

Exploration-Exploitation Motivations: An Investigation of Biotechnology Firms' Participation in Academic Consulting

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We employ the exploration-exploitation framework to examine how firm-level motivations influence a biotechnology firm's participation in consulting agreements with university scientists. This study presents hypotheses that explore whether biotechnology firms use consulting agreements as vehicles to explore new knowledge to develop their absorptive capacity and initiate a relationship with a scientist's university or to exploit their entrepreneurial orientation or formal technology transfer experience. Assessing survey data collected from biotechnology firms, our analysis revealed significant and positive associations for exploration motives; however, the findings were mixed for exploitation motives. The discussion offers theoretical and managerial implications and future research areas.

Organizational research on academic consulting has primarily focused on university faculties' motivation for working with industry participants (D'Este and Perkmann, 2011), creating unique classifications of consulting agreements (Perkmann and Walsh, 2008), or establishing links between consulting agreements and license development (Agrawal, 2006; Shane, 2004). This emerging research stream highlights university scientists, whose research underlies university entrepreneurial activities involving patenting, technology transfer, and new firm formation. Although these studies have expanded our knowledge of scientist-industry relationships, a review of the literature reveals two potential areas of improvement. First, Link et al., (2007) lamented the under-development of academic consulting research when compared to the vast literature involving licensing, a formal mode of technology transfer. Second, Bercovitz and Feldmann (2006) noted that scientists' under-reporting of their industry relations has led to a paucity of research examining firm-level motivations for participating in academic consulting.

The current study bridges these gaps by investigating how firm-level motivations influence a firm's engagement of university scientists in a consulting capacity. Academic consulting occurs when external organizations pay university scientists a fee for providing advice, resolving problems, and generating or testing new ideas (Perkmann and Walsh, 2008). Our study addresses the gap proposed by Link et al., (2007) by reconnecting technology and knowledge to the scientists who create the inventions. Scientists, along with their inventions, and knowledge represent three interconnected parts of a system. Research (Cohen et al., 2002; Agrawal, 2006) supports the notion that firms will seek to reestablish the connection between scientists and their inventions via consulting relationships when universities, as sellers, license technology without the support of the inventor.

Reestablishing the scientist as a critical part of the system is important to the transfer diffusion of knowledge from academia to industry. The scientist-inventors' knowledge is often difficult to articulate because it contains a high level of ambiguity - the pieces of the system work together, but it is difficult for those involved to articulate a reason (Simonin, 1999). Zucker and Darby noted, "It is misleading to think of scientific breakthroughs as disembodied information which, once discovered, is transmitted by a contagion-like process in which the identities of the people involved are largely irrelevant" (1996: 12709). Our study draws attention to the critical role that scientists play in the transfer process.

We also seek to fuse the gap proposed by Bercovitz and Feldmann (2006) by adopting a firm-based perspective to investigate consulting agreements. Many biotechnology firms emerged to commercialize scientists' inventions (Zucker and Darby, 1996). Although a firm's history influences the options available to that firm (Penrose, 1959), managers can and do make strategic choices that influence how the firm will find a fit with its environment to achieve its goals and objectives (Child, 1972). Finding a fit between resource and need is important to most firms; however, it can be especially significant to biotechnology firms. These firms have both limited resources and numerous investment needs, and the allocation of their limited resources is a critical managerial decision (Deeds, 2001).

March's (1991) exploration-exploitation framework describes how firms adapt to or attempt to find a fit with the environment by making strategic choices to explore or exploit opportunities. Academic consulting infuses biotechnology firms with a wide array of knowledge flows that can be used to explore new or exploit existing opportunities. Firms use consulting relationships to develop licensed inventions (Shane, 2004; Agrawal, 2006), solve problems involving existing scientific knowledge (Cohen et al., 2002), or access graduate students as potential new hires (Perkmann and Walsh, 2007). Since knowledge acquired via consulting agreements can have multiple applications, managers must resolve the tension between exploring new knowledge and exploiting existing knowledge to judiciously use the firm's resources.

Using March's (1991) framework, the current study presents exploration-exploitation hypotheses to delve into a biotechnology firm's motivation for securing university faculty as consultants. Our first set of hypotheses describes how biotechnology firms participate in consulting agreements to support their absorptive capacity and development relational capital. As small and resource-constrained firms, many biotechnology firms lack the routines to develop an absorptive capacity and instead rely on university scientists to identify and transform external knowledge. From a relational perspective, social networks are important because university transfer professionals can acquire information about a potential licensing partner. When a biotechnology firm initiates a relationship with university scientists, it establishes legitimacy by demonstrating commitment and trustworthiness - critical qualities in the development of a formal relationship (Ring and van de Ven, 1994) with the scientist's home institution.

Our second set of hypotheses examines academic consulting as an exploration vehicle. This study explores how firms exploit their entrepreneurial orientation (hereafter EO) and formal university technology-transfer experience by participating in consulting agreements. Knowledge is a key component of entrepreneurial activities (Schumpeter, 1934; Kirzner, 1979). Entrepreneurial firms exploit their innovative capabilities by using scientists' knowledge as inputs into the innovation process or by acquiring inventions directly from scientists. (Markman et al., 2005). In fact, knowledge is also important to firms that possess significant experience licensing university inventions or sponsoring contract research. These firms possess insight into the challenges involved in working with uncertain and complex university inventions (Rothaermel and Deeds, 2004) and use consulting agreements to leverage inventors' knowledge of the technical system (Jensen and Thursby, 2001; Agrawal, 2006).

The purpose of our research is to expand our understanding of a biotechnology firm's participation in consulting agreements. A firm's strategic choice to establish an inter-organizational relationship may emerge from managers' motivation to leverage existing or explore new capabilities (Rothaermel and Deeds, 2004). University scientists possess a diverse stock of knowledge as well as flows from different scientific networks that can support biotechnology firms' adaptation to a rapidly changing environment.

The structure of the paper proceeds as follows. The next section provides a deeper examination of consulting agreements and March's (1991) exploration-exploitation framework. This summary provides a platform that will be used in the third section to present the hypotheses. The fourth section puts forward the research methodology and the hypotheses testing results. In the final section, we summarize the relevance of the findings, draw attention to future research areas, and identify study limitations.

LITERATURE REVIEW

Consulting Agreements

The consulting agreement is one in which a faculty member accepts an engagement, on a private basis, with a company needing expert advice (Tornatzky et al., 1999: 20). University scientists draw on various sources of knowledge when offering expert advice. Researchers possess tacit technical knowledge or "know-how" that relates to a specific scientific area (Kachra and White, 2008) and accumulate latent knowledge that provides valuable intuition about the inner workings of a technical system (Agrawal, 2006). In addition, many are members of scientific communities that share and build on existing science

(Gittleman and Kogut, 2003). In these communities, academic scientists' understanding of basic scientific principles is edified by exchanging ideas and research with other members.

Consulting agreements allow university scientists to share their knowledge with biotechnology firms in several ways. First, scientists solve problems using their existing expertise. Cohen et al., (2002) survey of 1,478 research and development (R&D) managers revealed that consulting agreements significantly contributed to the initiation of new and completion of existing projects. Second, scientist-inventors work with licensing firms to help develop their inventions (Jensen and Thursby, 2001). Most licensees acquire inventions at the embryonic stage of development. Agrawal (2006) found that the odds of successful license commercialization improve by 23% when a licensee increases its engagement of the scientist-inventor by 100 hours.

Academics also participate in consulting relationships to understand industry challenges or gain access to research materials (Perkmann and Walsh, 2008: 1886). University scientists can use industry knowledge to inform their research and leverage the materials when training graduate students. As the university scientist gains insight into a firm's R&D activities, there is an increasing chance for the firm to outsource research into academic labs staffed by graduate or post-doc students (Stephan and Everhart, 1998), who then become attractive employment candidates because they are familiar with the firm's research. In summary, consulting agreements offer firms an opportunity to access a university scientist's knowledge capital. We propose firms are motivated to access this knowledge to develop or leverage their existing skills.

Exploration-Exploitation Framework

Exploration and exploitation are learning activities that enable a firm to acquire and leverage resources in order to survive (March, 1991). Exploration activities involve the search for new knowledge or technologies and the creation of products with uncertain demand (Greve, 2007). When engaging in exploration activities, firms acquire new knowledge and develop new capabilities that can be leveraged in the future. Since biotechnology is a knowledge-intensive industry, firms need scientists, suppliers, capital, and other resources to develop innovative capabilities. By working closely with a university scientist, a biotechnology firm has an opportunity to explore new scientific areas (George et al., 2002), develop new capabilities, and build new knowledge stocks that serve as a source of innovative inputs (Ahuja and Katila, 2001). While exploration activities have a future orientation, they are oriented toward gaining a current advantage.

Exploitation activities allow an organization to use routines and knowledge and involve less managerial attention and resources (Hoang and Rothaermel, 2010). In exploitation activities, a biotechnology firm seeks to leverage existing research by licensing it to other firms in order to earn cash flows that are critical to their survival and competitiveness. Bishop et al., (2011) examined how firms benefit from collaborating with universities. The survey found that 30 percent of respondents indicated that university links, such as consulting agreements, contribute to activities such as successful market introduction of new products and R&D project completion time.

Exploration and exploitation activities are critical to biotechnology firms. Since exploration and exploitation activities involve different routines and expertise, managers must make strategic choices to determine how to allocate scarce organizational resources between them to ensure survival. The following hypotheses examine the exploration-exploitation trade-off by examining the internal conditions that may lead managers to use consulting agreements to explore or exploit new knowledge.

Hypotheses

George et al., (2001) conceptualized university-biotechnology linkages as generative because they involve joint R&D with universities and involve the frequent exchange of knowledge. The following hypothesis describes how biotechnology firms use consulting agreements to gain technical knowledge to enhance their absorptive capacity.

Absorptive Capacity

Absorptive capacity describes an organization's ability to recognize opportunities and exploit new knowledge (Cohen and Levinthal, 1990: 142). A critical component of absorptive capacity is that firms must possess prior related knowledge to be able to recognize and absorb external knowledge. Technological development is path dependent, in that specific solutions are developed into a firm's infrastructure over time (Håkansson and Waluszewski, 2002). Firms that possess a strong overlap between prior and new knowledge may constrain their ability to uncover new possibilities (Zahra and George, 2002). Investing in R&D and experimenting with new knowledge and technology supports the development of new skills and routines to redirect scientific discovery and technology development (Deeds, 2001).

The ability to acquire external knowledge resides with the knowledge and skills of a firm's employees (Minbeava et al., 2003). Firms use consulting agreements to establish relationships with university scientists to gain access to their graduate students as potential employees (Bishop et al., 2011). Graduate students possess knowledge of key scientific disciplines (Lim, 2009) and gain membership in academic communities by presenting their research at conferences and co-authoring papers with university scientists (Cockburn and Henderson, 1998; Perkmann et al., 2011). By participating in a consulting agreement, a firm gains access to graduate students whose membership in scientific academies affords them opportunities to identify valuable external knowledge. However, when seeking to assimilate external knowledge, firms turn to university scientists. Assimilation involves domain-specific knowledge, which provides solutions to specific technical problems (Lim, 2009). University scientists possess a predisposition for research and publication and can use the skills needed for these activities to apply basic research in industrial settings (Gittleman and Kogut, 2003).

After acquiring and integrating external knowledge, a firm must transform and exploit it. For biotechnology firms, exploiting externally sourced knowledge involves reducing the technical uncertainty by developing a reproducible prototype (Rothaermel and Deeds, 2004). As consultants, university scientists perform development work (Mansfield, 1995) by assisting a firm's scientists in completing projects (Rothaermel and Deeds, 2004; Cohen et al., 2002). In summary, biotechnology firms use scientists' knowledge as a substitute for a lack of absorptive capacity. Therefore,

Hypothesis 1: Biotechnology firms with low levels of absorptive capacity will possess a high number of consulting agreements.

Exploration activities may extend beyond technical knowledge to encompass relational knowledge as well. Universities possess significant resources that can enhance a biotechnology firm's survival (Rothaermel and Thursby, 2005). To access a university's resources, a biotechnology firm must gain an introduction into the university's social network. Consulting agreements are an opportunity for firms to demonstrate their legitimacy as potential partners.

University-Specific Experience

Firms accumulate specific knowledge when they engage in repeated interactions with a specific partner. When collaborating with a university, firms develop routines that promote knowledge transfer and conflict resolution (Hoang and Rothaermel, 2005) and managers acquire insight on navigating the university's bureaucracy. Through repeated interactions, partners demonstrate their capabilities and their commitment to the relationship and show themselves as trustworthy, and trust emerges as partners rely on one another's capabilities and through their commitment to engage in agreed-upon activities (Ring and van de Ven, 1994). Once trust is established, a firm can rely on its social capital with a partner to acquire important resources (Ireland et al., 2002). The presence of social capital among partners improves the quality and diversity of knowledge that partners commit to the relationship (Yli-Renko et al., 2001).

When exchanging valuable R&D assets, a university is vulnerable to opportunism that emerges from a partner's misrepresentation of intent and ability (Das and Teng, 1998). To reduce their vulnerability,

universities conduct economic activity within a network of embedded actors (Perkmann and Walsh, 2007). A firm seeking to establish a foothold in a university's network may benefit from participating in a consulting relationship with a university scientist, many of whom are accessible at scientific conferences and other community events (Perkmann and Walsh, 2008). Firms do not need to navigate university rules to gain access to a scientist. A firm establishes its legitimacy to participate in the university's network by committing resources and demonstrating a commitment (Kale and Singh, 2009) to the consulting relationship. Although universities are not directly involved in consulting agreements, personal connections with a scientist can lead a firm to alliance opportunities by enhancing status and legitimacy (Larson, 1992).

Hypothesis 2: There will be an inverse relationship between a firm's previous experience with a university and consulting agreements, such that firms without previous experience will participate in a high number of consulting agreements.

Exploration activities involve creating knowledge while exploitation activities involve leveraging knowledge or completing projects that already exist. Although knowledge and capabilities creation is an important part of drug development, securing returns from previous exploration investments support a firm's ongoing operations. Consulting opportunities offer biotechnology firms the ability to acquire knowledge to exploit their entrepreneurial disposition and formal technology transfer experience.

Entrepreneurial Orientation

Entrepreneurial orientation (EO) indicates how the entrepreneurial choices made by the firm reflect its entrepreneurial posture, which is demonstrated by the extent to which top managers favor risk taking, innovation by supporting creativity and new product development, and an aggressive approach to becoming a first mover by identifying and exploiting opportunities. EO resides in a firm's culture and routines (Lumpkin and Dess, 1996), and encourages learning (Wang, 2008) and innovation (Pérez-Luño et al., 2010). There is consensus that EO contains three core dimensions, each of which may motivate managers to participate in consulting agreements. First, innovation involves a firm's experimentation and propensity to engage in new idea generation (Lumpkin and Dess, 1996). From a Schumpeterian (1934) perspective, innovation emerges from a recombination of previously existing inputs. Working closely with university faculty, biotechnology firms can acquire valuable scientific and technical knowledge inputs (George et al., 2002) that can be recombined with their existing knowledge to create new products.

Second, proactiveness describes a firm's willingness to leverage opportunities to obtain first-mover advantages (Lumpkin and Dess, 1996). University scientists establish bridging ties to other scholarly networks while conducting and disseminating their research. Proactive management teams recognize that developing close ties with university scientists enhances their firms' capacity to generate new ideas (Tiwana, 2008) by accessing other scientific communities.

Third, risk taking involves managers' willingness to commit resources under uncertain conditions (Miller, 1983). In close working arrangements with university scientists, managers can discover information about their competitors' research projects. Firms can use this competitive information to determine whether to support or terminate a project. Thus,

Hypothesis 3: An entrepreneurial orientation will be positively associated with a biotechnology firm's number of consulting arrangements with university scientists.

Formal University Technology Transfer Experience

Prior empirical research has found that once firms begin to enter into alliances, they develop a tacit proficiency in managing alliances more effectively (Kale et al., 2000). As a firm accumulates experience participating in certain organizational forms, it develops superior capabilities at managing them (Kale et al., 2002: 747). An alliance capability emerges as a firm solves problems that arise during specific inter-organizational relationships. These solutions are articulated, codified, and stored in a firm's routines,

people, and processes and can be retrieved to ensure successful outcomes (Kale and Singh, 2007). In this study, we draw attention to a firm's experience participating in formal university technology transfer that involves exchange of a legal instrument, such as licensing and sponsored contract research (Link et al., 2007).

Formal technology transfer is often associated with acquisitive learning - a form of learning associated with the acquisition and integration of knowledge from external sources (Dess et al., 2003). The intent is for firms to enhance their innovative capabilities by creating new knowledge combinations (Li et al., 2010). However, developing the new technologies is problematic because an acquiring firm's scientists often lack expertise working with cutting-edge science (Rothaermel and Deeds, 2004). Firms experienced in technology transfer develop routines that often involve hiring the scientist-inventor in a consulting agreement. Working closely with the scientist-inventor, a biotechnology firm's scientists develop an understanding of the novel science used to develop the technology and learn how to integrate this technology into the firm's R&D practices (Li et al., 2010). Given these insights,

Hypothesis 4: As a firm's cumulative formal university technology transfer experience increases, so will its participation in the number of consulting arrangements.

METHODOLOGY

Sample

The biotechnology industry was selected to test the hypotheses relating to a firm's use of academic consultants. By definition, biotech is knowledge intensive, meaning that the complementary processes of discovery and innovation necessitate the union of assets that characterize different types of organizations - both public and private (Feldman, 2003). Given the complexity and uncertainty of new drug development, these firms use academic consultants to gain access to new knowledge as well as to exploit existing capabilities.

We created a methodology to identify a representative sample of U.S. biotechnology firms engaged in the development of human health therapies. Firms focused on developing human health therapies encounter specific resource and regulatory challenges when commercializing new products (Rothaermel and Deeds, 2006). The firms identified for this study have North American Industry Classification Scheme (NAICS) codes that emphasize human health R&D. These include NAICS 325411: Medicinal and botanical manufacturing; and NAICS 541710: Physical, engineering and biological research. A sample of 1,000 potential respondents was obtained from reviewing member directories of the Biotechnology Industry Organization state associations and Hoover's business database. Next, Reference USA, a library business database, was used to verify the key information such as address, and verify key information such as NAICS codes. Our final sample included 838 firms: 300 public and 538 private.

Survey Administration

A questionnaire was used to collect data for the variables examined in this study. Secondary data were also obtained from Metropolitan Statistical Analysis from the U.S. Census Bureau to determine cluster, a control variable. In small- and medium-sized firm (SME) research, mail surveys are the most commonly used because archival data are unreliable on small and private firms (Bartholomew and Smith, 2006). Since top executives are typically the only knowledgeable source regarding their firm's transfer activities (Norbun, 1989), we mailed the questionnaire to executives familiar with a firm's technology strategy; their titles included CEO, VP of R&D, and chief scientific officer.

The questionnaire was administered using Dillman's (1978) method of mail survey response and design. This method proposes that researchers send three follow-up mailings after the initial mailing: a post card, a replacement survey, and another replacement survey sent by certified mail. Three industry professionals, each possessing at least 10 years of industry experience, reviewed the questionnaire to establish face validity. In addition, the questionnaire was pretested, via email, with pharmaceutical

professionals to improve the administration of the survey. No material issues emerged. During the data collection phase, three mailings were conducted six weeks apart to allow for updating the mailing list. The cumulative number of 960 questionnaires produced 204 responses - a response rate of 21%.

This response rate is typical of those produced from past survey studies; for example, Wang (2008) reported a rate of 15.4% and Bierly et al., (2009) achieved a response rate of 14.4%. Studies of small firms often yield low survey response rates because top executives must personally respond to the survey because these firms have few slack resources who are knowledgeable enough to assume the task (Bartholomew and Smith 2006). Supporting this premise, Baruch's (2008) meta-analysis of management studies' response rates revealed that studies conducted at the organizational level, which solicited top executives as respondents achieved an average response rate that was 17 points lower than the average response rate produced by studies that used individuals as respondents: 52.7 (Individual) vs. 35.7 (Top Executives). Thus, we believe our response rate is acceptable for this SME and top executive-focused research.

Low response rates may be an indication of the existence of material differences between respondents and non-respondents. To assess non-response bias, an independent-sample t-test was used to compare the size and R&D spending of responding public firms to non-responding public firms and ANOVA were used to assess non-response biases across the three mailings. Our results revealed no significant differences between responding and non-responding firms or across mailings; therefore, we believe sampling bias should not materially influence our analysis.

MEASURES

Dependent Variables

Consulting agreements (CA) constitute an arrangement in which a faculty member accepts an engagement, on a private basis, with a company that needs expert advice (Tornatzky et al., 1999: 20). This measure is calculated by counting the number (n) of consulting agreements that a firm has with a university's faculty.

Independent variables

Absorptive capacity (AC) reflects a firm's ability to acquire, assimilate, transform, and leverage externally generated knowledge and is a by-product of the firm's R&D activities. Previous studies (Bierly et al., 2009) used two measures to assess absorptive capacity in order to capture the bi-dimensional nature of the construct. The potential component of absorptive capacity reflects a firm's ability to value knowledge, which is a by-product of a firm's R&D spending. The realized component describes whether a firm can leverage external knowledge. We use the following measures:

- R&D intensity (AC-Value) is computed by taking the ratio of R&D expenditure to the number of employees (Tsai, 2001). Traditionally, the measure is calculated by dividing the R&D investment by sales (Cohen and Levinthal, 1990); however, many biotechnology firms do not have any sales (Deeds and Hill, 1996). To capture the scale effects, we use the number of employees. Respondents listed their firm's R&D spending for 2006, the year the survey was completed.
- Patents (AC-Exploit) represent a firm's ability to apply or exploit knowledge. Patents represent a firm's ability to identify previous knowledge and transform it into a novel combination (Schumpeter, 1934). Respondents were asked to list their firm's number of patents and patent applications over a 5-year period. Since the patent approval process takes between 2 and 3 years, the 5-year window was used to capture patents during the time frame of this study.

Entrepreneurial orientation (EO) is defined as "the entrepreneurial choices made by the firm reflecting its entrepreneurial posture, which is demonstrated by the extent to which top managers are inclined to take business-related risks, to favor change and innovation in order to obtain a competitive advantage for their firm" (Covin and Slevin, 1989: 77). We used Covin and Slevin's 9-item scale to assess top

management's posture on new product development, aggressive posture, and willingness to commit resources to activities where the outcomes were uncertain. The questions used a 5-point Likert-type response scale ranging from 5 (strongly agree) to 1 (strongly disagree). Firms with a higher score are likely to be more entrepreneurial. The Cronbach's alpha (α) for the scale is .832. Table 1 contains the scaled items for this measure.

Table 1: EO Survey Scale

Variables	Survey Items
Entrepreneurial Orientation	<ol style="list-style-type: none"> 1. Top executives exhibit a strong emphasis on R&D 2. Top executives promote a diversified product pipeline 3. Top executives favor dramatic change to pipeline 4. Top executives favor high-risk projects 5. Top executives favor bold acts to achieve firm goals 6. Top executives adopt a wait-and-see attitude 7. Top executives initiate actions and competitors respond 8. Top executives favor being the first business to introduce products, administrative techniques, and technologies 9. Top executives favor a strong tendency to be ahead of others

Formal university technology transfer experience (Formal UTT) reflects a biotechnology firm's experience in participating in formal technology transfer as revealed in university-industry links that result in a legal instrumentality (Link et al., 2007: 6) such as a new invention or patent. In this study, licenses and sponsored research contracts reflect a firm's formal technology transfer experience (Stuart, Ozdemir, and Ding, 2007). Licenses involve selling a company the rights to use a university's inventions in return for upfront fees and royalty payments depending on the commercialization of the technology (Feldman et al., 2002: 107). Sponsored contract research occurs when an industry participant commissions a university scientist to explore specific, previously unresolved aspects of a problem (Perkmann and Walsh, 2007). This contract specifies ownership of resulting intellectual property, provisions for licensing of future patents, and divisions of royalties (Bercovitz and Feldmann, 2006). The measure for formal technology transfer mechanism is the sum of the number of licensing and sponsored contract research agreements the responding firm participated in over the last 5 years.

University-specific experience (USE) captures the degree to which prior involvement with a specific partner predicts current involvement (Belderbos et al., 2011). This variable assesses whether the biotechnology firm had a previous relationship with the scientist's university prior to the consulting agreement. Partner-specific alliance experience leads to the development of routines between partners that promote knowledge transfer (Hoang and Rothaermel, 2005). Previous experience with a partner facilitates the development of social capital and the acquisition of resources (Yli-Renko et al., 2001) and the potential partnership opportunities (Ahuja, 2000). Belderbos et al., (2011) assessed alliance persistence using an indicator variable that reflected the length of an alliance equal to or greater than 2 years. Some university-industry links may last only one week (Agrawal, 2006); therefore, we relaxed the time constraint to capture all of a firm's prior university interactions. Respondents were asked whether they had a previous relationship with their current university partner(s): 1 reflects a prior relationship and 0 indicates no prior relationship.

Control Variables

Cluster refers to the geographical location of the biotechnology firm. Location is critical when transferring new technology between partners (Bishop et al., 2011). To compute this variable, we compared each firm's zip code with the biotechnology clusters listed in Ernst & Young's (2005) annual biotechnology report. We acquired the zip codes for the clusters listed in Ernst & Young's report from the U.S. Census Bureau's Metropolitan Statistical Analysis for 2005. If a biotechnology firm was located in a biotechnology cluster the variable was coded as (1); otherwise, it was coded as (0).

Size is included as a control variable because university faculty may prefer to establish relationships with large firms that offer greater research and teaching benefits than do small firms (Shane and Stuart,

2002). Respondents were asked to indicate the number of individuals employed by their firms. Origin indicates whether a venture is sponsored by an entrepreneur-scientist (i.e., independent venture) or by a corporation (i.e., corporate venture). Origin influences a firm's technological strategy and its available resources (Zahra, 1996). This construct is a dummy variable that is coded 1 (independent) or 0 (corporate sponsored).

Results

Table 2 lists the correlation coefficients and the descriptive statistics for the measures and scale used in this study. The highest correlation reflects the proposed relationship in Hypothesis 2, formal technology transfer experience and consulting arrangements (0.48). This relationship suggests that as firms accumulate novel technologies via formal technology transfer, they require complementary knowledge from university scientists to exploit the technology.

Table 2: Descriptive Statistics and Correlations

Variables	Mean	Std. Dev	1	2	3	4	5	6	7	8	9
1. Size	58.72	72.77	1								
2. Origin [#]	N/A	N/A	.16*	1							
3. Cluster	N/A	N/A	-.03	-.03	1						
4. AC-Value	\$10.2M	\$19.1M	.38**	-.03	-.04	1					
5. AC-Exploit	12.51	48.70	.17**	-.12	.17*	.25**	1				
6. EO	3.35	1.47	.09	-.07	.07	.19*	.33**	1			
7. Formal UTT	6.73	11.33	-.12	-.23	.02	-.03*	-.03	-.03	1		
8. USE*	5.16	8.21	.10							1	
9. CA	4.14	6.16	-.18*	-.19*	.28**	-.16*	-.04	.10	.48**	.21**	1

Note. N = 198. **p < .01; *p < .05.

[#] Frequencies: Prior Experience: Yes "1" – 34.4%; No "0" – 52.0%; N/A 13.6% (No university links)

Origin: Yes "1" – 83.3%; No "0" 16.7%

In this study, the dependent variable is a count of the number of consulting agreements. The hypotheses were assessed using a negative binomial regression model with a maximum likelihood procedure, which treats the dependent variable as a count while estimating heterogeneity (Rothaermel and Deeds, 2004). Similar inter-organizational relationship studies (Pérez-Luño et al., 2010; Rothaermel and Deeds, 2004) have employed this procedure for hypotheses testing when the variable of interest is a count.

Table 3 contains the results of our hypotheses testing using the negative binomial regression model with a maximum likelihood procedure. Model 1 includes the control variables where cluster (B = .342, p < .001) and scientist (B = .440, p < .001) have significant influence on the dependent variable. Biotechnology clusters are anchored by universities (Feldman, 2003) that provide opportunities to access knowledge spillovers via consulting agreements. Model 2 supports our assertion made in Hypothesis 1 that describes an inverse relationship between a firm's absorptive capacity, R&D intensity (B = -.200, p < .001) and patents (B = -.005, p < .10), and a firm's participation in consulting agreements.

Table 3: Results of GLM Negative Binomial Regression Model Predicting Participation in Consulting Agreements

	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	1.219*** (0.117)	1.670*** (0.378)	1.114*** (0.124)	1.112*** (0.232)	1.136*** (0.115)
Size	0.026 (0.119)	-0.183 (0.248)	-0.187 ⁺ (0.124)	0.033 (0.119)	-0.169 ⁺ (0.121)
Cluster	0.342*** (0.078)	0.518*** (0.084)	0.415*** (0.082)	0.346*** (0.079)	0.337*** (0.078)
Origin	0.440*** (0.080)	0.613*** (0.086)	0.539*** (0.081)	0.439*** (0.080)	0.054 (0.089)
R&D Intensity (AC-Value)		-0.200*** (0.060)			
Patents (AC-Exploit)		-0.005 ⁺ (0.000)			
USE			-0.180* (0.077)		
EO				0.003 (0.006)	
Formal UTT					0.047*** (0.003)
Log Likelihood	-775.01	-621.28	-730.80	-775.86	-696.39
Chi-square (X ²)	44.14***	101.12***	62.97***	44.43***	221.38***
Change over base (ΔX ²)		66.98	18.83	0.29	177.24

Standard Errors in Parentheses. ***p < 0.001; **p < 0.01; *p < 0.05; ⁺p < 0.1

The analysis reveals support in Model 3 for Hypothesis 2, which proposes that firms use consulting agreements to establish links with a specific university partner ($B = -.180, p < .10$). However, contrary to our prior contention, Model 4 does not offer support for Hypothesis 3. Firms that possess an entrepreneurial orientation ($B = .003, p = n.s.$) do not have a high number of consulting agreements. The regression coefficients in Model 5 indicate a strong positive relationship between a firm's formal technology transfer experience and the number of times a firm hired university faculty as consultants; this finding supports Hypothesis 4.

Post-Hoc Analysis

Given the large standard deviation on the size control variable, we conducted additional regression analyses using three stratified samples. Table 4 lists the results. In the first stratified sample, we used the mean of size ($M = 59$) to segment our sample ($n = 198$) into subsamples—those firms that employed more than 60 employees and those firms that had fewer than 59 employees. Retesting the hypotheses only revealed a significant difference in the entrepreneurial orientation independent variable. For those firms that employed fewer than 59 employees, the results revealed a non-significant relationship between EO and a firm's participation in consulting agreements ($B = .005, p = n.s.$), which was similar to the finding in our initial analysis listed in Table 3, Model 4 ($B = .003, p = n.s.$).

However, in those firms that employed more than 59 employees, the results were positive ($B = .030, p < .05$). Biotechnology firms with 50-501 employees are more likely to accumulate funds from IPOs than do those firms with fewer than 50 employees (U.S. Department of Commerce, 2003). Issuing an IPO is a rigorous process where investors analyze the firm's management team and organizational capabilities (Laurent-Ottomane and Weimer, 2010). Since entrepreneurial activity is a resource-intensive endeavor, large entrepreneurial firms may possess the resources that are necessary to develop and leverage an EO.

Table 4: Stratified Samples of Age to Examine the EO-Consulting Agreements Relationship

Stratified Sample	Firm Size	<i>B</i>	Std. Error	Significance
Means	M < 59	.005	.008	.505
	M > 59	.030	.014	.021
Middle Distribution	Q2 (22-48)	.007	.012	.194
	Q3 (49-86)	.041	.018	.018
Tail-end of Distribution	Q1 (3-21)	.002	.008	.427
	Q4 (87-325)	-.006	.020	.531

*Quartile Percentage: Q1 (Size < 25%), Q2 (26-50%), Q3 (51-75%), Q4 (Size >76%)

We conducted a second stratified sample that segmented the firms into quartiles. This analysis focused on the second and third quartiles (Q2 & Q3) because the middle half of the distribution will be less affected by extreme observations (Nachimas and Nachmias, 1987). The findings revealed a non-significant result for those firms located in Q2 ($B = .007, p = n.s.$) and a positive and significant relationship for those firms located in Q3 ($B = .041, p < .05$). The existence of slack resources is a possible explanation for the difference between those firms located in Q2 and Q3.

Penrose (1995) argued that slack resources are critical to firm growth. Firms located in Q3 may possess a sufficient number of employees who can conduct operational activities, which provides managers and scientists with time to identify entrepreneurial opportunities by acquiring knowledge in one domain and applying it in another (Tushman and Scanlan, 1981). Research reveals that biotechnology firms gain access to resources to enhance their innovative capacity when their scientists participate in boundary spanning activities such as presenting conference or co-authoring papers (Cockburn and Henderson, 1998). Our final stratified sample tested those firms located in the two extremes: Q1 and Q4. The findings were non-significant for firms that fell within Q1 as well as Q4.

In summary, the findings support our exploration hypotheses but results were mixed for our exploitation hypotheses. The following discussion elaborates on these findings.

DISCUSSION

In this study, we sought to use March's (1991) exploration-exploitation framework to examine firm-level motivation for a firm's participation in consulting agreements. Development of routines and capabilities plays a critical role in the actualization of Cohen and Levinthal's (1990) absorptive capacity and March's (1991) exploration-exploitation framework. Many new and small firms may not possess the resources and managers may not have the experience to create exploration and exploitation routines (Geroski et al., 2010). The current study's findings confirm existing empirical research (George et al., 2001; Rothaermel and Deeds, 2004; Hoang and Rothaermel, 2005) that positions university-industry linkages at the explorative end of March's (1991) learning dichotomy.

Exploration Results

In hypothesis 1, we proposed that biotechnology firms with low absorptive capacity would have significant participation in consulting agreements. Absorptive capacity is based on the premise that an organization needs prior knowledge to assimilate and use new knowledge (Cohen and Levinthal, 1990: 130). Some scholars (Minbaeva et al., 2003; Liao et al., 2007) proposed that prior learning resides in the prior knowledge and expertise of a firm's employees. Given their resource constraints, biotechnology firms leverage university scientists' knowledge to substitute for their lack of absorptive capacity. By participating in consulting agreements, firms gain access to skilled and trained staff (Perkmann et al., 2011), acquire scientific knowledge to complement existing R&D activities, use scientists to conduct these activities (Etkowitz, 1998), and identify external knowledge through university and laboratory contacts (Slowinski et al., 2000: 31).

Hypothesis 2 also proposed an inverse relationship between a firm's previous links with a university and its willingness to participate in consulting agreements. We argued that biotechnology firms use consulting agreements to establish legitimacy and trust, and to demonstrate their commitment in order to gain access to other university resources. However, strategic management literature offers an alternate explanation for using consulting relationships as entrée into a university's network. University scientists are accessible ambassadors of the university's research expertise. Establishing a relationship with university scientists is a probing mechanism that firms use to determine whether engaging in more costly relationships such as sponsored research or licensing meets their strategic needs.

Exploitation Results

Contrary to our initial assertion, the findings did not support Hypothesis 3: a direct, positive relationship between EO and a firm's consulting agreements. Our post hoc analysis found a positive relationship between EO and participation in consulting agreements in those firms that employ more than 59 employees. Speculatively, larger firms may have the financial and human resources to allow employees to pursue entrepreneurial opportunities. Small firms may have the desire to use consulting agreements as a vehicle to leverage their EO; however, they may lack the resources to do so.

Interestingly, our post-hoc analysis revealed a negative relationship between large firms' with EO and their participation in consulting agreements. Although this relationship was non-significant, the change in signs of EO variable requires additional attention. Very large entrepreneurial firms may possess the internal resources needed to solve specific problems. We speculate that managers in large entrepreneurially oriented biotechnology firms may trust their scientists' abilities to solve problems thereby decreasing their need to participate in academic consulting. Although our data is limited to sufficiently explain this result, future researchers may explore whether seeking advice and support from a university scientist may impede the creative problem solving and learning associated with the entrepreneurial process (Wang, 2008) in large biotechnology firms.

Hypothesis 4 linked formal technology transfer experience and securing university faculty as consultants. Bringing new technologies into the firm often involves problems that are unrelated to a firm's existing expertise (Thomke and Kuemmerle, 2002). Firms that engage in a high level of formal

technology transfer have accumulated knowledge and intuition regarding the disruptions that can occur in their R&D activities (Ahuja and Katilia, 2001) when their scientists attempt to make sense of the novel scientific knowledge embodied in the acquired technologies. They engage the scientist-inventors to minimize potential disruptions, assisting the firm's scientists to make sense of and integrate the new knowledge into existing R&D activities. Given that consulting agreements play an important role in the development of biotechnology firms, the results have several implications for managerial practice and future research.

Implications and Future Research

Several theoretical and practical implications emerge from our study. First, an implicit assumption is that firms learn during consulting agreements, which involve a university scientist working closely with a firm's scientists. The frequency and closeness of these working arrangements foster an environment conducive to learning that occurs through a social process of converting knowledge between tacit and explicit categories (Nonaka and Takeuchi, 1995). Learning is critical to biotechnology firms located in environments where knowledge spillovers create entrepreneurial opportunities (Acs et al., 2009). Lacking the requisite routines to create an absorptive capacity, these firms will be unable to capitalize on the munificence of their environment. In the future, researchers may seek to explore whether the different uses of consulting support organizational learning.

There is a positive bias associated with firm-level benefits associated with consulting. The second implication highlights the adequacy of advice offered by a university scientist. Implementing a consultant's recommendations may be problematic for two reasons: length of time and adequacy of the solution. Problem-solving consulting engagements tend to be of short duration (Perkmann and Walsh, 2011). The length of these engagements is not conducive to the developing of relationships that are required to transfer tacit knowledge (Williams, 2008). In a short-term consulting engagement, a faculty consultant may solve the problem, leaving the firm's scientists to make sense of and apply the solution.

Second, prior research indicates that second-tier and medium-sized universities may be more willing to work with local R&D firms than are their larger peers (Mansfield and Lee, 1996; Laursen et al., 2008). At lower ranked universities, scientists may lack familiarity with the biotechnology firm's R&D processes to identify the problem and develop the correct solution. A future area of scholarly inquiry may examine (1) whether managerial perceptions of the quality of consulting advice differs among scientists based on their institutions' research classification from the Carnegie Institute, and (2) factors that influence whether managers are willing to implement consultants' advice.

The final theoretical implication of our findings draws attention to the university-industry relationship lifecycle. Prior research has depicted the importance of university-industry relationships; however, research illustrating the lifecycle and progression of the relationship from scientist to institution is largely lacking. Different economic implications emerge if a consulting agreement progresses to contract research or yields a licensing agreement. In the former, the scientist is the direct beneficiary. In the latter, the university captures a licensing fee and future royalties. Future researchers may explore whether the scientist and the university may possess competing agendas regarding the evolution of the university-industry relationship.

Finally, a practical implication of these findings suggests firms may benefit by managing their university relationships. Since biotechnology firms often rely on their links with universities to source knowledge (Stuart et al., 2007), managing the development and evolution of these links can enhance a firm's ability to access novel knowledge to support their innovative activity. Kale et al., (2002) found that firms that possess a dedicated alliance function participate in more successful alliances than do firms without an alliance role.

Limitations

One limitation of this study involved the conceptualization of consulting agreements, which prevented a more robust exploration of scientist-industry interactions. In addition, small-firm studies generally use

surveys to collect data from single organizational informants (Bartholomew and Smith, 2006). This reliance may inflate assessments as well as decrease response rates, which is another potential limitation of our research. Despite these limitations, this research is a novel attempt to investigate biotechnology firms' motivations for participating in consulting agreements, an under-explored stream of university technology-transfer research.

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