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UNIVERSITY TECHNOLOGY TRANSFER FACTORS AS PREDICTORS OF ENTREPRENEURIAL ORIENTATION

DOROTHY M. KIRKMAN

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DOROTHY M. KIRKMAN
University of Houston - Clear Lake

University technology transfer is a collaborative effort between academia and industry involving knowledge sharing and learning. Working closely with their university partners affords biotechnology firms the opportunity to successfully develop licensed inventions and gain access to novel scientific and technological discoveries. These factors may enhance a firm's entrepreneurial orientation by supporting innovative, proactive, and risk-taking behaviors. This study investigates whether university technology transfer characteristics such as the transfer process, transfer modes (formal and informal), and transfer terms influence entrepreneurial orientation. Using survey data from biotechnology firms that develop human health therapies, the findings suggest that the transfer process and informal technology transfer promote a firm's ability to act entrepreneurially. Exclusive licensing terms, on the other hand, have a negative influence, and formal technology transfer does not significantly contribute to a firm's entrepreneurial disposition.

Keywords: research, quantitative, entrepreneurship, technology

The drug development process is a long, arduous journey for many small and medium-sized biotechnology firms that must cope with considerable competitive pressures to remain aware of the latest technological trends and increase the speed of their product development times (Hung & Tang, 2008). In turbulent and rapidly changing environments, creatively using resources and effective scanning can lead to an aggressive pursuit of outcomes that include organizational survival and profitability (Puffer, McCarthy, & Peterson, 2001). These aggressive behaviors emanate from an entrepreneurial orientation (EO), which reflects a firm's ability to recognize and exploit opportunities, take risks, engage in creative problem solving and experiment with novel technologies, and act boldly when facing uncertain situations (Covin & Slevin, 1989; Miller, 1983). EO changes over time (Wiklund, 1999) because it is embedded in organizational processes and routines (Lee, Lee, & Pennings, 2001); thus, any changes to a firm's resources and capabilities, such as those that may occur when a firm participates in open innovation (Perkmann & Walsh, 2007), may influence that firm's EO.

Open innovation takes place when firms acquire external technologies and knowledge via licensing or research collaborations to complement their internal R&D activities (Lichtenthaler, 2008). Participating in open innovation is critical to biotechnology firms that lack the requisite resources and capabilities to commercialize new therapies (Gopalakrishnan, Scillitoe, & Santoro, 2008). These firms can acquire knowledge and technology from many potential partners, such as governments, universities, and commercial firms. However, university collaborations are particularly beneficial to biotechnology firms. These collaborations provide biotechnology firms with access to groundbreaking science which, left uncommercialized, serves as a source of entrepreneurial opportunity (Audretsch & Keilback, 2007). Formal collaborations among diverse organizations in a science-based industry may convey innovation benefits, either as diffuse channels for information spillovers or as proprietary pathways for directed information and resource transfer among partners (Owen-Smith & Powell, 2004). These resources and benefits may influence a firm's ability to act entrepreneurially by supporting learning, knowledge creation, and innovation.

Knowledge and learning are critical inputs to the entrepreneurial process. An entrepreneur's ability to acquire, use, and disseminate knowledge ignites entrepreneurial activity (Harper, 1996). Although prior research has established linkages between knowledge, learning, and entrepreneurship (Dess et al., 2003; Zahra, Neilsen, & Bogner, 1999), most EO studies focus on performance or knowledge outcomes (Pérez-Luño, Wiklund, & Cabrera, 2010, in press; Li, Huang, & Tsia, 2009). Interestingly, few studies have examined how external knowledge influences a firm's entrepreneurial orientation.

The goal of this study is to explore the relationship between university technology transfer and EO by examining the transfer process, transfer experience, and transfer terms. In this study, technology transfer is a process through which a biotechnology firm acquires the ability to replicate technology and knowledge (Lundquist, 2003). Replication, which involves efforts to copy or reproduce a technology at a firm's discretion, is a collaborative effort among partners (Kotabe, Martin, & Domoto, 2003). A joint effort is required to reproduce technology because know-how is often embodied in routines, and firm members may not understand or be able to articulate the causal link between action and outcome (Williams, 2008). Technology transfer studies (Harmon et al., 1997; Kotabe et al., 2003; Lundquist, 2003) reveal that frequent social interactions, trust, and resource exchanges promote successful transfer. In the biotechnology industry, innovation occurs among closely connected firms (Owen-Smith & Powell, 2004). Close relationships with universities provide biotechnology firms with access to technology, scientific expertise, and potential employees—all factors that may contribute to a firm's ability to act entrepreneurially.

In addition to the transfer process, this study also investigates how a firm's transfer experience influences its entrepreneurial orientation. Transfer experience reflects a firm's cumulative experience participating in different types of technology transfers. There is a prevailing sentiment that firms learn by doing (Tsang, 2002). This study proposes that technology transfer experiences provide biotechnology firms the opportunity to participate in acquisitive and experimental learning. Acquisitive learning occurs when a firm gains access to and integrates external knowledge (Dess et al., 2003) that resides in the public domain (e.g., patents), which leads to increased technical knowledge and innovation benefits via recombination (Zahra et al., 1999). Experimental learning occurs through informal technology transfer such as consulting agreements in which a firm's scientists have the opportunity to gain access to a university faculty member's tacit and experiential knowledge and learn through practice, exploration, and discovery.

Finally, this study will also explore the influence of licensing terms on a firm's entrepreneurial orientation. A license represents a right to use, develop, and commercialize a university invention. This right, which may be exclusive (granted to only one firm), provides a firm with an opportunity to capture first-mover advantages and monopoly profits by successfully commercializing the invention. Arguably, an exclusive licensing term can be a substitute for knowledge that an entrepreneurial firm's managers would leverage to identify and exploit an opportunity. Therefore, the possession of an exclusive license may decrease a firm's entrepreneurial orientation.

This study makes two contributions to the existing literature. First, it represents one of the few attempts to identify and explore the factors that contribute to the development of EO. The general premise in entrepreneurial orientation research is that firm-level entrepreneurship may generate beneficial outcomes. However, it is not so clear how firms ascertain entrepreneurial orientation in order to exploit it. This study seeks to contribute to the development of this base of knowledge. Second, Hagedoorn's (1993) research noted that biotechnology firms generate more research-based alliances than any other field because drug development is a complex, multidisciplinary process requiring firms to possess a broad array of knowledge (DeCarolis & Deeds, 1999). This study may offer managers an understanding of how a firm's knowledge-based activities influence the development of entrepreneurial capabilities. Given this insight, managers may then decide to engage in purposeful activities to create or maintain a bundle of resources that will enable a firm to innovate, take risks, and lead rather than follow.

LITERATURE REVIEW

The passage of the Bayh-Dole Act in 1980 gave universities permission to profit from federally funded research by patenting their inventions and then licensing the patent rights to firms for commercialization (Lemley, 2008). Since university and industry profits are potential outcomes, transfer mechanisms such as licensing have garnered significant academic attention. However, this focus ignores the process of transferring technology and the factors that condition its success (Bercovitz & Feldmann, 2005). Few empirical studies have examined the process of university technology transfer. However, Harmon et al.'s (1997) mapping of university technology transfer is a guide to understanding university-industry linkages.

Harmon et al. (1997) described three ways by which technology flows from academic to commercial settings: market, relational , or a market-relational combination. This discussion will cover the first two perspectives, market and relational, because they highlight two divergent approaches to academic technology transfers. The first perspective is a market-based transaction in which a transfer agent facilitates the completion of a signed licensing agreement or contract to sponsor faculty research. Although a signed contract reflects the transfer of property rights, a licensee's acquisition of a prototype in no way guarantees its ability to replicate that invention (Lundquist, 2003). This focus on formal contracts overlooks challenges that arise when transferring knowledge across organizational boundaries.

University Technology Transfer: Relational Perspective

Harmon et al.'s (1999) second perspective describes how relationships among transfer parties may reduce transfer barriers. Knowledge stickiness (Szulanksi, 1996) and causal ambiguity (Bhagat, Kedia, Harveston, & Triandis, 2002) are two mobility barriers that receive significant scholarly attention. First, scientific knowledge, even when it is codified, is highly tacit, and high levels of competence are required to generate, transmit, and communicate it (Antonelli, 2008). Tacit knowledge "indwells" in a comprehensive cognizance of the human mind and body (Polanyi, 1966). Therefore, it is "sticky" and resides very close to the domain of origin (Szulanski, 1996). Firms that seek to acquire such knowledge must be willing to commit resources and effort to dislodge and transfer specialized knowledge (Santoro & Bierly, 2006). A biotechnology firm's ability to develop a relationship with its university partner is critical to the transfer's success.

In addition to knowledge stickiness, ambiguity is another barrier that impedes the transfer (Simonin, 1999). It is present when knowledge cannot be reduced to its basic elements (Bhagat et al., 2002). Rothaermel and Deeds (2006) argue that there is a high level of ambiguity associated with university inventions because the science is new. Firms focused on commercialization lack understanding of the new scientific knowledge and principles used to create the inventions; therefore, these firms must deploy high levels of resources to develop the technology. Exploring the role of ambiguity, Williams (2008) examined how ambiguity influences knowledge transfer activities. The level of ambiguity associated with transferred knowledge determines whether the acquiring firm replicates the system that created the knowledge or simply adapts the knowledge to its systems. Firms that attempt to acquire discrete knowledge will engage in replication activities when acquiring knowledge. Discrete knowledge is self-contained with few external linkages. When knowledge is complex and causally ambiguous, a firm may not be able to predict which elements of the knowledge are essential for its operation (Williams, 2008, p. 871). Therefore, the acquiring firm attempts to copy or replicate the routines that facilitate knowledge emergence. Relationships are critical to replication because they offer the acquiring firm's employees opportunities to observe and ask questions.

Empirical studies highlight how relationships support transferring university knowledge. Santoro and Bierly (2006) examined whether relational factors such as social connectedness, trust, and intellectual property rights (IPR) enhance firms' ability to learn from their university partners. The scholars argue that trust between the partners reduces suspicions of opportunistic behavior, thereby facilitating richer, more open knowledge exchanges. Social connectedness also supports knowledge transfer because social networks increase the ability to acquire and absorb new knowledge. The findings reveal that both social connectedness and trust significantly influence a firm's learning. However, trust is the most significant predictor of successful learning.

Trust is critical to the knowledge transfer process because recipients who view knowledge transfer sources as trustworthy are more likely to change their behavior (Andrews & Delahaye, 2000) and are more willing to share their knowledge when they feel connected to their colleagues (Bresman, Birkinshaw, & Nobel, 1999). Frequent interactions between partners establish a common knowledge basis and facilitate mutual understandings (Tortoriello & Krackhardt, 2010, p. 169). However, physical interactions are not the only way to develop relationships. Munos (2006) argues that interactive online networks can be used to bring scientists together for knowledge-sharing and problem-solving activities. In an Internet environment, relationships emerge based on scientists' expertise and community participation. Whether in person or via the Internet, frequent social interactions encourage the development and strengthening of relationships, which contribute to successful transfer.

Entrepreneurial Orientation

Miller (1983) and Miller and Friesen (1982) examined how entrepreneurship occurred in different types of firms by specifically examining firm-level behaviors. Covin and Slevin (1989) refined Miller's (1983) entrepreneurial research by reducing the number of dimensions from 11 to three. Entrepreneurial choices made by the firm reflect its entrepreneurial posture, which is demonstrated by the extent to which top managers are inclined to take business-related risks, to favor new product development, and aggressively pursue opportunities to obtain a competitive advantage for their firm (Covin & Slevin, 1989). Scholars generally agree that entrepreneurial orientation includes three main dimensions: innovativeness, proactiveness, and risk taking. The following discussion provides an overview of the dimensions and establishes their link to knowledge.

Innovativeness reflects a firm's tendency to support new ideas and to foster creative processes that are aimed at developing new products and services (Walter, Auer, & Ritter, 2006). Schumpeter (1934) identified the importance of knowledge to the innovative process. Entrepreneurs earn surpluses not because they invent but because they innovate. They have not accumulated goods or created an original means of production, but they have employed existing means of production differently, more appropriately, more advantageously (Schumpeter, 1934, p. 132). The Schumpeterian entrepreneur innovates by combining new and existing knowledge.

Proactiveness refers to how firms relate to market opportunities in the process of new entry, and how they seize such opportunities in order to shape the environment (Wang, 2008). Drug development occurs within an interconnected network of actors where knowledge spillovers emerge from alliances and social connections (Whittington, Owen-Smith, & Powell, 2009). Proactive management teams seek to leverage relationships to acquire resources (Lee et al., 2001).

Finally, risk taking highlights a firm's proclivity to support projects in which the expected returns are uncertain (Lumpkin & Dess, 1996). Strong links exist regarding knowledge between risk taking and proactiveness. Organizations with better information and knowledge use their resources to make bets that are not available to their rivals (Magretta & Stone, 2002). This knowledge reduces uncertainty and increases the likelihood of opportunity exploitation. In summary, there is an inextricable connection between knowledge and entrepreneurial orientation. The following hypotheses explore university technology transfer as a vehicle for learning and new knowledge creation that incites firm-level entrepreneurial processes.

HYPOTHESES

University Technology Transfer—Entrepreneurial Orientation

Because of the nature of technology, technology transfer is not as simple as the exchange of blueprints. Recent research highlights the need for collaborative knowledge exchanges between transfer parties. Kotabe et al.'s (2003) study of technology transfer between U.S. and Japanese automotive firms revealed that technology transfer requires extensive and dedicated coordination and interactions because it is comprised of causally ambiguous and tacit knowledge that emerges through frequent interactions, commitment, and possessing and demonstrating a high level of capabilities. Relationships play an important role in the transfer process "since the important elements of organizational knowledge tend to be tacit, the ability to observe, ask, articulate and check in is an essential element of improving practices through knowledge transfer relationships" (Williams, 2008, p. 872). Given the challenges of transferring complex knowledge, effective transfer involves intense social interactions and the development of trust in order to compel parties to share their knowledge. Trust between partners loosens knowledge stickiness, thereby facilitating learning (Kotabe et al., 2003).

University technology transfer, as a bilateral exchange of knowledge and resources, should positively inform biotechnology firms' EO. From an innovative perspective, firms that have intense connections with their partners experience greater rates of learning and the exchange of new ideas during the transfer (Mesquita, Anand, & Brush, 2008). In addition to innovativeness, activities that require intense interactions often lead to long-term relationships, which support managers' willingness to act proactively. Universities are wellsprings of knowledge and resources. These relationships serve as bridges between the small firms and potential partners (Tiwana, 2008) and provide access to graduate students and potential board members (Perkmann & Walsh, 2008). A proactive firm will leverage its university relationships to develop the firm's technology strategy. Finally, cooperation among partners increases commitments and reduces the risk of transfer failure (Lundquist, 2003).Therefore, H1: The higher the university technology transfer that exists between a biotechnology firm and its university partner, the higher a biotechnology firm's entrepreneurial orientation will be.

Technology Transfer Experience

Learning by doing is one explanation in alliance management literature that describes how organizations acquire knowledge through direct experience (Tsang, 2002). The sheer fact of having engaged in more alliances is hypothesized to help companies develop a tacit proficiency in managing alliances more effectively (Kale, Singh, & Perlmutter, 2000). More importantly, firms with successful alliance experiences develop a relational culture that encourages employees to develop a partnering mind-set that involves developing strong working relationships, valuing partnerships, and sharing knowledge (Kale, Singh, & Bell, 2009). These factors contribute to a firm's competitiveness by supporting organizational learning.

There are two forms of learning by doing: acquisitive and experimental. Acquisitive learning occurs when a firm gains access to and subsequently internalizes preexisting knowledge from its external environment (Dess et al., 2003). This type of learning takes place in a formal university technology transfer, which involves a university's exchange of a legal instrument such as a patent with a biotechnology firm and occurs within licensing agreements or sponsored contract research (Link, Siegel, & Bozeman, 2007). When firms acquire external knowledge, they lower their innovation costs by imitating and replicating existing external knowledge (Li, Zhang, Liu, & Li, 2010). Experimental learning occurs during participation in informal technology transfer modes such as consulting agreements and co-authorship. It usually involves individuals (or groups) who have the discretion to experiment and a process that translates individual (group) experiences into organizational knowledge (Zahra et al., 1999).

The following hypotheses explore how the learning accumulated by participating in informal and formal university technology transfers influences entrepreneurial orientation.

Informal technology transfer experience. University inventions are licensed at an early stage of development before commercial potential can be assessed. Thus, there are high levels of ambiguity and complexity associated with university inventions (Rothaermel & Deeds, 2006). Biotechnology firms often engage university scientists as consultants to help develop licensed university inventions (Perkmann & Walsh, 2008) because the interworkings of the technological system reside in the inventor's mind (Argawal, 2006). Consulting arrangements involve frequent face-to-face interactions between university inventors and firm scientists. Knowledge is created when the inventors articulate their tacit knowledge, in common terms, which is then internalized by the firm's scientists (Nonaka & Takeuchi, 1995) and embedded into organizational processes and routines during experimentation. New knowledge and interpersonal relationships may develop from frequent social interactions, which are critical to organizational learning and EO.

First, the new knowledge that becomes embedded in the firm's practices increases the firm's domain-absorptive capacity, which refers to the ability to directly acquire knowledge necessary for solving problems related to innovation commercialization (Lim, 2009). Firms with high levels of absorptive capacity generate higher innovative output than their peers do (Liao, Fei, & Chen, 2007). In terms of proactiveness, close collaborations with university scientists increase a firm's ability to search for and identify technological opportunities (Fabrizio, 2009). Since most biotechnology firms are located in geographical clusters, those firms with superior technological search capabilities are well suited to capitalize on R&D knowledge spillovers (Audretsch & Keilback, 2007). Furthermore, working closely with university inventors may increase the firm's ability to address relational and administrative transfer issues. This experience can be diffused throughout the firm, thereby providing managers with the ability to act boldly when addressing potential problems.

Second, technical learning is a critical outcome of informal technology transfers, but a firm may also benefit from the development of interpersonal relationships between its scientists and the university inventor. Research universities' primary goal is the creation and widespread dissemination of cutting-edge, basic knowledge (Hoang & Rothaermel, 2010). Working in porous knowledge environments, university scientists contribute to knowledge dissemination by publishing their research and establishing industry relationships. Social interactions with a university scientist provide a biotechnology firm access to opportunities to acquire an invention directly from the scientist

(Markman, Phan, Balkin, & Gianiodis, 2005) and leverage the scientist's social network to discover information about competitors' research projects. The possession of knowledge reduces the risk that the firm will invest its limited resources into a new project that is similar to one conducted by a competitor. In summary, experimental learning supports technical and organizational learning and enables the firm to benefit from interpersonal relationships. In light of these arguments, the following hypothesis is proposed:

> H2a: Increases in a biotechnology firm's participation in informal university technology transfer will positively influence its entrepreneurial orientation.

Formal technology transfer experience. Acquisitive learning is partly based on a biotechnology firm's ability to understand and adapt acquired knowledge within its R&D processes. Dess et al. (2003) put forth the premise that there are direct and indirect effects of acquisitive learning. The direct effects involve a firm's understanding of new technical knowledge, and the indirect effects highlight possible recombination benefits that may emerge as the scientists attempt to integrate the technology into the firm's existing system. From a combinatorial perspective, knowledge diversity increases the possibility of creating new linkages among existing knowledge elements and newly explored ones (Ahuja & Katila, 2001; Henderson & Cockburn, 1994; Wu & Shanley, 2009). Biotechnology firms that frequently license university inventions expand their knowledge base, which supports entrepreneurial activities.

As a biotechnology firm increases its participation in formal university technology transfer, its innovative capability increases (Li et al., 2010) as the firm acquires new knowledge sources that can be reconfigured (Schumpeter, 1934) to develop new products. Participation in formal university relationships fosters a mutually dependent relationship in which successful commercialization requires a committed effort of both partners. Thus, biotechnology firms that license an invention are more likely to acquire additional resources from their university partners that support survival (Rothaermel & Thursby, 2005). From a risk-taking perspective, a broad knowledge base reduces the risk of core rigidity (Leonard-Barton, 1992), which occurs when the creation of new knowledge reduces the firm's ability to use existing knowledge to generate value. Therefore,

> H2b: Increases in a biotechnology firm's participation in formal university technology transfer will positively influence its entrepreneurial orientation.

Licensing Terms

Universities use various tools to structure a licensing deal. An exclusive license is one such option that provides firms with exclusive rights to capture monopoly profits (Scotchmer, 1996) by commercializing a university invention (Lemley, 2008). The promise of monopolistic profits is necessary because university inventions are typically quite embryonic, high risk, and require extensive development (Rothaermel & Thursby, 2005). Absent a patent or exclusive license to a patent, or some other mechanism that allows recovery of these development costs, firms may be unwilling to incur such costs (Pusellini, 2006). The need for an exclusive license may be particularly germane for small and medium-sized biotechnology firms that often lack resources to compete with their larger peers and may wait 10 years to capture a return on their R&D investments. An exclusive license protects the firm's investment throughout the commercialization process by denying competitors access to the technology (Van den Berghe & Guild, 2008). Thus, firms securing exclusive licensing terms achieve advantages similar to benefits that may accrue to firms that adopt an entrepreneurial orientation. It is conceivable that managers may be less inclined to devote resources to entrepreneurial activities because the firm possesses property rights that offer similar advantages. Thus, securing an exclusive license may serve as a substitute for entrepreneurial activity in some biotechnology firms. Given these insights,

> H3: An exclusive license will have a negative and significant influence on a biotechnology firm's entrepreneurial orientation.

METHODS

Sample and Survey Administration

The biotechnology industry was selected to test the hypotheses relating to university technology transfer, university transfer experience, and licensing terms. By definition, biotech is knowledge intensive, which means that the complementary processes of discovery and innovation necessitate the union of assets that characterize different types of organizations, both public and private (Feldman, Feller, Bercovitz, & Burton, 2002). Most biotechnology firms are small, resource-constrained firms that do not possess the requisite companies to transform their discoveries into a consumer-ready product (Gopalakrishnan et al., 2008).Consequently, biotechnology firms typically engage in long periods of entrepreneurial activity due to the long, complex process of developing and commercializing new drugs (Rothaermel & Deeds, 2006). In light of the characteristics of this industry, biotechnology firms must acquire external knowledge in order to compete with other markets.

A three-step process was employed to identify operational firms. First, information on public firms was collected from HOOVERs, a business industry directory, and information on private firms was sourced from nonprofit industry association directories. In total, information was gathered on 1,000 potential respondents. The final stage involved verifying firm-level data and ensuring the firms' North American Industry Classification Scheme (NAICS) codes matched those codes possessed by firms that create human therapies: NAICS 325411, NAICS 325414, and NAICS 541710. Biotechnology researchers commonly use classifications because not all biotechnology products undergo a rigorous approval process (Hoang & Rothaermel, 2005). Reference USA, a library business database, was used to verify firm-level data and exclude firms from the list based on their NAICS codes. The final sample included 838 biotechnology firms, of which 300 were public and 538 private.

A survey instrument was used to collect data for all the variables assessed in this study. It is common among EO scholars (Covin & Slevin, 1989; Lumpkin & Dess, 2001; Walter et al., 2006) to assess a firm's entrepreneurial orientation using survey data. The survey's unit of analysis is the firm level. EO is a firm-level process. The surveys were mailed to executives whose titles suggested that they were familiar with the firm's research and development alliance activities. Most of the firms were small, with fewer than 100 employees. In small firms, the head of R&D is the primary source and perhaps the only source that is knowledgeable about the firm's transfer activities (Norburn, 1989).

Similar to previous EO studies (Hughes & Morgan, 2007; Wang, 2008), the questionnaire used in this study was created using Dillman's (1978) method of mail survey response and design. In terms of this type of research, Dillman (1978) proposed that researchers send pre-notification letters, a questionnaire package, and several follow-up reminders to potential respondents. A retired R&D executive from a pharmaceutical firm provided advice regarding the content of the pre-notification, questionnaire package, and reminders. Three mailings were administered, and 990 questionnaires were sent to the most senior executives in charge of R&D; 204 surveys were completed and returned, for a response rate of 21%. Six surveys were eliminated from the sample due to missing data. The response rate in this study compares favorably with the 15.4% rate achieved in Wang's (2009) EO study.

In survey research, lack of response from certain groups and use of a single organizational informant may distort the findings. First, issues regarding the timing of responses or lack of responses from certain groups may increase the potential of response bias. To assess the existence of response bias, t tests were used to determine whether any response bias exists between responding firms and nonresponding firms on variables such as EO and university technology transfer. The analyses revealed no significant differences between early and late responders. Second, the data were analyzed for common method variance (CMV) using Harmon's one-factor test (Podsakoff & Organ, 1986) because the data used in this study were obtained using single organizational responses. CMV is a concern if a single factor is extracted or a majority of the covariance is accounted for by one factor (Thacker & Wayne, 1995). An exploratory factor analysis, consisting of the entrepreneurial orientation dimensions and the technology transfer construct, extracted four factors with eigenvalues greater than 1 that accounted for 74.52% of the variance, with the first factor accounting for only 18.93% of the total. In this study, common method variance is not a concern.

Measures

The pretest included three activities: (1) reviewing the survey with a panel of experts to establish content validity of the scales, (2) administering the survey to practitioners during site visits and telephone interviews, and (3) administering an electronic survey to pharmaceutical professionals who completed questions or who were debriefed about their survey experience. No significant changes were made to the scales listed in Table 1. All scales used in this study were measured on a 5-point Likert-type scale ranging from 5 (strongly agree) to 1 (strongly disagree). Table 1 lists the primary measures used in this study.

Table 1

Survey Items for Independent and Dependent Variables

Variables	Survey Items
Entrepreneurial Orientation	(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.
Technology Transfer	(1) This firm shared technological capacities w/ partner.
	(2) This firm was willing to transfer technologies to partners.
	(3) This firm received technology transfer from partners.
	(4) Relied on our partner's scientific capabilities.
	(5) Solved problems using the partners' support.

Dependent Variable

The dependent variable is university technology transfer (UTT). In this study, university technology transfer is a concerted project that allows one partner to access or replicate complete technological capabilities of the other partner (Kotabe et al., 2003, p. 298). A successful transfer results in ownership, or the acquirer's ability to replicate technology at its discretion (Lundquist, 2003). This transfer requires a collaborative effort that involves mutual exchange of knowledge, problem solving, and mutual reliance (Kotabe et al., 2003). This construct was measured using Kotabe et al.'s (2003) technology transfer 5-item scale, which assesses a firm's willingness to share and rely on their partners' knowledge and expertise. A high score suggests that a biotechnology firm willingly participated in and benefitted from the transfer process. The Cronbach's alpha (α) for the scale is .834.

Independent Variables

Entrepreneurial orientation (EO). A firm's EO is demonstrated by the extent to which top managers are inclined to take business-related risks and to favor change and innovation in order to obtain a competitive advantage for their firm (Covin & Slevin, 1989, p. 77). The EO scale is comprised of a 9-item scale created by Miller and Friesen (1982) and later revised by Covin and Slevin (1989). Firms with a higher score are likely to be more entrepreneurial. The Cronbach's alpha (α) for the scale is .832.

Technology transfer experience reflects a biotechnology firm's experience in participating in formal and informal technology transfer. A formal technology transfer experience directly results in a legal instrumentality (Link et al., 2007, p. 6) such as a new invention or patent. In this study, 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 five years. An informal technology transfer mechanism facilitates the flow of technology knowledge through an informal communication process such as consulting agreements (Link et al., 2007). In this study, the measure for informal technology transfer mechanism is the number of consulting agreements the responding firm participated in over the last five years. The measure of university technology transfer experience is consistent with those measures used to assess a firm's alliance experience (Rothaermel & Deeds, 2004).

Licensing terms (Licensing). There are two forms of licensing terms: exclusive and nonexclusive. When a biotechnology firm acquires an exclusive license, it receives the sole rights to use, develop, and profit from an invention (Markman et al., 2005). Universities give nonexclusive license to many firms that then race to become the first to commercialize the invention. The question asked respondents to select the terms of their most recent licensing agreement. This control variable is an indicator, where 1 represents an exclusive license and 0 reflects a nonexclusive license.

Control Variables

A review of the literature identified several variables that may influence a biotechnology firm's ability to develop EO. Age refers to the number of years that have passed since the firm was established (Wiklund, 1999). Younger biotechnology firms may participate in more R&D collaborations with universities than do their older peers (Deeds & Hill, 1996). Respondents were asked when their organizations became incorporated. Cluster reflects the richness of the biotechnology firm's environment. In the United States, the trend of most biotechnology companies has been to follow the "location is key" rule by clustering in the same geographic areas (Kermani & Bonacossa, 2003, p. 157). DeCarolis and Deeds (1999) used the Metropolitan Statistical Analysis (MSA) to determine the munificence of a location in their study of biotechnology firms' knowledge stocks and flows. The MSA used in this study is based upon Census Bureau population estimates for July 1, 2005, and July 1, 2006. A 2005 report published by Ernst and Young identified 11 biotechnology clusters. The location variable classified each biotechnology firm into their MSA by their zip code, which was then compared to the zip codes for the biotechnology clusters. This control variable reflects the percentage of public firms located in the biotechnology firm's MSA. If a biotechnology firm was located in a biotechnology cluster, then a percentage of biotechnology firms in their MSA was entered for this control variable; otherwise it was coded as a 0.

R&D reflects a firm's investments in research and development activities. Firms that make significant R&D investments are more likely to develop absorptive capacity than firms that do not. This measure is a log of the ratio of a firm's total spending in R&D versus the number of full-time employees, which adjusts for differences in spending based on company size (George, Zahra, & Wood, 2002). Size is included as a control variable to eliminate complexities (e.g., learning and resource accumulation) that emerge as a firm grows (Zahra, 1996). Respondents were asked to indicate the number of individuals employed by their firms.

ANALYSIS

Descriptive statistics and correlations for the relevant variables are displayed in Table 2. The most significant correlation depicts the relationship between size and R&D investments ($r = .54$, $p < .0005$), with high levels of R&D investments associated with large firms. This relationship reflects the notion that large firms have resources to invest in research and development activities. The relationship between university technology transfer and entrepreneurial orientation ($r = .31$, $p < .05$) suggests that higher levels of EO are associated with increased willingness to actively participate in the transfer process by exchanging knowledge and resources. Since the correlations in this analysis were moderate, the variation inflation factors (VIFs) were computed. The VIFs ranged between 1.06 and 1.527, which is less than the limit of 10 suggested by Hair, Anderson, Tatham, and Black (1995). Given the results of the analysis, multicollinearity is not a significant concern in this study.

Table 3 presents the regression analysis results. Model 1 contains the control variables. Hypothesis 1 suggests a positive relationship between university technology transfer and entrepreneurial orientation. Model 2 presents the direct effect of university technology transfer ($B = .42$, $p < .001$). As proposed, university technology transfer complements a biotechnology firm's investment in basic R&D and enhances the firm's creativity, willingness to accept new ideas, and explorative processes. Hypothesis 2a puts forth the notion that informal technology transfer would positively influence a biotechnology firm's EO. The analysis contained in Model 3 supports the hypothesis (B = .17, $p < .05$). When a biotechnology firm hires a university scientist in a consulting role, the firm has an opportunity to access the scientist's experiential and latent knowledge through frequent and close interactions.

Table 2

Descriptive Statistics and Correlations

	Variables	Mean	SD	1	2	3	4	5	6	7	8	9
1.	Age	.849	0.29	1.00								
2.	Size	1.55	0.53	**.42**	1.00							
3.	R&D	47.5	20.7	**.34**	.54	1.00						
4.	Cluster	0.78	0.12	-.04	.06	.01	1.00					
5.	UTT	3.56	1.09	-.09	-.05	.07	-.04	1.00				
6.	Licensing	n/a	n/a	.07	.11	-.01	<u>-.15</u>	**-.38**	1.00			
7.	Formal TT	5.15	6.33	.11	.03	<u>-.15</u>	-.10	-.05	**-.24**	1.00		
8.	Informal TT	4.14	5.16	**-.21**	.06	<u>.19</u>	.04	<u>.15</u>	.08	**-.37**	1.00	
9.	EO	3.36	1.09	-.09	-.05	-.07	<u>-.15</u>	**.31**	**-.22**	.11	<u>.18</u>	1.00

Note. $N = 198$. Bold correlations $p < .01$. Underline correlations $p < .05$.

Table 3

Multiple Regression Analysis

Dependent Variable = University Technology Transfer						
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Full Model**
Control Variables						
Age (log)	-0.12	-0.14*	-0.12	-0.15*	-0.16**	.10
Size (log)	-0.17**	-0.13	-0.16**	-0.15*	-0.18**	-0.14*
R&D Investments (log)	0.10	0. 13	0.14*	0.16**	0.14*	0.18**
Cluster	-0.19**	-0.16**	-0.24***	-0.25***	-0.21***	-0.20**
Independent Variables						
UTT		0.42***				0.39***
Informal TT			0.17**			0.15*
Formal TT				-.09		-.004
Licensing Terms					-0.20**	-0.15*
Fitness Indices						
Adj. R^2	0.06	0.24	0.12	0.10	0.13	0.25
ΔR^2		0.111	0.023	0.006	0.043	0.186
F value	3.40***	10.07***	4.88*	4.15	5.91**	6.82***

Note. $N = 171$, *** $p < .001$, ** $p < .05$, * $p < .10$

In contrast to the results for Hypothesis 2a, results for Hypothesis 2b, listed in Model 4, indicate a nonsignificant negative relationship (B = -.09, $p > .10$) between formal university technology transfer experience and EO. When a biotechnology firm participates in formal university technology transfer, it may develop expertise in negotiating formal contracts; however, this knowledge may not enhance the firm's creativity or ability to identify opportunities to leverage their innovative capacity. Finally, Model 5 supports the initial premise that an exclusive license would have a negative impact on a firm's entrepreneurial orientation (B = -.20, $p < .01$). The full regression analysis contained in Model 6 indicates that university technology transfer, informal technology transfer experience, and licensing terms are significant predictors of entrepreneurial orientation, while formal technology transfer experience is negative and not significant.

DISCUSSION

As anticipated, the findings revealed a positive association between university technology transfer, as a means for exchanging knowledge and information among transfer partners, and entrepreneurial orientation. The necessity of relationships to facilitate transfer highlights the uncertainty of university knowledge and possible risks that may emerge during the process. A university has a stake in the development of its technologies. As biotechnology firms demonstrate their capabilities, competence-based trust emerges between partners and leads the university to make more resources available to support further development. Rothaermel and Thursby's (2005) study of incubator graduation revealed that firms that had strong relationships, such as exclusive licenses, with their university partners received resources and support which improved their graduation rates. Thus, firms that actively participate in the transfer process gain ownership of the technology (Lundquist, 2003), receive higher quality and more diverse knowledge from their partner (Yli-Renko, Autio, & Sapienza, 2001), and acquire information that opens future collaboration opportunities (Ahuja, 2000). These benefits positively inform a firm's EO.

The study also found that informal technology transfer experience and exclusive licensing terms were also significant predictors of a firm's EO. The former draws attention to informal channels of communication that develop as a firm increases its participation in consulting agreements. The informal aspect of the relationship indicates that a tangible outcome may not always emerge from these linkages. Organizations are social institutions that consist of inter- and intraorganizational relations. Relations or ties facilitate the exchange of information among partners (Levitt & March, 1988) and enable top managers to identify an innovation and evaluate whether it matches their organization's needs and goals (Westphal, Gulati, & Shortell, 1997). When working closely with university faculty, a biotechnology firm's managers can gain insight into emerging trends, access to inventions, and use of the faculty's knowledge to solve problems. Since access to knowledge is critical to entrepreneurship, informal technology transfer experience enables firms to develop their informal scanning mechanisms and improves the scientists' ability to develop trusting relationships with university scientists. The latter suggests that when developing university technology it may be beneficial for firms to cease their entrepreneurial activities and focus on developing the invention. A biotechnology firm may be better served in the end by dedicating their resources to developing a saleable product to earn the profits that often elude them.

Contrary to an initial assertion, the analysis revealed a nonsignificant and negative relationship between formal technology transfer experience and EO. Acquisitive learning is not always beneficial and can be disruptive because the change is more likely to occur in the routines that are closest to a firm's innovative activity (Ahuja & Katila, 2001). Leveraging technological knowledge is often risky; doing so requires organizations to modify their existing practices because faulty interpretations can impede an organization's ability to benefit from its technology investment. This finding does support Zahra et al.'s (1999) assertion that acquisitive learning, although it is important, is not as critical to corporate entrepreneurship as experimental learning, which emerges through exploration and criticism. Given the importance of university-industry linkages, the results have several implications for managerial practice and future research.

Theoretical and Managerial Implications

Three theoretical implications can be ascertained from the current research. First, university technology transfer is an entrepreneurial endeavor for universities as well as biotechnology firms. Technology transfer is commonly associated with entrepreneurial behaviors of universities and faculty. Scant attention has been paid to the presence of entrepreneurship on the biotechnology side of the relationship, which is not controversial because many biotechnology firms emerged as spin-offs to commercialize revolutionary science. From a Schumpeterian perspective, these new firms are entrepreneurial because they entered the market with revolutionary science to change the new-product development process. This study was an exploratory attempt to incorporate another classification of entrepreneurial activities—those that emerge from firm-level capabilities—into the discussion of biotechnology firms.

Second, performance is often the outcome associated with a firm's entrepreneurial orientation. In the biotechnology industry, many firms wait nearly a decade before appropriating returns for their R&D efforts. Despite the lack of profits, university technology transfer and alliances are critical sources of resources to biotechnology firms that often suffer from liabilities of newness and smallness (Stinchcombe, 1965). Survival and competitiveness for many biotechnology firms depends on their ability to use collaborations to access resources. University collaborations are linkages that biotechnology firms can use to access flows of knowledge that may provide scale, scope, and recombination benefits (Henderson & Cockburn, 1994). This study is consistent with DeCarolis and Deeds's (1999) argument that "the performance of biotechnology firms should depend on both their stocks of knowledge and their access to flows of knowledge" (p. 955).

Third, university support is critical to the commercialization of transferred technologies because small biotechnology firms lack the necessary skills to gain ownership of the technology through their internal efforts alone. Most university technology transfer studies explore the effectiveness of the university technology transfer office in terms of the efficiency of formal technology transfer performance as measured by the number of spin-offs, revenue generation, IPOs, and licensee selectivity (Chapple, Lockett, Siegel, & Wright, 2005; Markman et al., 2005; Powers & McDougall, 2005). The need for further support is a strategic issue. The availability of support influences successful commercialization, which in turn stimulates national systems of innovation (Gittleman, 2006).

In addition to theoretical implications, the present study offers practical implications. First, many biotechnology firms have a diverse group of alliance partners that possess unique knowledge and capabilities. Although many biotechnology firms lack the size and resources needed to develop a comprehensive knowledge-management system, these firms should create a process that enables employees to collect knowledge or insights that emerge during interorganizational interactions. By developing a process to manage the knowledge acquired via collaborations, biotechnology firms build a stock of knowledge that can be leveraged in their pursuit of innovation. Second, technology transfer is a complex and resource- and time-intensive process. There is no guarantee that the firm will produce a saleable product. Therefore, it may be useful to managers to develop a strategic plan evaluating factors such as technology quality, development stage, additional costs of the consulting agreement, opportunity costs associated with deploying employees to develop the invention, and the university's transfer success rate. In considering these factors, managers attune themselves to the risks and reality of technology commercialization and may identify potential problem areas that could hinder development.

Future Research and Limitations

Future research may seek to expand these findings by investigating which factor of university technology transfer—social interactions, competency demonstration, or resource exchange—most significantly influences EO. The line of inquiry puts forth the notion that university technology transfer is a complex, dynamic process, and it may be simplistic to propose that all the factors uniformly influence EO. Finally, Argawal's (2006) study of consulting agreements and Rothaermel and Thursby's (2005) examination of incubator graduation rates highlight the critical role that university resources play in the commercialization process. In the future, researchers may assess the resources and internal incentives that small and medium-sized universities deploy to support their technology transfer activities.

There are several limitations of this study. First, entrepreneurial studies use surveys to collect data from single organizational informants (Bartholomew & Smith, 2006). This reliance may inflate assessments as well as decrease response rates. A firm's alliance-management capabilities are often assessed by counting the number of alliances; however, this measurement assumes that learning occurs with increasing participation. This measure, although generally accepted, may not accurately assess organizational learning. Despite these limitations, the study is a novel attempt to examine the predictors of EO.

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Dorothy M. Kirkman is Assistant Professor of Management at University of Houston – Clear Lake. She holds a PhD in Organizational Management from Rutgers University. At University of Houston Clear Lake, she specializes in technology strategy and entrepreneurship research.