

We analyzed two commercial activities by university scientists: (i) founding one or more for-profit companies and (ii) joining companies' scientific advisory boards. We identified advising and founding information from the biotech firms' IPO prospectus documents. Most firms report their founders in their IPO prospectuses. Even though this is not legally required, research-intensive firms such as biotech often opt to report its founders to increase its legitimacy, particularly when university-affiliated scientists are involved in the founding process. For companies that do not report founder information in the prospectuses, we conducted a thorough web search to fill in the missing information. We used the date of firm incorporation as the year in which a scientist founded the firm. Hence, for an entrepreneurial scientist, the incorporation year of the first firm he or she founded is the year of his or her first-time transition to entrepreneurship.

In comparison, there is more information about a company's SAB members, if the company has an SAB. However, for SAB members, the difficulty is that most prospectuses do not provide information on when a scientist joined the SAB. We assumed that a SAB member joins at the time of firm founding. Thus when a scientist joins a SAB, we coded the individual's SAB event equal to when the firm he or she joined was founded.

We constructed several measures of individual level variables that may affect commercial activities. We coded gender based on scientists' first names. The literature on naming conventions suggests that gender is the primary characteristic choosers seek to convey in the selection of given names (Alford, 1988; Lieberson and Bell, 1992). When a first name is androgynous, we searched the web for the scientist's vitae, bio-sketch or pictures, and code gender accordingly. We were able to confidently identify gender for 98% of the scientists in our data, either based on first names or from web searches. We assumed that all remaining scientists with androgynous first names are male. Most of the gender-ambiguous names belong to foreign-born scientists of East Asian decent. Given the well-documented gender imbalance in science education in these countries, we think it is reasonable to assume that these individuals are male.

From the *Web of Science* we retrieved annual research publication count (publication flow) for each scientist. We counted all papers in which a scientist is listed as an author. We also computed each scientist's cumulative research publication count (publication stock) and updated the measure annually. To measure a scientist's standing in academia, we computed the total citation count a scientist has received. The Web of Science database supplies the total citation count for each published article at the time we downloaded the data (i.e., 2002). Thus, we know the total number of citations garnered by all articles in our database between the date of publication and calendar year 2002. However, to compute the annually updated citation counts we need to know the total number of citations each article has received up to any given year. We therefore must distribute each paper's total citations backward through time. We did so by assuming that the arrival of citations follows an exponential distribution with hazard rate (i.e., inverse mean) equal to 0.1. The bibliometric literature suggests that citations accumulate according to an exponential distribution (Redner, 1998). We

[5] The size of the random-draw sample results from the matched sampling process. For example, if there were two company founders and advisors who had a Ph.D. in microbiology in 1975, we randomly drew ten names from the pool of those who filed their dissertation with the UMI database in microbiology in 1975.

[6] Some scholars believe that biotech started in the 1970s, particularly with the founding of Genentech in 1976. We tested our models with this assumption and starting our risk set in 1976 in our models. Our results from this specification do not differ meaningfully from our original set.

Table 3
Descriptive statistics.

	Mean	Std. dev.	Min.	Max.	*N*
Publication flow	2.214	3.595	0	157	121,094
Publication stock	28.91	55.45	0	2262	121,094
Total citation count	16.01	21.42	0	647.4	121,094
Research patentability score	0.048	0.085	0	4.112	121,094
Number of industry coauthors	2.025	9.548	0	453	121,094
Patent flow	0.069	0.462	0	36	121,094
Patent stock	0.594	3.404	0	142	121,094
Number of coauthors	21.16	36.54	0	1134	121,094
Number of AE coauthors	0.222	0.873	0	32	121,094
Employer in top 20	0.274	0.446	0	1	121,094
Employer has TTO	0.469	0.499	0	1	121,094
Employer patent count	81.73	187.2	0	2189	121,094
Experience (career age)	13.58	9.920	0	45	121,094
Female	0.177	0.382	0	1	6138

assumed that this distribution is true of the typical paper in our database.

We included several measures for the commercial orientation of the scientists' research. First, using the informative keywords reflected in the titles of scientists' research papers; we computed a patentability score to proxy the extent of the commercial appeal of a scientist's research. The details of this measure are described in Azoulay et al. (2009). Second, since collaboration with company scientists often indicate projects to solve industrial problems, we counted the total number of company scientists with whom a scientist has coauthored by a given year, and again updated this variable every year. Third, we gathered the scientists' patents from NBER patent database and computed yearly updated patent application flow and stock. High research patentability score, high number of industrial collaborators, and more patent applications are associated with stronger commercial orientation of a scientist's research.

We also included two measure of a scientist's network structure. First, as a general measure of a scientist's academic network, we computed the total number of coauthors he has accumulated in his research publications. Having more coauthors indicates an extensive social network in academia. Second, we counted and annually updated the number of scientist-turned-entrepreneurs (i.e., university scientists in our sample who have already become founders) with whom a scientist has co-authored publications.

At the institutional level, we included three measures of a scientist's employing university. First, we enter a dichotomous measure of the ranking of a scientists' employer, which is a dummy variable indicating whether in a given year a scientists' employer was ranked in the top 20. Specifically, we collected the Gourman Report rankings for all institutions in our dataset. Gourman rankings are available at the field level and were issued for the first time in 1980. We assigned universities the 1980 ranking for all years prior to 1980 (and updated them every other year for the subsequent period). Second, we used the AUTM survey (AUTM, 2003) to create a technology transfer office (TTO) dummy variable, which is set to one in all years when a scientist's employing university has an active TTO. Finally, we counted the number of patent applications filed by a scientist's employer university and used the employer patent count as a more nuanced measure of how effective the university's TTO is in facilitating the transfer of academic science to the commercial sector.

To control for period-specific effects, we created a series of dummies of 3-calender-year windows. These dummies and the Ph.D. subject field dummies are included in all models.

4. Results

We conducted the following comparisons of scientists' advising and founding activities. First, we drew unconditional hazard graphs to reveal the timing of scientists' first-time engagement in advising or founding activity. Second, we ran Cox proportional hazard models to estimate the effects of individual, peer and institutional factors on the likelihood that a scientist engages in one of the activities. Table 3 reports descriptive statistics.

4.1. Unconditional hazard profiles

When do scientists start engaging in advising and founding activities? Fig. 1 summarizes unconditional hazard of the first time commercial engagement, broken out by activity type. In the founding graph of the top row, we present the probability that a scientist founds a company at different stages of his professional life-cycle. The graph for advising activity in the first row presents the probability that a scientist becomes a SAB member at different stages of his professional life-cycle. Kernel smoothing method is used in drawing the unconditional hazard graphs.

The graphs suggest that the two activities take place at different points in a scientist's career cycle. Audretsch and Stephan (1996) and Ding et al.'s qualitative evidence (2007) suggests that advising tends to happen at a later professional age, as the role of a scientific advisor requires that the scientist has established his human capital and reputation in the academic community and has accumulated an extensive academic network. Based on the top row in Fig. 1, we observe the following. Advising happens quite late during a scientist's career. In comparison, those who founded companies to commercialize their discoveries are relatively younger—the hazard of founding a company peaks at around 12 years after the Ph.D. is granted while the hazard of joining a SAB peaks at a much later point, about 31 years after earning the Ph.D. In addition, the propensity to advise companies climbs up gradually as a scientist gains more experience. For founding activity, however, the propensity increases relatively more precipitately during a scientist's career, but decreases gradually once it has peaked. This pattern lends some support to the prediction of role identity theory that young academic scientists have an easier time transitioning into an entrepreneurial role. The transition into the advisor role, however, is not as dramatic as the transition into entrepreneurship; hence any role identity benefit associated with earlier transition to SAB probably will be outweighed by human and social capital considerations.

The next three sub-graphs in Fig. 1 break down the comparison by cohort, gender and employer prestige. First, we ask whether the career cycle effect on SAB and founding activities is stable over time. Past research has suggested vintage effects on scientists' research productivity (Levin and Stephan, 1991, 1992) and commercial orientations (Ding et al., 2007). We examined the hazard curves separately for two different Ph.D. cohorts—those who obtained their Ph.D. in or before 1973 (shown as a solid line) and those with a Ph.D. between 1974 and 1984 (shown as a dashed

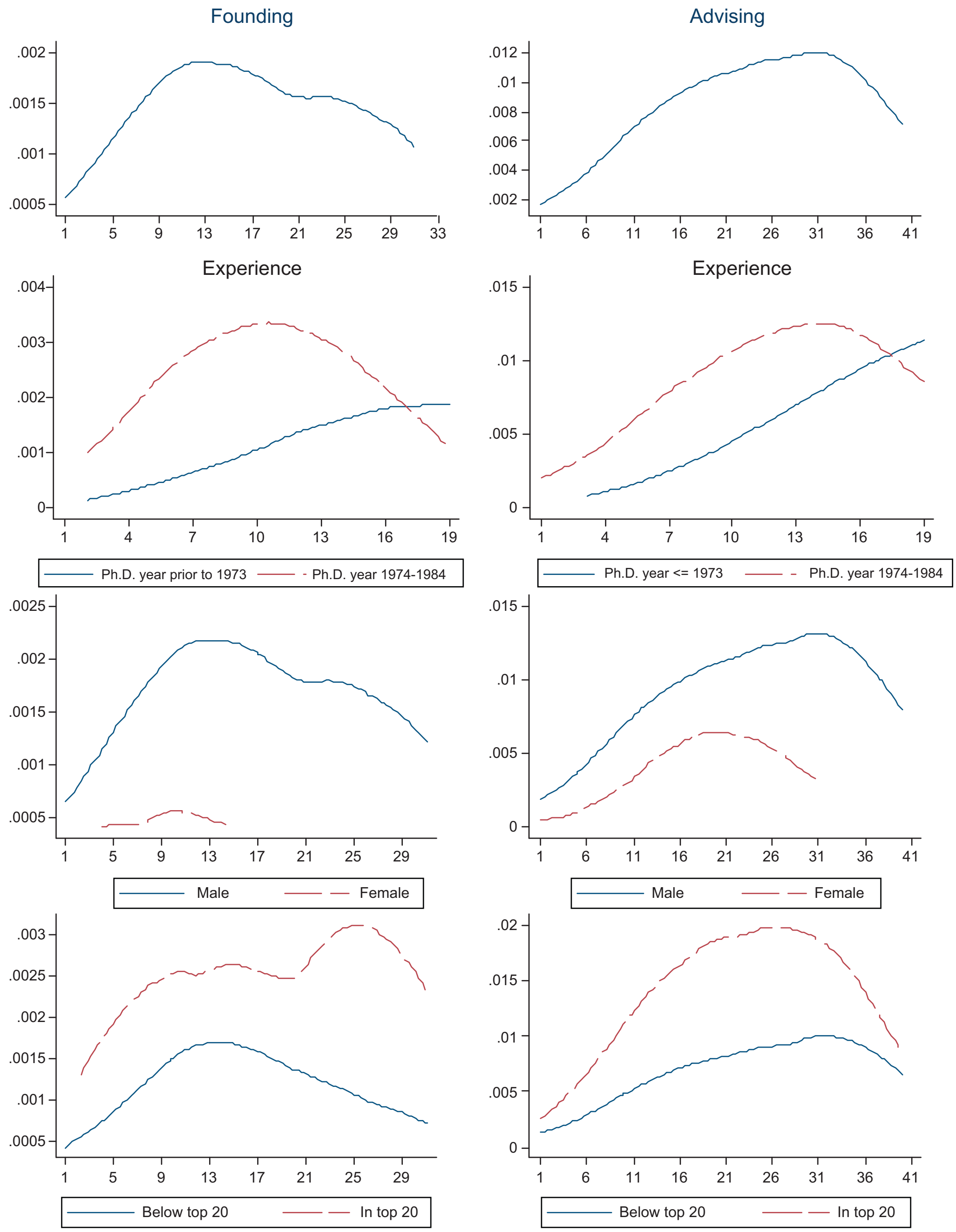

Fig. 1. Comparison of unconditional hazards.

line).[7] The hazard of both founding and advising companies for the younger cohort increases faster than the older cohort of scientists. Also, the younger cohorts are more active at an earlier professional age than the older cohorts. The hazard of founding activity of the younger cohort peaks around 10 years after the Ph.D. is granted, much earlier than the 16th year point of peak hazard for the older cohorts. A similar trend is found for the hazard of advising companies. It seems that the younger cohorts are more open to commercial opportunities overall. The other key point to note is that again we find that founding events tend to take place at an earlier career stage than advising. This suggests that the hazard patterns we observed in the main (first) sub-graph are not affected by the choice of cohort in the analysis.

The two graphs in the third row of Fig. 1 break down the hazard rate of the two events by gender. Consistent with prior research (Ding et al., 2007; Murray and Graham, 2007), women are much less likely to either found or advise companies. For both activities, the hazard rate of women scientists never passes those of men. The general pattern in the overall sample—that founding tends to happen earlier than advising, remains valid for both men and women scientists. However, it is worth noting that the hazard of women's advising activity peaks much earlier than men's (for women, the hazard of advising peaks around 20th year after the Ph.D. is granted, which predates the 33-year-or-so wait time for male scientists to

[7] The year 1973 is the cutoff because it is the median value of the Ph.D. year variable. In drawing these graphs, we excluded scientists with a Ph.D. degree after 1984 because the window of observation might not be long enough to draw the hazard graph properly.

reach peak hazard). This may have to do with the demographics of female advisors. Ding et al. (2007) found that female scientists who venture into the commercial arena (e.g., patenting research discoveries) are more likely to come from the younger cohort, who seems to be less hesitant at commercial engagement at an earlier career stage. Though the hazard of founding for women scientists seem to peak earlier than men in the left panel of this sub-graph, it may not be appropriate to give too much weight on this finding due to the small number of women founders in the data ($N = 10$).

The last row in Fig. 1 compares the hazard of founding and advising across scientists employed by universities with different levels of prestige. For a scientist working at a university ranked below the top 20 (shown as a solid line), the hazard of founding companies arrives at its peak around the 13th year after the Ph.D. is granted, much earlier than that of advising companies, which peaks close to the end of a scientist's career. It is also interesting to note that although overall hazards of founding and advising are lower for lower ranked university scientists, the shape of the hazard curves for these scientists is quite different from the curves of their counterparts employed in higher ranked universities. For founding events, scientists working at lower ranked universities are at their highest risk much earlier than those working in top ranked schools. In contrast, for advising events, scientists working at lower ranked universities are at their highest risk somewhat later than their counterparts in top schools. Two reasons might explain this observation. One, lower ranking university scientists have less vested interests. As the status dynamics perspective would predict, they stand to lose less in transitioning towards entrepreneurship, hence they might have more incentives to make the transition early on in their career. Two, advisors are invited based on their deep expertise, academic reputation and extensive social networks. Higher-ranked university scientists would have more opportunities to obtain credentials and be desirable as an advisor faster than scientists working for less prestigious employers.

We also observed a convergence of the founding and advising hazard peaks for the top 20 university scientists. There are likely three reasons causing the convergence. First, firms are founded to exploit scientists' inventions, so timing of the founding events is associated with the level of scientific productivity. In general, Stephan and Levin's research productivity cycle model predicts high productivity and cutting edge knowledge most likely occurs at the early-to-mid-career stage. At the higher-ranked universities, however, because of the more conducive research environment, scientists at a more advanced professional age may still be at the forefront of their fields. The academic selection and attrition process helps re-enforce this effect. This suggests top-20 universities may produce more eligible founders who are at a later career stage. Second, there are high opportunity costs for junior scientists at top universities to engage in entrepreneurship. Such engagement may distract one from research, lower productivity, and reduces one's chance of obtaining tenure at the top university. The opportunity costs could have deterred junior scientists in top universities from pursuing entrepreneurship early during their career. Third, we also observed an earlier peak time for the hazard of advising for top-20 university scientists (around 26 years after Ph.D.) than the time for scientists at lower ranked universities (around 31 years after Ph.D.). This is likely due to more opportunities for top-tier university scientists to be invited to a SAB after they have obtained tenure.

Our conclusions based on the unconditional hazard graphs of founding and advising are two-fold. First, the finding about the relationship between career stage and the two types of commercial activity partially confirms Stephan and Levin's life-cycle model of research scientists. The academic life-cycle model predicts that at a very early career stage, scientists focus on basic science research and develop their academic reputation by publishing research finding in scientific journals without any delay. Commercialization is not a key concern for this group of scientists. Note that even though founding hazard peaks much earlier than that of advising, its peak is 12 years after Ph.D., which has passed the time for tenure evaluation, a key milestone in the academic life-cycle. Only after scientists have accumulated enough knowledge and more job security in the tenured academic employment system, do they start to seek financial returns to science.

Second, several of the theories discussed in our Section 2 predict divergent profiles of scientist advisors and founders. It takes more than twice the amount of time for the advising hazard to reach its peak than it does for founding. This pattern holds even if we break down our analysis by gender, cohort and rank of employer. Moreover, the last sub-graph also hints to us that founders and advisors are likely to command different levels of human or social capital.

4.2. Antecedents of founding and advising companies

In this section, we assess the impact of factors that can potentially influence scientists' propensity to advise or found a biotech company. Table 4 reports Cox proportional hazard models of founding and advising companies, with weights included to adjust for the case cohort sampling design. Models 1a and 2a use the full sample as the risk pool. Models 1b and 2b replicate the results in 1a and 2a, respectively, with a restricted sample—in 1b, all advising scientists (i.e., those who advised one or more companies in their life time, regardless of the timing of their first advising activity) have been excluded and in 2b, all founding scientists (i.e., those who founded one or more companies in their life time, regardless of the timing of their first founding activity) have been excluded. These models are estimated to ensure that different specifications of the risk set do not lead to significant difference in the results. Because the set of results of models 1a and 2a do not differ substantially from those of models 1b and 2b, we focus on comparing the results of 1a and 2a in the following section.

Our first observation is that the directions of the effects of most of the included variables do not differ between founding and advising activities. Fig. 2 presents the standardized coefficients of models 1a and 2a in Table 4. Except for the effects of publication stock and number of coauthors, most factors either increase the probability of both founding and advising activities or decrease these probabilities.

However, when examining the strength of effects of these factors, we find that several of them show notable differences. Among the factors that significantly shape the propensity for founding or advising activity, the impact of gender is one of the strongest. Based on model 1a of Table 4, the hazard ratio (relative probability) of female scientist becoming a founder to male scientist becoming a founder is 0.22 ($=\exp[-1.533]$) to 1, i.e., female scientists are about one fifth as likely as male scientists to become an academic entrepreneur. The hazard ratio of female to male scientists becoming an advisor is 0.37 ($=\exp[-0.981]$) to 1 based on model 2a in Table 4. Though in both areas female scientists lag behind male scientists, the gender gap for advising, a less deviant and risky activity for university scientists is about one third narrower than the gender gap in founding.

Next, research productivity affects advising and founding differently. Contemporaneous research productivity (publication flow) has a weakly significant and positive effect on founding but no significant effect on advising. The magnitude of the effect of publication flow is also much higher in the founding model than in the advising model. This suggests that contemporaneous productivity is more important for founders than for advisors. In contrast, long-term research productivity (publication stock) has significant effects on advising and no effects on founding. This might be because scientists who found companies attempt to capture the sci-

Table 4
Cox proportional hazard model of advising and founding firms.

	(1a) Founding	(1b) Founding	(2a) Advising	(2b) Advising
Female	−1.553	−1.342	−0.981	−0.937
	(0.437)**	(0.382)**	(0.185)**	(0.185)**
Publication flow$_{t-1}$	0.061	0.062	0.009	0.006
	(0.036)†	(0.043)	(0.016)	(0.016)
Publication stock$_{t-2}$	−0.002	0.001	0.006	0.006
	(0.004)	(0.003)	(0.001)**	(0.001)**
Total citation count$_{t-1}$	0.012	0.013	0.013	0.013
	(0.001)**	(0.002)**	(0.002)**	(0.002)**
Research patentability score$_{t-1}$	2.820	3.573	3.927	3.939
	(0.247)**	(0.643)**	(0.264)**	(0.270)**
Number of industry coauthors$_{t-1}$	0.004	−0.021	−0.024	−0.021
	(0.017)	(0.036)	(0.017)	(0.016)
Patent flow$_{t-1}$	0.192	0.188	0.177	0.185
	(0.041)**	(0.041)**	(0.028)**	(0.028)**
Patent stock$_{t-2}$	0.014	0.016	0.009	0.006
	(0.012)	(0.012)	(0.008)	(0.008)
Number of coauthors$_{t-1}$	−0.0004	−0.001	0.003	0.003
	(0.003)	(0.003)	(0.001)*	(0.001)*
Number of AE coauthors$_{t-1}$	0.205	0.401	0.254	0.260
	(0.064)**	(0.085)**	(0.066)**	(0.067)**
Employer in top 20	0.448	0.346	0.716	0.691
	(0.208)*	(0.211)	(0.116)**	(0.118)**
Employer has TTO	0.520	0.508	0.311	0.284
	(0.212)*	(0.218)*	(0.110)**	(0.111)*
Employer patent count	0.001	0.002	0.001	0.001
	(0.0004)**	(0.0004)**	(0.0003)**	(0.0003)**
Risk pool excluding		Advising scientists		Founding scientists
Number of subjects	6138	5381	6138	5995
Number of events	174	174	821	786
Time at risk	119,885	97,772	111,953	109,444

Notes: (1) All models control for 3-year period dummies and Ph.D. field dummies. (2) Founding-event-specific Barlow weights are applied to models 1a and 1b to adjust for over-sampling of founders; advising-event-specific Barlow weights are applied to models 2a and 2b to adjust for over-sampling of advisors. (3) Robust standard errors in parentheses.
† Significant at 10%.
* Significant at 5%.
** Significant at 1%.

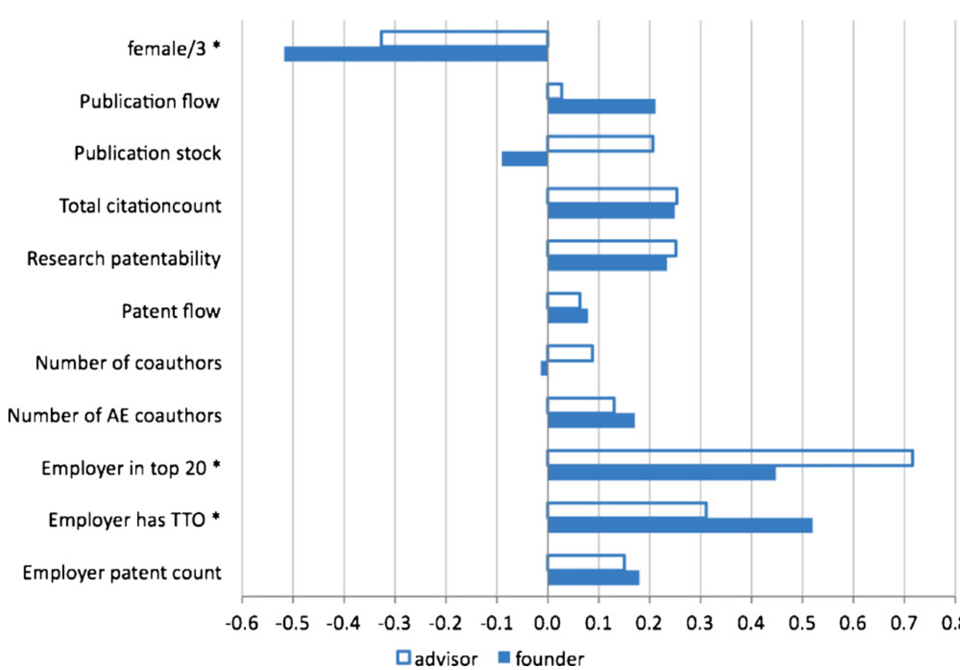

Fig. 2. Antecedents of advising and founding activities: comparison of standardized coefficients. The figure compares the standardized coefficients reported in Table 4. The value for each variable is obtained by multiplying the raw coefficient for the variable with its standard deviation. The exceptions are made for the three dummy variables: “female”, “employer in top 20”, and “employer has TTO”. The values for these variables presented in the graph are obtained by multiplying raw coefficients with value 1. The values for the variable “female” are also rescaled (divided by 3) for this presentation purpose.

entific opportunities in their recent surge of scientific discoveries. Hence, when a scientist has a good run of research and has made some discoveries with commercial potential, he is likely to capitalize on the scientific breakthrough and make the transition into entrepreneurship. In comparison, advisors are sought after for their deep expertise and academic reputation. Hence, when a scientist enjoys a high level of research publication stock, it makes him an attractive scientific advisor candidate. Total citation count seems to equally affect founding and advising activities.

How does scientists' research orientation affect founding and advising? Among the variables, the research patentability score increase both founding and advising propensities. Based on models 1a and 2a of Table 4, one standard deviation increase in research patentability score raises the probability of founding by 27% (This percentage is calculated by taking the inverse of the natural logarithm (i.e., the exponent) of the product of the coefficient in Table 4 and one standard deviation of the research patentability score found in Table 3 = exp[2.82 × 0.085]) and the probability of advising by 40% (=exp[3.927 × 0.085]). The other factor that significantly affects both founding and advising is the scientists' patent flow. This factor increases the propensity for founding by 9.3% (=exp[0.192 × 0.462]) and the propensity for advising by 8.5% (=exp[0.177 × 0.462]) with one standard deviation change in patent flow count, again based on models 1a and 2a. The number of industry coauthors and patent stock do not affect the two commercial activities significantly. Hence, overall scientists' research orientation has similar effects on founding and advising.

A scientist's social network is important in explaining academic scientists' commercial engagement (Shane and Cable, 2002; Stuart and Ding, 2006). In our models, two variables have been included. Among them, the effect of the number of academic coauthors (measuring the overall extensiveness of a scientist's academic network) on founding and advising differs substantially. While the variable has no effect on founding, a good academic network helps increase the propensity to become an advisor significantly (one standard deviation increase in the number of academic coauthors raises the hazard of advising by 11.6% (=exp[0.003 × 36.54]). However, the effect of the more instrumental type of network – ties to coauthors who have already transitioned to entrepreneurship – shows a different pattern for the two activities. One standard deviation increase in the variable "number of academic entrepreneurs (AE) coauthors" raises the hazard of founding by 19.6% (=exp[0.205 × 0.873]) while one standard deviation increase in this variable raises the hazard of advising by 24.8% (=exp[0.254 × 0.873]). One key role of advisors is to help a firm evaluate scientific projects and hire key employees by way of connecting the firm to the advisor's extensive academic network. Hence, maintaining an extensive academic network – both with academic and academic-turned entrepreneurs – is crucial for advisors. Founders, in contrast, benefit more from task-specific social network ties than from a network of coauthors who have not specifically become entrepreneurs. Knowing other university-scientist-turned entrepreneurs provides access to information on how to navigate through the patent process, negotiate with the TTO office, negotiate contracts with potential business partners, or how to manage a new venture. Thus, having entrepreneurial coauthors may reduce the hurdles in the process of the entrepreneurial transition and significantly increases the propensity for founding a firm.

Finally, the institutional environment may affect how scientists perceive commercial activities (Krimsky, 2003; Kenney and Goe, 2004). In our models, all institutional variables appear to affect the propensity for founding and advising. The effect of employer patent count is the same on founding and advising. However, employer ranking and institutional support for commercial activity show different impacts on founding and advising. Being employed by the top 20 universities helps increase the propensity for founding by 57% (=exp[0.448]) and advising by 105% (=exp[0.716]). The effect of a prestigious employer on advising is about twice that on founding. Consistent with previous research (Colyvas, 2007), being employed by universities with a technology office raises the probability of founding by 68% and the probability of advising by 36%. Thus founding activity seems to be influenced by university institutional support while the advising activity seems to be influenced by university prestige.

To summarize, we find that antecedents of scientists' commercial activities differ by the activity type. First, female scientists are less likely than male scientist to become either founders or advisors, but the negative effect of gender is stronger for founding than for advising. Second, research productivity affects the two activities differently. While the surge in contemporaneous research productivity is associated with a higher probability of founding firms, high level of long-term research productivity is associated with a higher probability of advising firms. Third, founding and advising are also affected by a scientist's social network. Having network ties with other scientists who have already become entrepreneurs increases the propensity for founding more than advising, but it is the general academic network that helps scientific advisors most. Lastly, institutional support at a scientist's employing university (e.g., having a technology transfer office) raises the propensity for founding a firm about twice as much as that of advising a firm while the university employer's prestige increases a scientist's advising risk twice as much as it does to the founding risk.

4.3. Are advisors more likely to found companies?

In this section, we explore whether advisors are more likely to become founders, or whether scientists focus on one activity and ignore the other. Many of the theories discussed in Section 2 predict a divergence in the profiles of the two types of scientists. If this is true, we should expect engagement in one activity does not trigger the other. Among all scientists in the sample who have founded or advised companies, 71 (7%) of them have engaged in both founding and advising companies. Among these cases, it is possible that being an SAB member triggers a scientist's interest in going further down the commercial path and becoming an entrepreneur. There is also the possibility that in an advisory role, a scientist could learn the operations of a new company and such knowledge facilitates his transition to entrepreneurship.

Table 5 reports results from the adjusted Cox model of hazard of founding a firm. The first model in this table uses the full sample and the same set of variables as in Table 4. The new variable included in this model is a "SAB dummy", which indicates whether a scientist has been a scientific advisor at any point during his career. The result of model 1 in this table suggests that those scientists who have or will become advisors are less likely to become company founders. Being an advisor lowers the probability of founding a company by half.

Model 2 uses a different indicator of a scientist's advising activity. We included a "SAB regime dummy" which is coded 1 in years after a scientist has advised a company. This is to test whether the actual advising experience increases the likelihood of founding a firm. Because the randomly selected university scientists can dilute the risk pool, we used a restricted sample of all scientists who have experienced either a founding or advising activity in this model. The result in model 2 suggests that once a scientist has advised a company and entered the advisory regime, the probability that he becomes a founder is reduced by about half when compared to other commercially oriented scientists.

In both models, being on an SAB or the experience of being on an SAB appears to have a negative effect on a scientist's propensity to found a company. The last two models conduct robustness check with a restricted sample of scientists who graduated after 1973.

Table 5
Cox proportional hazard model of founding firms.

	(1)	(2)	(3)	(4)
Female	−1.430	−1.342	−1.162	−1.268
	(0.391)**	(0.644)**	(0.456)*	(0.705)†
Publication flow$_{t-1}$	0.047	0.034	0.068	−0.028
	(0.032)	(0.039)	(0.047)	(0.066)
Publication stock$_{t-2}$	−0.001	−0.007	−0.001	−0.001
	(0.003)	(0.004)†	(0.006)	(0.013)
Total citation count$_{t-1}$	0.011	0.001	0.011	−0.012
	(0.002)**	(0.002)	(0.003)**	(0.009)
Research patentability score$_{t-1}$	2.148	0.417	2.246	0.882
	(0.239)**	(0.499)	(0.317)**	(0.382)*
Number of industry coauthors$_{t-1}$	0.007	0.006	0.018	0.020
	(0.006)	(0.004)	(0.017)	(0.009)*
Patent flow$_{t-1}$	0.195	0.187	0.300	0.222
	(0.045)**	(0.065)**	(0.092)**	(0.112)*
Patent stock$_{t-2}$	0.003	0.011	0.001	−0.028
	(0.016)	(0.028)	(0.033)	(0.051)
Number of coauthors$_{t-1}$	0.0005	−0.001	0.0004	−0.008
	(0.002)	(0.003)	(0.003)	(0.006)
Number of AE coauthors$_{t-1}$	0.088	0.003	0.212	0.207
	(0.058)	(0.085)	(0.113)†	(0.146)
Employer in top 20	0.402	−0.286	0.262	−0.350
	(0.198)*	(0.271)	(0.291)	(0.417)
Employer has TTO	0.571	0.153	0.415	−0.113
	(0.203)**	(0.244)	(0.299)	(0.386)
Employer patent count	0.001	0.001	0.001	0.0006
	(0.0004)**	(0.0004)†	(0.0005)*	(0.0006)
SAB dummy	−0.687		−2.116	
	(0.309)*		(0.709) **	
SAB regime dummy		−0.729		−1.749
		(0.298)*		(0.579)**
Risk pool	All	Founders and advisors	All	Founders and advisors
Ph.D. cohorts	All	All	>1973	>1973
Number of subjects	6138	936	3296	396
Number of founding events	174	174	87	87
Time at risk	119,889	24,728	47,858	7211

Notes: (1) All models control for 3-year period dummies and Ph.D. field dummies. (2) Founding-event-specific Barlow weights are applied to all models. (3) Robust standard errors in parentheses.
† Significant at 10%.
* Significant at 5%.
** Significant at 1%.

This test is performed because scientists of earlier cohorts might not have the opportunity to engage in advising activity since there were few biotech firms in existence before 1970. The SAB coefficients turn out to be both significant and negative, suggesting that the pre-1973 cohort of scientists and the stage of the biotech industry did not influence our results. Together, the results in Table 5 suggest that founding and advising are two separate paths and those scientists who are likely to advise companies are no more likely to found companies than the group of scientists who have never been an advisor.

5. Conclusion

We investigated the question of whether university scientists who have become company scientific advisors differ in profile from those who have become company founders. We constructed a case cohort sample that consists of (i) all Ph.D.-trained university scientists who have been reported in biotech firms' IPO documents as either founders or scientific advisory board members, and (ii) a stratified random sample of scientists who are university faculty members, from corresponding Ph.D. years and fields. We followed the career development, research productivity and commercial activity for a combined sample of approximately 6100 scientists. We analyzed the timing and determinants of advising and founding activities of these scientists.

Our results showed differences in the effects of scientists' career cycle on founding and advising activities along with other determinants of founding and advising. First, when examining the timing of founding and advising activities during scientists' career cycle in unconditional hazard graphs, we found that the probability of founding rises relatively faster than that of advising and peaks much earlier in one's career cycle. This is consistent with prior qualitative evidence regarding the opportunity structure for scientists to join a SAB. The finding is also consistent with several of the theoretical predictions discussed in our Section 2. For example, cognitive theories of entrepreneurship, role identity theory and status dynamics theories all predict differences in the profile of founders and advisors. Indeed, we observed different life-cycle effects for founders and for advisors in our analysis.

Our regression analysis suggests that human capital, social capital and institutional characteristics affect founding and advising differently. The gender gap is more significant for founding than for advising. Contemporaneous research productivity boosts founding while long-term research productivity boosts advising. Different types of social networks and institutional support also contribute differently to advising and founding activities. Lastly, regressions that assess the effect of scientists' advising experience on founding show that being an advisor negatively influences the likelihood of becoming a founder. Together, these results lend more support to the view that founding and advising follows divergent paths for commercially oriented scientist, rather than the view that one is a stepping-stone for another.

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