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From Human Capital to Social Capital: A Longitudinal Study of Technology-Based Academic Entrepreneurs

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This article develops theory relating to how differences in the human capital of academic entrepreneurs influence their ability to develop social capital that can address the barriers to venture development. We examine the development of social capital by three types of academic entrepreneurs with differing levels of entrepreneurship experience: nascent, novice, and habitual entrepreneurs. Using a longitudinal study, critical differences are observed between the structure, content, and governance of their social networks. We propose that entrepreneurs with prior business ownership experience have broader social networks and are more effective in developing network ties. Less experienced entrepreneurs likely encounter structural holes between their scientific research networks and industry networks. Support initiatives help attract industry partners for novice entrepreneurs from engineering and the material sciences but academics based within biological sciences encounter greater difficulties building such ties. Regardless of academic discipline, business ownership experience appears essential to learn to build relationships with experienced managers and potential equity investors.

Introduction

Technology-based academic entrepreneurs are attracting increasing attention as a consequence of the noncommercial environment of the universities from which they typically emanate (Siegel, Waldman, & Link, 2003). Such entrepreneurs face a number of significant barriers in creating and sustaining new ventures (Vohora, Wright, & Lockett, 2004). First, the venture is generally based upon a technological breakthrough that may have multiple commercial applications (Shane, 2000). Second, the entrepreneur may not have the skills or knowledge to recognize opportunities (Venkataraman, 1997). Third, the entrepreneur is unlikely to possess the skills or knowledge required to exploit an opportunity (Franklin, Wright, & Lockett, 2001). Fourth, the traditionally noncommercial environment of universities poses serious issues regarding the level of support available to create and develop such ventures (Lockett & Wright, 2005; Siegel, Waldman, Atwater, &

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Link, 2003). The debate about how to overcome these barriers has focused on the human capital shortages of the entrepreneurs. Studies have increasingly distinguished between the general and specific nature of entrepreneurs' human capital (Davidsson & Honig, 2003). Entrepreneurial experience adds to specific human capital by providing direct learning and episodic knowledge about the entrepreneurial process.

Typologies of academic entrepreneurs have typically not considered the heterogeneity of the entrepreneurs' experience as an entrepreneur (Mustar et al., 2006), the implicit assumption being that they are creating a venture for the first time. Yet there is growing recognition of the heterogeneity of entrepreneurial experience (Westhead, Ucbasaran, & Wright, 2005; Westhead & Wright, 1998). There is an absence of systematic studies that identify the extent to which habitual entrepreneurs exist in universities. Academics seeking to commercialize a radical innovation may need to accumulate broader legitimacy through accessing social capital (Delmar & Shane, 2004). The human capital of entrepreneurs may be influential in developing social capital (Adler & Kwon, 2002).

In contrast to entrepreneurs in commercial environments, the traditionally noncommercial environment of universities likely means that academic entrepreneurs face major challenges in developing social capital, especially if they remain within the university (Mustar et al., 2006; Nicolaou & Birley, 2003). However, we know little about the development of social capital by academic entrepreneurs with different human capital derived from entrepreneurial experience. Understanding these differences is important since unlike the private sector context, the process of developing greater social capital from ownership experience may not be straightforward in an academic entrepreneurship context. First, academic entrepreneurs face challenges in moving from scientific networks to commercial networks (Vohora et al., 2004). Second, support mechanisms may be weak and beset with conflicts of interest regarding academic entrepreneurs (Lockett & Wright, 2005). Third, differences in human capital emanating from the academic discipline base and prior industrial experience of academic entrepreneurs may interact with human capital from differences in business ownership experience to influence the extent and nature of social capital development (Corrolleur, Carrere, & Mangematin, 2004).

This study represents the first attempt to consider the role of different academic entrepreneurial experience in developing social capital. In general, human capital models have developed separately from social capital models, but in the academic entrepreneurship context the two are not easily disentangled (Bozeman & Mangematin, 2004). We address the gap in the literature using an inductive theory building empirical approach. Specifically, we examine the broad research question: How do differences in the human capital derived from the entrepreneurial experience of academic entrepreneurs influence their ability to develop social capital?

We utilize a longitudinal study of academic entrepreneurs. Adler and Kwon (2002) propose that longitudinal studies are necessary to develop understanding of the dynamic interplay between human and social capital; yet few studies adopt this approach. Similarly, Hoang and Antoncic (2003) in calling for an increased focus upon the relationship between network development and entrepreneurship argue that longitudinal analysis is required to understand the contextual factors at play.

Consequently, we identify a group of technology-based nascent, novice, and habitual academic entrepreneurs and observe the development of their social capital over an academic year. Nascent entrepreneurs are individuals considering starting their own businesses (Ucbasaran, Wright, Westhead, & Busenitz, 2003). Novice entrepreneurs are individuals who have created a venture for the first time and habitual entrepreneurs undertake multiple entrepreneurial ventures (Westhead & Wright, 1998). To enable comparisons, academics were selected who were engaged at a similar stage of their

most recent venture development at the start of the period of study. Respondents were chosen from applicants for intervention schemes designed to assist early stage venture development.

This article is structured as follows. The following section situates our study within the entrepreneurial human capital and social capital literatures. We then outline our methodology and data collection. The fourth section presents the findings of a case study investigation of 24 academic entrepreneurs. The fifth section builds upon the case material to develop a theoretical framework and provide propositions to guide future research. Finally, conclusions and implications are presented.

Theoretical Perspectives: Human and Social Capital

We draw on two separate literatures. First, we draw on the literature relating to the link between the human capital derived from entrepreneurs' business ownership experience and their behavior. Shane (2000) found that prior knowledge of markets and ways to serve markets in order to address customers' problems influence the discovery of opportunities. Venkataraman (1997) argues that the ability to connect specific knowledge and a commercial opportunity requires a set of skills, insights, and circumstances that are neither uniformly nor widely distributed. Within the university environment, Kassicieh, Radosevich, and Umbarger (1996) found significant differences between entrepreneurs and non-entrepreneurs in terms of factors such as the level of involvement in business activities outside the laboratory.

Leading academic researchers may be entrepreneurial in identifying new research areas and sources of funds but they may have difficulties identifying opportunities with commercial market applications (Lockett, Wright, & Franklin, 2003). It is an empirical question whether leading scientists are homogeneous with regard to their ability to identify commercial opportunities (Wright, Birley, & Mosey, 2004).

The phenomenon of habitual entrepreneurs is widespread (Westhead & Wright, 1998). This has implications for understanding the behavior of habitual entrepreneurs versus novice entrepreneurs. Moreover, consideration of the specific needs of nascent entrepreneurs is also necessary to further encourage entrepreneurship (Ucbasaran, Wright, et al., 2003; Westhead et al., 2005).

To gain an insight into barriers faced by nascent academic entrepreneurs, we also draw upon the social capital literature. Bozeman and Mangematin (2004) argue that social mechanisms underpin the production of knowledge and are critical for its subsequent distribution and use. We propose that social capital is important for the creation of ventures based upon university research Yet the social network of academics is typically constrained to a narrow scientific research network. Academics may have close or strong ties with team members in their department leading to the creation of bonding social capital. However, many academics may only have loose or weak ties with actors located outside their department (Granovetter, 1973) An academic seeking to address a barrier to venture creation may develop their ties to gain access to valuable information that would otherwise be difficult or costly for them to obtain (Cooper & Yin, 2005). Weak ties between an academic actor and industrial actors may lead to bridging social capital (Adler & Kwon, 2002). Academics who access industrial actors may subsequently develop their social and entrepreneurial skills, which can ensure mutually successful relationships with a variety of nonacademic actors.

The human capital profiles of academics may be enhanced by focusing on weak ties with industry actors (Davidsson & Honig, 2003). Moreover, weak ties can sometimes

develop into strong ones, leading to relationships based on mutual trust that in turn can enable resources to be accessed (Mayer & Schooman, 1993).

Hoang and Antoncic (2003) consider three aspects of social networks. First, is the network structure, defined as the patterns of relationships between actors in the network. Second, is the network content, defined as the nature of the resources exchanged between actors. Third, is the network governance, defined as the mechanisms that govern relationships between actors. These three aspects provide a framework within which to explore more specific elements of the broad research question stated in the Introduction.

The academic entrepreneurship literature has not considered the role of prior entrepreneurial experience but has implicitly assumed that scientists are starting a business for the first time. However, academic entrepreneurs may be heterogeneous with respect to their previous entrepreneurial experience. Experienced entrepreneurs in a commercial environment likely build new weak ties to identify new opportunities (Burt, 1992; Ucbasaran, Wright, et al., 2003) and strong ties with experienced managers and employees within their ventures that are necessary to the venture's resources, distinctive capabilities, and social capital (Vohora et al., 2004). The traditional university environment raises questions about whether and how the human capital of inexperienced and experienced academic entrepreneurs is related to the development of social capital. At present we know little about these relationships. Thus we pose the following research questions (RQs):

RQ1a: What structural social capital is in place at the start of new venture development for academic entrepreneurs with different levels of prior business ownership experience?
RQ1b: What new ties are developed during the early stages of new venture development by academic entrepreneurs with different levels of prior business ownership experience?

Considering social network content, experienced entrepreneurs in a commercial environment likely have access to more diverse resources through their social network (Callon, Laredo, & Mustar, 1997). By contrast, less experienced entrepreneurs with more limited social networks may lack access to seed finance, industry knowledge to recognize opportunities, or access to investment finance (Mosey, Lockett, & Westhead, 2006). Hence:

RQ2: What is the nature of the resources gained through the social networks of academic entrepreneurs with different levels of prior business ownership experience at the early stages of venture development?

Considering network governance, experienced entrepreneurs in a commercial environment likely will have built relationships based upon trust that may enhance the quality of resource flows through social networks (Larsson & Starr, 1993). Trust and other more "open-ended contracts" enforced by loss of reputation are particularly desirable when developing technology-based ventures where the route to market and development timescales are inherently unpredictable (Yli-Renko, Sapienza, & Hay, 2001).

Through prior business ownership experience, entrepreneurs can establish such relationships and have a positive reputation and credibility with key actors (Delmar & Shane, 2004). Less experienced entrepreneurs are less likely to have an established reputation and may be unsure how to build one. They may have difficulties communicating with actors from outside the scientific research network due to differences in knowledge, goals, and assumptions (Davidsson, 2002).

Universities may offer a context where the development of trust relationships and reputation are different and problematical. Universities have introduced technology

transfer officers (TTOs) designed to bridge structural holes between research and industry networks. However, some authors question their effectiveness (Clarysse, Wright, Lockett, Van de Velde, & Vohora, 2005; Lockett & Wright, 2005). An alternative mechanism is the use of surrogate entrepreneurs, that is, experienced managers that can help grow the venture, but identifying these entrepreneurs may require the university to develop suitable networks (Franklin et al., 2001). Additionally, academic colleagues may operate informally as mentors to academic entrepreneurs but may have limited expertise (Mosey et al., 2006). However, prior research has not established how different levels of prior business ownership experience by academic entrepreneurs can address these challenges. Hence:

RQ3: What governance mechanisms are utilized by academic entrepreneurs with different levels of prior business ownership experience to access resources through social networks at the early stages of venture development?

Ownership experience may not be the only aspect of human capital influencing the development of social networks. Previous research assigns a potentially important role to the level of education, although in the context examined here, academic entrepreneurs typically all have PhDs. Rather, there may be an important contribution to human capital from the discipline base of education and research; different disciplines may involve different business models with varying lead times, initial capital requirements, and links with customers for both innovations and revenue streams (Klevorick, Levin, Nelson, & Winter, 1995; Wright et al., 2004). Industrial experience may also contribute to human capital and enable access to social networks for the identification and exploitation of opportunities (Almeida & Kogut, 1999). The degree of success of prior business ownership may also be linked to the development of social capital. Entrepreneurs may learn from previous failure to develop more effective social networks; alternatively, entrepreneurs may not adapt sufficiently to the need to develop new social networks in new contexts if previous efforts have been successful (Ucbasaran, Wright, et al., 2003). The university incubator environments in which academic entrepreneurs find themselves differ in terms of providing access to commercial social networks (Lockett & Wright, 2005). Accordingly, our fourth research question is:

RQ4: What is the influence of discipline-based and industrial experience aspects of human capital, the degree of success of previous ventures and the nature of the university incubator environment on the ability of academic entrepreneurs with different levels of prior business ownership experience to develop social networks and access resources through social networks at the early stages of venture development?

Methodology

This research utilizes the logic of inductive inquiry to investigate complex phenomena where the interaction between the phenomena and context are unclear (Yin, 1993). The aim is to allow new theoretical insights to emerge through the process of gathering data from multiple sources, analyzing that data through comparison, and iterating between nascent theories and reexamination of the data (Glaser & Strauss, 1967; Strauss & Corbin, 1990). A multiple case-study approach was adopted, using a system of replication logic, with each case treated as an independent experiment (Yin, 1993). Multiple cases are generally more rigorous than single case studies (Eisenhardt, 1989). Within each case, the level of analysis is the entrepreneur and the unit of analysis the social capital developed by the entrepreneur. Forty-four interviews were conducted with academics, business development officers, and heads of schools involved in the process of new venture creation (Table 1).

Table 1

Characteristics of the Interview Respondents

Respondent†	Academic position	School (university)	Industrial experience††	Level of technology transfer within school 2002–2003 inclusive*	University technology transfer office FTEs**	Venture stage at start and end of 2002–2003 (Vohora et al., 2004)
Nascent 1	Professor	Mechanical engineering (5)	No	Low	22	Opportunity recognition Gaining credibility
Nascent 2	Postdoctoral	Pharmacy (3)	No	Low	1	Opportunity recognition Entrepreneurial commitment
Nascent 3	Lecturer	Bioscience (1)	Biotechnology researcher	Moderate	2	Opportunity recognition
Nascent 4	Postdoctoral	Bioscience (2)	No	Moderate	4	Opportunity recognition
Nascent 5	Lecturer	Food science (2)	No	Moderate	4	Opportunity recognition Entrepreneurial commitment
Nascent 6	Lecturer	Pharmacy (6)	No	High	8	Opportunity recognition
Novice 1	Professor	Mechanical engineering (5)	No	Low	22	Entrepreneurial commitment Gaining credibility
Novice 2	Senior lecturer	Electronic engineering (4)	No	Low	5	Entrepreneurial commitment Gaining credibility
Novice 3	Senior lecturer	Electronic engineering (4)	No	Low	5	Entrepreneurial commitment Gaining credibility
Novice 4	Lecturer	Pharmacy (3)	No	Low	1	Entrepreneurial commitment
Novice 5	Lecturer	Electronic engineering (4)	Electronics industrial engineer	Low	22	Entrepreneurial commitment Gaining credibility

Novice 6	Professor	Food science (2)	Food industry researcher	Moderate	4	Entrepreneurial commitment Gaining credibility
Novice 7	Professor	Chemistry (4)	No	Moderate	5	Entrepreneurial commitment Gaining credibility
Novice 8	Senior lecturer	Bioscience (1)	No	Moderate	2	Entrepreneurial commitment
Novice 9	Senior lecturer	Bioscience (1)	Pharmaceutical researcher	Moderate	2	Entrepreneurial commitment
Novice 10	Senior lecturer	Chemistry (3)	No	Moderate	1	Entrepreneurial commitment Gaining credibility
Novice 11	Lecturer	Pharmacy (1)	Pharmaceutical researcher	Moderate	2	Entrepreneurial commitment
Novice 12	Professor	Pharmacy (6)	No	High	8	Entrepreneurial commitment
Habitual 1	Senior lecturer	Mechanical engineering (5)	No	Low	22	Opportunity recognition Gaining credibility
Habitual 2	Lecturer	Pharmacy (3)	No	Low	1	Entrepreneurial commitment Gaining credibility
Habitual 3	Senior lecturer	Bioscience (2)	Pharmaceutical researcher	Moderate	4	Entrepreneurial commitment Gaining credibility
Habitual 4	Senior lecturer	Bioscience (1)	Pharmaceutical researcher	Moderate	2	Entrepreneurial commitment Gaining credibility
Habitual 5	Senior lecturer	Bioscience (4)	No	Moderate	5	Entrepreneurial commitment Venture growth
Habitual 6	Postdoctoral	Pharmacy (6)	No	High	8	Opportunity recognition Venture growth

* A technology transfer rating of high means greater than one USO or licensing deal, a rating of moderate means between zero and one USO or licensing deals, a rating of low means zero USO and licensing deals (adapted from Wright et al., 2003).
** Full-time equivalent staff in post in TTO FY 2002–2003.
† From each of the 10 schools the head of school and technology transfer officer were also interviewed.
†† Relates to industrial experience prior to current academic position.
USO, university spin out; TTO, technology transfer office.

Twenty-four academics were selected exhibiting a variance in terms of prior business ownership experience as follows: 6 nascent entrepreneurs, 12 novice entrepreneurs, and 6 habitual entrepreneurs. The threshold point for the entrepreneurs is prior business ownership experience at the start of the year of study. Following the stages in the university spin-out process identified by Vohora et al. (2004), nascent entrepreneurs were defined as those entrepreneurs in the process of addressing the opportunity recognition juncture between research and the framing of an opportunity at the start of the period. Here they are engaged in identifying alternative markets, what applications of the technology to develop for those markets, and how best to access customers to target with the innovation. Novice entrepreneurs were defined as those that had already crossed the opportunity recognition juncture and were addressing the entrepreneurial commitment juncture at the start of the period. Here they have formed a business that is operational and engaged in business transactions. Habitual entrepreneurs were defined as having previously formed at least one other business at the start of the period. The last column in Table 1 provides information on the venture stage at the start and end of year, and shows how each type of entrepreneur progressed their current venture over the period of study. We considered the ventures to progress to the gaining credibility phase when they were transacting with potential customers and accessing stocks of resources from suppliers and (or) partners. We defined the ventures to have reached venture growth when they were reconfiguring existing resource weakness and inadequate capabilities into resource strengths that enable the spin-off to generate returns.

The respondents were based within 10 schools of engineering or applied science in 6 U.K. universities, with the different schools and universities selected to exhibit a diversity of prior commercialization performance (Mustar et al., 2006). Ten business development officers and 10 heads of school were also interviewed to provide a different perspective.

The academics were identified through their participation in intervention schemes to stimulate academic entrepreneurship. Thus we could observe the development of academics' social capital over the academic year 2002–2003 as they engaged with business plan competitions, proof of concept funding, and fellowship schemes. As our purpose is not to compare the development of social capital between those entrepreneurs using such schemes and those not using them, this focus should not pose selection bias problems. Moreover, focus on this set of entrepreneurs provides a degree of homogeneity that helps control for other factors outside the study's focus. We interviewed academics at the start and end of the academic year during which the intervention schemes were in place.

With respect to network structure, respondents were asked to consider which types of network actors they used to help create and develop their ventures. They were asked to select from a list of actors based within and outside the university (Wright, Binks, Lockett, & Vohora, 2003). From this list, respondents were asked to indicate which actors they used at the start of the year of study and which relationships they developed during the year. With respect to network content, respondents were asked to report the value of the categories of actors to their commercialization efforts using a 5-point scale.[1] Concerning network governance, respondents were asked to explain how they had built new relationships over the course of the year, what governance mechanisms they used, and what resources they gained from these new ties.

The interviews lasted on average two hours. Interview transcripts were analyzed separately for each case by consideration of the research questions and a running record

1. The following scale was used: (1) not at all useful, (2) not useful, (3) neither not useful nor useful, (4) useful, and (5) very useful. The results are shown in Table 3.

of analysis and interpretation was kept (Voss, 2002). This allowed for the analysis of each case as a "stand-alone entity" to allow the patterns of each case to emerge, before comparisons were made between cases (Eisenhardt, 1989). Interactions with the participants also took place during the year through workshops and informal meetings.

Subsequently, cross-case analyses were made to help highlight the exceptional from the norm (Miles & Huberman, 1984). Construct validity was considered by comparing the views of the academics with the views of TTOs and heads of school and through examination of sources of secondary data. Sources included records of commercialization performance of the participating schools, curriculum vitae of the academics, and evaluation reports from the various intervention schemes. This evidence was recorded in a unique, identifiable way to provide a chain of evidence (Voss, 2002). Internal validity was maximized by considering cases from different geographic and academic contexts. Time sequences of certain, key events were observed directly by one researcher during attendance at workshops and informal meetings. This was augmented by capturing opinions of potential causality made during respondent interviews. The interview transcripts, documentary evidence, and notes on opinions of potential causality were read and reread as data were collected; emerging themes were refined as this process progressed. Throughout the analysis the validity of the emerging insights were checked by discussion with key actors (Yin, 1993). In order to avoid confirmatory biases, one of the researchers was kept at a distance during the data collection and examination process. The data analysis is presented in two-ordered steps (Taylor & Bodgan, 1984). In the next section, we present our findings. Initially, a first-order analysis of the patterns of social capital development is presented under the three headings of network structure, network content and network governance for each of the three types of entrepreneur in turn. This is followed by a second-order analysis that is used to develop propositions through analytical generalization (Yin, 1993).

Findings

Patterns of Social Capital Development

The entrepreneurs were situated in schools and universities with a diverse track record in the encouragement and support of entrepreneurship. Some academics were working in schools without previous experience in new venture creation, yet others were based within schools that had developed several spin-offs during the previous academic year (Table 1, cols. 5 and 6). Through analysis of the data we found consistent differences in human and social capital between entrepreneurs that managed to progress their ventures during the year and those that did not, irrespective of the entrepreneurial environment.

Specific human capital such as prior business ownership experience appeared to relate to differences in social capital and venture development. Table 2 summarizes the significant differences seen in structural social capital between nascent, novice, and habitual entrepreneurs. Table 3 summarizes the perceived value of each aspect of social capital for the three types. At the start of the study, novice entrepreneurs had on average only developed two types of network tie. By contrast, novice entrepreneurs had developed 9 types of tie and habitual entrepreneurs 13 different types of network tie. An analogous pattern was observed when comparing network structure and governance between different types of entrepreneur.

In contrast to business ownership experience, prior industrial experience did not appear to relate to venture growth. This may reflect the fact that, for those academic entrepreneurs who did have prior industrial experience, this was typically as a research

Table 2

Summary of Structural Social Capital of Different Types of Entrepreneur

	Average number of types of tie	Standard deviation	Number of entrepreneurs
Existing ties nascent entrepreneurs	**2.3**	**1.4**	**6**
New ties nascent entrepreneurs	2.5	1.4	6
Existing ties novice entrepreneurs	**8.7**	**3.9**	**12**
New ties novice entrepreneurs	1.8	1.7	12
Existing ties habitual entrepreneurs	**13.3**	**1.6**	**6**
New ties habitual entrepreneurs	4.3	1.4	6

Table 3

Perceived Value of Social Capital of Academic Entrepreneurs

	Nascents		Novices		Habituals	
Network actor	Frequency	Average	Frequency	Average	Frequency	Average
Venture capital firms	0	—	4	2.5	4	3.00
Business angels	1	5.0	4	1.8	6	3.67
Surrogate entrepreneurs/interim managers	0	—	2	2.0	4	5.00
Professional venture management firms	0	—	1	1.0	2	2.00
University challenge/proof of concept funds	2	4.0	5	4.4	5	3.40
Business link (or regional equivalent)	0	—	9	2.6	5	2.20
Regional development agencies	1	5.0	8	2.6	6	2.33
Management consultants	0	—	5	3.4	5	3.20
Intellectual property/legal firms	5	4.2	9	4.6	6	3.67
Other universities	1	5.0	5	3.6	4	3.50
Private laboratories	0	—	2	3.0	2	4.00
SMEs	3	5.0	9	3.6	5	3.80
Large firms/industry	1	5.0	11	4.0	6	3.83
Science parks	0	—	4	3.5	2	4.50
Business incubators	0	—	4	4.3	3	4.00
TTO	4	3.0	12	4.4	5	3.00
Government grants (e.g., SMART awards)	0	—	8	4.6	6	3.17
Research colleagues	4	4.8	5	4.0	6	4.33
N	**6**		**12**		**6**	

Note: Respondents were asked to report the value of the categories of actors to their commercialization efforts using a 5-point scale where the following scale was used: (1) not at all useful, (2) not useful, (3) neither not useful nor useful, (4) useful, and (5) very useful.
SMEs, small- and medium-sized enterprises; TTO, technology transfer officer.

scientist rather than in a direct commercial role (Table 1, col. 4). Seniority of academic position also did not appear to reflect the rate of venture development (Table 1, col. 2).

A notable observation emerged in comparing entrepreneurs with similar levels of prior business ownership experience; the academic discipline of the entrepreneur was related to venture development rate (Table 1, col. 3). Consequently, findings are reported separately for academics having different levels of prior business ownership experience at the start of the year of study and, within each section, comparisons are made between academics from different disciplines.

Nascent Entrepreneurs

Network Structure. For nascent entrepreneurs, the two most commonly used categories of actor were research colleagues and intellectual property (IP)/legal firms (Table 2). At the start of the year, four out of the six nascent entrepreneurs used these actors and three of the six developed new ties with these actors during the course of the year. The remaining categories were utilized less. Two used the TTO, two used local government advisors, and one used small- and medium-sized enterprises (SMEs)/large firms. However, a greater diversity of ties was developed during the course of the year, including university proof of concept funds and business angels.

Network Content. The nascent entrepreneurs perceived all of the categories of actors they used to be useful with the exception of the TTO, having an average score of 3. Subsequently, we asked open-ended questions regarding the resources gained from the different categories of actors. Four of the six nascents approached the TTO for advice on opportunity recognition. Yet, they perceived the advice they received to have less value than that received from other sources. For some nascents this was due to the lack of direct commercialization experience of the TTO [Na5].

Another negative issue was the perception that the TTO thought that academic scientists should not be directly involved in the commercialization process, as explained by Na4:

> The TTO have a very fixed model and that is that the scientist is the bench monkey and there isn't really anything else that they see a scientist doing, there is a credibility issue there.

By contrast, nascent academics were more complimentary regarding the opportunity recognition advice they received from academic colleagues who had direct commercialization experience:

> Two of my research colleagues are quite inspirational, they are both people that you can turn to for advice and opinion, to look for an example of how to drive things ahead and how to make things happen [Na4].

Network Governance. In explaining how they had built new relationships over the course of the year and what governance mechanisms they used to gain resources from these new ties, a clear distinction was seen between Na1, Na2, and Na5 and the other nascents. These academics had developed their ventures during the course of the year, becoming novice entrepreneurs by the end of the period, whereas the remainder had not.

For instance, Na2 and Na5 gained critical resources through building ties with local government funding agencies. They were positive regarding the financial resources and management advice they gained from these proof-of-concept funds. This was typically regarded as a "less bureaucratic" source of funding, with less stringent monitoring, than

usual research funding sources [Na2]. In addition Na5 used networking events organized by government support agencies to build less formal ties with founders of SMEs to gain their advice:

> Talking to people that had previously been scientists and had taken their projects forward and had started businesses made me realize that a scientist could do that work and it wasn't just a select few people who effectively trained and were born to do it.

The single nascent entrepreneur that developed their venture to the stage of "gaining credibility" by the end of the year was Na1. They achieved this by building more formal ties with potential development partners. In this way they could gain proof of concept funding and valuable industry-specific knowledge. Na1 explained how the TTO helped them to attract potential partners:

> To attract potential partners the IP office suggested we make some commercial in confidence flyers. We disseminated these everywhere we could think. . . . Six firms of differing sizes came to visit us and signed confidentiality agreements. We had a dialogue with a number and then one came on board as development partners. They have been absolutely fantastic. They provide in kind funding . . . they provide advice, collaboration and time. They provide market info as we have access to their customers who would make use of this technology so we have a route to market. They gave us an insight into how companies work with customers and how the system should be changed to meet customer needs.

In summary, nascent entrepreneurs appear inspired by more experienced colleagues but frustrated by the lack of assistance provided by the TTO, with the exception of Na1. Na1 had already built a relationship with the TTO and spent the year of the study building ties with industry partners using the TTO as an intermediary. One factor that differentiates this academic from the remaining nascents is their academic discipline. Na1 is a professor of mechanical engineering whereas the remainder are mainly pharmaceutical and biological scientists. The potential significance of this difference in human capital is explored further below. However, within the nascent entrepreneurs group it appears a more significant differentiator than prior industrial experience. The only nascent entrepreneur with industrial experience was Na3, an academic who did not manage to develop their venture during the course of the year, despite prior experience within a biotechnology firm.

Considering the remaining nascents that were still attempting to build such relationships, TTO2 gave an insight into this frustration:

> I haven't enough resource to spoon feed these guys. They have no idea if there is a market for their technology or an appreciation of how to find out. I focus my efforts on the more experienced guys, the low hanging fruit, to meet my targets.

Novice Entrepreneurs

Network Structure. The group of novice entrepreneurs had in place a greater number and variety of network ties at the start of the year of study than the nascent group. They were seen to develop a greater number of ties during the year of study. Considering the network structure in place at the start of the year, the most commonly used actors were the TTO, utilized by the entire group. This can be seen in Table 2.

The majority also used IP firms, local government advisors, large firms, and SMEs. By contrast, fewer made use of providers of proof of concept funding and providers of equity finance. The least utilized types of actors were surrogate entrepreneurs and professional venture management firms. The most commonly used actors with whom new ties

were developed were large firms. The next most popular were finance providers in the form of government grants and equity investment. Finally, a minority built new ties with research colleagues, incubators, and SMEs.

Network Content. Respondents supported the views of the nascent entrepreneurs in the perceived high value of advice received from research colleagues. However, they also saw value in resources gained from a wider diversity of resources than the nascent entrepreneurs, as shown in Table 3.

It appears that, when controlling the same university, novice entrepreneurs gave greater credence to the assistance provided by the TTO than the nascent entrepreneurs [e.g., No5]. Respondents were also consistently positive regarding providers of proof of concept funding such as government grants and the university challenge fund,[2] which No5 argued were easy to get once the process was understood. Equally, respondents were positive regarding the resources they gained from actors within large firms, such as valuable proof of concept knowledge and manufacturing facilities [e.g., No10]. This is supported by No2 who sees similar resources through a partnership agreement:

> I formed a partnership with two power stations and got the prototype closer to market. I set it up as a demo in the station for a low price and then we will prove the concept together in an industrial environment. My firm is jointly owned by me, the Uni, and an SME. They are still a major shareholder and are my gateway to the market as they are leaders in power generation supply and route to market.

By contrast, respondents were less positive regarding the advice they received from regional business advisors and consistently negative regarding their interactions with providers of equity finance.

Network Governance. Considering network governance, all respondents had built a relationship with the TTO by the start of the year, and were positive regarding the value of the legal advice given. However, a critical difference was seen when comparing those academics that had progressed their ventures from entrepreneurial commitment to gaining credibility with those that had not. Two such academics, No1 and No10 used the established relationship with the TTO to help connect them to new network ties. For instance, No1 gained assistance from the TTO to formulate legal documents and to help find potential licensees for their technology. The value of the "brokering" role of the TTO was explained by this entrepreneur:

> The TTO had contact with this [large] firm before and tried to spin out another firm but failed so they introduced us and we walked out after half and hour with an agreement.

No7 was another novice that managed to progress their venture forward in a similar way. They worked together with a TTO based within their school to apply for University Challenge proof of concept funding and found the process effective.

In addition to using the TTO network of contacts to access potential partner firms' expertise, the remaining entrepreneurs that managed to develop their ventures, No1 and No2, were also seen to utilize their research contacts to appropriate business resources. This is explained by No2:

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2. University Challenge Funds are a U.K. government-funded scheme. For discussion see Wright, Lockett, Binks, and Clarysse (2006).

> I was working with the SME owner on a [government-funded] research project and we were sitting down watching a football match. . . . We discussed the ramifications of my technology and how it could be applied in x/y/z. He was an adventurous guy he would say let's try it . . . and see if they meet a real industrial need to convert from the lab to a hostile industrial environment. He put up the cash to do it.

In summary, it appears that the novice entrepreneurs' broader social networks are reaping rewards in terms of critical resources for their ventures. They have all built effective relationships and credibility with the TTO and utilized this relationship to gain access to legal advice and additional resources through the TTO extended network. Through this "brokering" role, the TTO helps bridge a structural hole by drafting formal partnership agreements with potential industry partners, from whom entrepreneurs gained proof of concept funding, facilities, and industry knowledge. Moreover, two entrepreneurs were seen to develop their own direct ties with industry by appropriating existing research ties with industry contacts to help develop a route to market for their technologies.

Here the initial distinction observed relating to the discipline of study within nascent entrepreneurs is reinforced. The seven novices progressing to the stage of gaining credibility for their ventures were situated in schools of mechanical engineering, electronic engineering, food science, and chemistry. Those who did not progress beyond entrepreneurial commitment were situated in schools of bioscience and pharmacy. It appears that within the novice entrepreneurs group, this specific facet of human capital relates to the rate of social capital and venture development. Again the influence of prior industrial experience held by No9 and No11 does not appear to positively influence their venture development capability.

Habitual Entrepreneurs

Network Structure. The habitual entrepreneurs exhibited the greatest number of ties at the start of the year. Yet they were surprisingly focused regarding the new ties they built. At the start of the year the majority of respondents utilized the majority of sources, as shown in Table 2. Critical exceptions were the use of surrogate entrepreneurs by only two of the six respondents, private labs with only one user, and professional venture management firms with no users.

During the year, respondents were focused and consistent regarding the new ties they built. They were all engaged in building ties with large firms and three of them were also building ties with SMEs. Equally, they were all developing new ties with equity investors, either business angels or venture capitalists. However, they were active in seeking professional venture growth advice with three seeking surrogate entrepreneurs, two seeking professional venture management firms, and two building ties with science parks.

Network Content. Habitual entrepreneurs proposed that their most valuable ties were those to the providers of industry knowledge, business development knowledge, and technical knowledge (Table 3).

Considering potential providers of industry knowledge, surrogate entrepreneurs were rated the most highly by the two respondents engaged with them. Habitual entrepreneur #5 [H5] explains their value:

> I approached a local entrepreneur renowned for helping start-ups . . . he wanted 15% of the business to help develop it. However, I didn't take the offer, because it seemed a lot of equity to give away. But I should have taken the offer as it was a lot slower developing the business by myself. However, through this meeting I was introduced

to (Surrogate entrepreneur #1, [Su1]) from Insight and made him a nonexecutive director . . . . Su1 gave a talk and I trusted him. I went to him for advice for one year before convincing him and his colleague to sign up to the business.

Similarly, H4 was complimentary regarding the assistance received from science parks, specifically the science park manager who gave them access to "a trusted network of investors, people with business development experience, and potential customers." A perhaps surprising result was the continued value seen in research colleagues by habitual entrepreneurs. These ties were seen to provide credibility to the venture through the reputation of academia and also through providing a source of new technologies to retain its competitive position [H2].

Yet, habitual entrepreneurs appear scathing of local government advisors and government support initiatives:

> In my region for each spin-out company there are 20 local government employees supposedly providing assistance. What a waste of resources. When I worked in the U.S. there was no government help, if you wanted to do it you went out and did it. The money was there if you wanted it. [H4]

Regarding other sources, there was a less consistent view of their value. For instance, some entrepreneurs saw value in their relationship with the TTO, yet others were more negative, as explained by H1, and supported by Head of School #1:

> TTOS are OK but they have a fundamental conflict of interest. . . . They look out for the university's interests first and foremost so tend to delay for the highest deal. This happened to me and we lost the deal, so next time we employed our own lawyers and got a better deal in half the time.

The habituals interviewed from universities where the TTO has a strong track record still argued that they succeeded despite of rather than because of the TTO, that is, the TTO intervention was seen by habituals as a barrier regardless of the TTO capabilities.

A similar dichotomy of views was seen regarding equity finance providers. This may be influenced by the outcome of the interaction. For instance, H2 had difficulty in raising equity finance for their drug discovery business:

> It's very frustrating, you send off business plans, make pitches and they drag you along for six months and then drop you like a stone. I would like to know what they are looking for.

In contrast, entrepreneurs that had previously gained equity finance were more positive in their evaluation, as explained by H6:

> Through conducting due diligence with the VCs [venture capitalists], I really had to understand the technology to give comfort to the investors. And until you have done a deal you don't know what it all involves. Once you have done a couple of deals and met a couple of times, trust comes thereafter.

Network Governance. Habitual entrepreneurs were prolific networkers during the year of study. They were active in maintaining their established relationships with research colleagues, IP firms, and large and small firms. Moreover, they were also engaged with building new ties with providers of business development knowledge, equity finance, and industry knowledge/potential customers. H5 and H6 were the most effective at this. They were also the only two entrepreneurs able to attain venture growth during the year. Here again prior industrial experience did not appear to be a contributory factor. When

questioned regarding how they built these new relationships these two entrepreneurs appeared more strategic (and effective) in their aims than the novice and nascent entrepreneurs. This is expounded by H5:

> I am very focused when I attend meetings and conferences. Targeting the right people is so important. . . . So when you first build a contact with someone it becomes your asset. Then the next time you talk you are welcomed differently. You are equipped with a stronger network that makes you stronger.

This view is supported by H6, who argues that seeking to learn drives their networking behavior.

They also see their role as helping others to learn, to motivate the next generation of entrepreneurs. These ties can also provide an additional benefit in terms of a potential source of new technologies for their ventures, as explained by H6:

> When you meet new researchers you don't know where it will lead. I never thought I would set up another firm. It just happened. You are presented with an opportunity and you think about it. It looks great, they are enthusiastic and it's exciting so you go for it.

This view is supported by TTOs who see successful academic entrepreneurs as invaluable in inspiring others to follow [TTO3].

Habitual entrepreneurs also appear to value experienced managers more highly than the other two groups. They seek out these actors to learn from them and to help grow their ventures, as explained by H3:

> I need someone I can trust to manage the business when I am away, which is most of the time. Experienced managers are worth their weight in gold, so pay more than you can afford to keep them.

In summary, habitual entrepreneurs appear to have broader social networks than their less experienced colleagues. This gives them access to a wider range of resources from finance to industry-specific knowledge. However, what is less obvious is that it is not just that they had more ties but it was the nature of such ties that was important. They are seen to focus upon ties to gain equity finance and venture development knowledge to rapidly grow their early stage ventures.

They are also seen to build new ties with researchers to identify new opportunities and match technologies to their knowledge of industry needs. In terms of governance they used a wide range of mechanisms, but predominantly informal "open-ended" contracts were utilized due to their established reputations.

Surprisingly, the observed differences relating to academic discipline within nascent and novice entrepreneurs were not seen for habituals. It may be that prior business ownership experience can allow entrepreneurs to overcome discipline-related limitations.

The past performance of the habitual entrepreneurs may influence their social networks in respect of the current venture. Table 4 summarizes the number of prior ventures, the venture growth stage of the prior venture, and an indication of previous venture performance in terms of whether it had exited, failed, or was growing. The only clear pattern that emerges appears to be the increased likelihood of habitual entrepreneurs obtaining venture capital investment if they had already done so; this seems to be at some variance with evidence from habitual entrepreneurs in general (Wright, Robbie, & Ennew, 1997).

Table 4

Performance of the Prior Ventures of Habitual Entrepreneurs

	Number of ventures owned prior to year of study	Venture stage at start of year of study	Performance of ventures in FY prior to year of study
		Failed	—
H1	2	Venture growth	Licensing income
H2	1	Venture growth	2nd round VC investment
H3	1	Venture growth	Contract research income
H4	1	Exit	Trade sale to cosmetics firm
H5	2	Venture growth	2nd round VC investment
		Venture growth	Consultancy income
H6	2	Exit	Trade sale to pharmaceutical firm
		Venture growth	2nd round VC investment

H, habitual entrepreneur; VC, venture capitalist.

Development of Propositions

We found consistent differences between the social capital developed by the different types of entrepreneurs over the year of study. These differences are summarized in numerical terms in Tables 2 and 3. Table 5 develops a framework, based upon the evidence presented in the previous section, which identifies the specific types of social capital for each type of entrepreneur. Using this framework, we compare these findings with contemporary research and develop propositions to guide future research.

Network Structure. We highlighted a major distinction between the number of network ties in place at the start of the year between nascent, novice, and habitual academic entrepreneurs (Table 2). More experienced academic entrepreneurs have access to broader social networks as proposed by Westhead and Wright (1998) in respect of commercial sector entrepreneurs. Novice academic entrepreneurs had broader social networks than nascent entrepreneurs but encountered structural holes to providers of equity finance and management knowledge. However, it is the nature of the social networks that differ not just their breadth.

Evidence in the previous section shows nascent entrepreneurs to have the most limited social networks. They found it difficult to engage outside their immediate scientific research network. Their most-valued ties were with more experienced academic colleagues with prior business ownership experience (Table 5, col. 1). Yet they found it difficult to establish relationships with the TTO. This supports studies that call for fundamental changes in the support for nascent academic entrepreneurs (Mosey et al., 2006).

Our evidence also indicates that the nascent and novice entrepreneurs that built ties outside their scientific research network were more likely to be based within schools of engineering or the material sciences. Entrepreneurs within such schools may be approaching industries more receptive to such collaborative working relationships because of the complementarity of expertise (Gans & Stern, 2003). Alternatively, it may be due to the nature of the technology they develop. Their technologies appear more suitable for development into prototypes and ultimately industrial products or processes

Table 5

Summary Findings of Social Capital Development between Different Types of Entrepreneur

Type of entrepreneur	Focus of social network structure developed (col. 1)	Network content gained (col. 2)	Network governance issues (col. 3)	Typical stage of venture development after 1 year (col. 4)
Nascent entrepreneur (row 1)	More experienced academic colleagues Engineering & materials science more able to build ties outside scientific network	Advice on recognizing opportunities and IP protection but difficulties in engaging with TTO	Experienced structural holes to industry networks Links with more experienced academic entrepreneurs & TTO	Opportunity recognition Entrepreneurial commitment
Novice entrepreneur (row 2)	TTO Industry networks Engineering & materials science more able to build outside ties	Proof of concept funding Market knowledge Identification of potential customers Materials science & engineering disciplines use TTO & broker deals with industry contacts	TTO acts as broker managing formal legal agreements to funding bodies and industry contacts especially for engineering and materials science	Entrepreneurial commitment Gaining credibility
Habitual entrepreneur (row 3)	Academic colleagues Equity funders Professional Managers Not discipline constrained	New technologies Equity finance building on prior success Venture management knowledge Going beyond TTO	Developing direct "open ended" relationships based upon trust to replace TTO & government advisers	Gaining credibility Venture growth

Source: Interviews.
IP, intellectual property; TTO, technology transfer officer.

than the technologies typically emanating for the biological sciences. Established industry practices exist to develop such "product-ready" technologies through early-stage investment and codevelopment. Such practices are less commonplace within the pharmaceutical sector and are exacerbated by the relatively high regulatory barriers present for developing new pharmaceutical or biological entities (Oliver, 2004). To overcome these barriers, a significant capital investment is necessary thereby equity investors are typically required to finance the development to the later stage where industry players will seek involvement.

Selected habitual entrepreneurs with a successful track record of raising equity investment overcame this discipline-related barrier. This suggests that prior business ownership experience can help gain credibility within industries that have such limitations regarding time to market and appropriability regime (Ucbasaran, Wright et al., 2003). Hence:

> **Proposition 1a:** Nascent and novice academic entrepreneurs from engineering and material science disciplines are more likely to build new ties outside the scientific research network than those based in biological sciences and pharmacy (Table 5, col. 1, rows 1 and 2).
>
> **Proposition 1b:** Technology-based academic entrepreneurs with prior business ownership experience are more likely to build new ties outside the scientific research network regardless of their academic discipline (Table 5, col. 1, row 3).

Network Content. Different types of entrepreneurs typically gained different types of resources from their network ties during the year of study (Table 5, col. 2). This may be partly due to the experienced entrepreneurs developing their ventures more rapidly (Larsson & Starr, 1993). An initial barrier to new venture formation is a lack of opportunity identification knowledge (Vohora et al., 2004). This issue appeared to be especially important for the majority of nascent entrepreneurs who spent the year of study seeking advice regarding opportunity recognition. Specifically, they sought legal advice to protect their IP and advice regarding how to develop their research to meet a commercially attractive opportunity (Table 5, col. 2, cell 1). Nascent entrepreneurs exhibited an inability to conceptualize how their technologies can be best applied to satisfy a real industry need, finding it difficult to engage with the TTO, let alone actors external to the university.

By contrast, novice entrepreneurs were typically engaged at the next stage of venture development, where they were seeking proof of concept funding and industry knowledge regarding potential customers and their unmet needs (Table 5, col. 2, cell 2). Here a lack of prior business ownership experience posed problems in gaining credibility outside the university (Vohora et al., 2004). This limited their ability to attract surrogate entrepreneurs or experienced managers and constrains their likelihood of raising initial equity finance.

Different again, habitual entrepreneurs were typically engaged in raising equity finance and gaining management knowledge to help grow their ventures, thereby overcoming the potential barrier of reorientation (Table 5, col. 2, cell 3). Here the need to manage growth and secure next round finance has to be balanced with the reorganization of resources to meet market needs.

An important difference emerged when the three types of entrepreneurs were engaged at a similar stage of venture development. Habitual and novice entrepreneurs spent the year of study focusing upon gaining credibility for their ventures and habitual and nascent entrepreneurs were concurrently engaged with gaining entrepreneurial commitment.

By comparing these entrepreneurs, we are able to propose that different types of entrepreneurs have a differing efficacy at gaining resources. Habitual entrepreneurs appear more likely to gain initial equity finance than nascents, possibly due to prior experience

(Ucbasaran, Wright et al., 2003) or established social capital (Kassicieh et al., 1996). Equally, habitual entrepreneurs appear more likely to gain management knowledge from surrogate entrepreneurs than novices. This could be due to their social capital (Franklin et al., 2001) or because they are more discerning customers; through venture creation experience they know what they are looking for.

An interesting observation was the apparent lack of influence of prior industrial experience upon the capability of academics to build ties outside the research network. Experience as a researcher within a large pharmaceutical firm or biotechnology firm may not necessarily be advantageous in developing relationships with managers who provide finance or management knowledge for new ventures.

Another observed distinction between different types of entrepreneurs is in the perceived value of the TTO. Novice entrepreneurs, in particular those from engineering and material science disciplines, appear consistently positive. A minority of habitual and nascent entrepreneurs support this view. However, others are more critical of the lack of direct commercial experience and the potential conflict of interests within the TTO. Given the target and incentives for TTOs regarding the establishment of spin-off companies, nascent entrepreneurs appeared to require a disproportionate amount of their limited expertise and effort. By contrast, novice entrepreneurs from engineering and the material sciences appear to offer the TTO a more attractive option. Here they can more easily broker deals with established industry contacts and thereby meet their institutional targets. Habitual entrepreneurs' experience may make them more independent of the TTO. Nonetheless, the different types of entrepreneur share similar views of the value of one type of actor, their research colleagues. These actors were rated consistently highly by all types and were seen to provide advice, guidance, and access to new technological knowledge. Hence:

Proposition 2a: Novice academic entrepreneurs from engineering and the material sciences are more likely to gain proof of concept funding and market and industry knowledge using the university technology transfer office than habitual and nascent entrepreneurs (Table 5, col. 2, rows 1 and 2).

Proposition 2b: Nascent and novice academic entrepreneurs are more likely to gain management resources from their research colleagues than are habitual academic entrepreneurs (Table 5, col. 2, rows 1 and 2).

Proposition 2c: Prior business ownership experience is more important than more generic industrial experience in gaining management knowledge and equity finance from network actors external to the university (Table 5, col. 2, row 3).

Proposition 2d: Habitual academic entrepreneurs are more likely to gain technical resources from their research colleagues than are nascent and novice academic entrepreneurs (Table 5, col. 2, row 3).

Network Governance. Clear differences were observed between the methods used by different types of entrepreneurs to maintain existing ties and to build new ones. Nascent entrepreneurs were typically limited to building ties within the university network, with more experienced academic entrepreneurs, and TTOs (Table 3, cols. 1 and 2). This was a natural extension of their existing relationships and did not require them to radically change their behavior. When they attempted to build relationships outside the university network they found it challenging, as the "rules of the game" were uncertain and they encountered language and goal uncertainties (Davidsson, 2002).

Novice entrepreneurs were more effective at building ties outside the university through attending networking events held by local government agencies and through

brokerage activities managed by the TTO (Table 3, cols. 3 and 4). They were also effective at building relationships with proof of concept funding agencies. They were less effective at engaging with equity financiers, large and small companies, and professional managers. A minority, based within engineering or material sciences, engaged with partner firms using joint ventures to manage this relationship. Again this process was typically brokered by the TTO.

Habitual entrepreneurs built relationships very differently. They tended to have already worked closely with research colleagues, TTOs, local government advisors, and proof of concept funders (Table 3, cols. 5 and 6). Through this interaction, they were active in strengthening useful relationships and finding alternatives to less effective ones. For instance, as some habitual entrepreneurs had found TTO and government advisors to be obstructive, they had built new relationships with professional legal advisors, to replace the TTO, and with large and small firms, to replace the government advisors. Thus, they could negotiate deals on their own terms without the need for a "middleman" who may have a different agenda.

Habitual entrepreneurs were also more strategic regarding the new ties they wished to build. For instance, if they saw a resource gap within their venture(s) for professional management, they subsequently used their existing social capital to identify a suitable manager or build a relationship with a new one. Equally their relationships with equity financiers were more effective than the other two groups (Oliver, 2004). Again by repeatedly working together with these actors they established relationships based upon trust rather than formal contracts. Consequently, they were in a better position to understand their partners' needs and to identify new providers to meet their goals. These relationships were typified by the parties agreeing to share the risks and rewards. Hence:

Proposition 3a: Nascent and novice academic entrepreneurs from engineering and material sciences are more likely to develop joint ventures with large and small firms, brokered by the university TTO than those based in biological sciences or pharmacy (Table 5, col. 3, rows 1 and 2).

Proposition 3b: Habitual academic entrepreneurs are more likely to build open-ended relationships based on trust with equity financiers through repeated interactions than novice or nascent academic entrepreneurs (Table 5, col. 3, row 3).

Venture Development. We observed significant differences in the stage of venture development typically attained by the different types of academic entrepreneur during the year (Table 4, col. 4). Nascent entrepreneurs are typically constrained by the difficulties of gaining entrepreneurial commitment in forming a business that is trading and engaged in commercial transactions, as observed by Vohora et al. (2004). The novice entrepreneurs had passed this juncture but then encounter barriers to gaining credibility with external stakeholders for their fledgling ventures. By contrast, habitual entrepreneurs more rapidly gained credibility for their ventures and were typically addressing issues of venture growth. Consequently, we propose that differences in social capital developed by habitual entrepreneurs with actors external to the university help them to gain credibility for their ventures. Hence

Proposition 4: Habitual academic entrepreneurs are more likely to overcome the critical juncture of gaining credibility for their new ventures than novice or nascent academic entrepreneurs.

Discussion

Despite a diversity of entrepreneurial environments, consistent differences were observed between entrepreneurs with different levels of business ownership experience. A number of structural holes were identified that appear to constrain the development of nascent and novice entrepreneurs. First, a structural hole exists between scientific research networks and industry networks that constrains opportunity recognition. Nascent entrepreneurs appeared unable to engage with industry actors to match their nascent technologies to a market need. By contrast, for selected novice entrepreneurs based within engineering or material sciences, the provision of TTOs, government advisors, and proof of concept funding appears to have partially bridged this structural hole.

Second, structural holes between academics and financiers and professional managers appear to constrain novice entrepreneurs' ability to gain entrepreneurial commitment, venture credibility, and venture reorientation. Here, there appears to be no obvious substitute for direct business ownership experience. Habitual entrepreneurs have gained this knowledge through building network ties with equity financiers, professional managers, industry partners, and potential customers. Yet it appears that few nascent and novice entrepreneurs are building those relationships.

A surprising commonality was the consistently high value in which all entrepreneurs regarded their relationships with their research colleagues. Less experienced entrepreneurs value their research colleagues as potential role models and more experienced entrepreneurs value their colleagues as potential sources of technological opportunities. In these respects, academic entrepreneurs would appear to be distinctive from their commercial sector counterparts.

For policy makers and practitioners, we suggest there may need to be development of focused policies that meet the needs of the different types of entrepreneur and entrepreneurs from different academic disciplines. Efforts to develop more specific business networks and relationships with industrial partners may be more effective in the creation of ventures that can realize growth potential than general assistance programs. This may include the need for TTOs to recruit executives with direct commercial experience in the specific disciplines that they are targeted to support. Such actions may help address policy concerns that academic spin-offs are being created without the necessary resources to create value.

Our evidence regarding the role of experienced colleagues provides a distinctive policy insight in the context of academic habitual entrepreneurs in contrast to habitual entrepreneurs from a commercial environment. We suggest that TTOs seeking to stimulate academic entrepreneurship might usefully attempt to develop systematic ways of drawing on this experience. Entrepreneurially experienced academic colleagues may be encouraged and incentivized to become involved as team members or advisors to ventures created by nascent and novice academic entrepreneurs (Ucbasaran, Lockett, Wright, & Westhead, 2003; Vanaelst et al., 2006). The ability of entrepreneurially experienced academic colleagues to help build external networks introduces a further potential method of bridging structural holes. The role of such colleagues may also reflect the lack of experience of TTOs in starting ventures and their conflict of interest as representatives of the university. This may further emphasize the need to develop the expertise of TTOs (Lockett & Wright, 2005). A potential downside, however, is that entrepreneurially experienced academic colleagues may not necessarily be a conduit for passing on good practice. The importance of entrepreneurially experienced academic colleagues as mentors to nascent and novice entrepreneurs may help to address some of the shortcomings of TTOs in

respect of their relationships with external surrogate entrepreneurs. Previous research has suggested that surrogate entrepreneurs may have an important role to play in commercializing academic research but in this study they appeared to have a greater role to play with habitual rather than nascent or novice academic entrepreneurs.

The findings have implications for researchers. Further large-scale quantitative studies are required to test the generalizability of the propositions developed here. We suggest that the propositions can be operationalized using the typology of network actors developed by Wright et al. (2003) and the mechanisms of network content exchange developed by Callon et al. (1997). Wright et al. (2003) categorized actors within the scientific research network to include research colleague, other universities, and private laboratories. Conversely, types of actors categorized to be outside research networks include venture capital firms, business angels, surrogate entrepreneurs, professional venture management firms, university challenge/proof of concept funds, regional development agencies, management consultants, IP/legal firms, SMEs, large firms, science parks, business incubators, university technology transfer offices, and government grant providers. Callon et al. (1997) proposed that a number of mechanisms could be utilized to gain resources from these different types of actor. These include written documents (scientific articles, reports, patents, etc.), embodied knowledge (i.e., the mobility of researchers, engineers, etc.), technical objects in varying stages of development (prototypes, machines, end products), money (collaborative contracts between a research center and a firm, loans, the purchase by a client of goods or services), and orders or informal exchanges.

Moreover, our findings regarding the role of academic colleagues raise the potential for further research to compare the relative importance of internal versus external mentors. Recent attention is being addressed towards entrepreneurial team building in high-tech ventures and academic spin-offs (Ucbasaran, Wright et al., 2003; Vanaelst et al., 2006). An important dimension of team building concerns the entry and exit of members as the venture progresses and of the important role of advisors (Vanaelst et al., 2006). Thus, an additional area for research might examine the role of entrepreneurially experienced academic colleagues as part of this process. More generally, the study has also extended previous research on the heterogeneity of entrepreneurial experience which has tended to compare novice and habitual entrepreneurs (Westhead & Wright, 1998). Our study emphasizes that this heterogeneity may extend to nascent entrepreneurs in the area of social capital and that future studies of the influence of entrepreneurial experience might usefully incorporate this group of individuals.

Our findings indicate a weak negative association between seniority of academic position, entrepreneurial experience, and the development of social capital. The debate about star researchers and academic entrepreneurship has suggested that academic research may not be adversely affected by their development of commercialization activities (Van Looy, Ranga, Callaert, Debackere, & Zimmerman, 2004). Our findings suggested that this may be nuanced as mid-range senior faculty appear to be actively involved as habitual entrepreneurs. Corrolleur et al. (2004) identified an analogous situation in their study of biotechnology start-ups in France. More quantitative analysis is required to establish if this is a general phenomenon, but an additional explanation may be that the more junior faculty are opting to devote more effort to commercialization as they perceive limited options for promotion to full professor through research publications.

Finally, a number of limitations need to be borne in mind. First, the propositions are derived from a small sample comprising differences between the position, school, and universities. As such, further research might explore the issues addressed here in other academic contexts. Second, the study relates to the U.K. context and may not necessarily

be replicated elsewhere since significant differences may exist between U.S. and U.K. universities and between U.K. and other European universities with respect to incentives and support for academic entrepreneurship (Wright, Clarysse, Mustar, & Lockett, 2007). Third, although we carried out a longitudinal study the period considered was only one year. The low incidence of social network development by nascent and novice entrepreneurs may reflect the length of this period. Previous research suggests that considerable progress in gestation activities can be made by early stage entrepreneurs within a 12-month period (Alsos & Kolvereid, 1998).

Conclusions

We have used a novel longitudinal approach to examine links between different entrepreneurial experiences of technology-based academic entrepreneurs and development of their social capital. We addressed an important gap concerning the influence of the nature of academic entrepreneurs' entrepreneurial experience on the development of social capital. We also add to research linking human and social capital among entrepreneurs (Davidsson & Honig, 2003; Mosey et al., 2006).

We find important differences between the social capital of academic entrepreneurs which is related their differing levels of human capital derived from their business ownership experience. Academic entrepreneurs with prior business ownership experience have broader social networks and are more effective in developing network ties. Less experienced academic entrepreneurs encounter structural holes between their scientific research networks and industry networks that constrain opportunity recognition. Importantly, we also find that the nature of social capital is associated with the academic discipline base, with novice entrepreneurs from engineering and the material sciences encountering fewer problems in building ties than those within biological sciences. Regardless of academic discipline, business ownership experience appears essential to learn to build relationships with experienced managers and potential equity investors. Finally, academic entrepreneurs appear distinctive from their commercial sector counterparts with respect to the importance of relationships with their research colleagues but these also differ according to business ownership experience: less experienced entrepreneurs value them as potential role models while experienced entrepreneurs value them as potential sources of technological opportunities.

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