

9. The Role of the university in the genesis and evolution of research-based clusters

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The modern research university, by its commitment to research and the advancement of science and technology, continuously produces inventions, as well as the occasional technological breakthrough, that provide the type of opportunities that allow entrepreneurs to create new firms. The discovery of these opportunities, and assembling the resources to exploit them, has been described as the entrepreneurial event (Feldman 2001) or as the act of entrepreneurial discovery (Kirzner 1997), and the promotion of these entrepreneurial opportunities is now seen by some observers as a major responsibility of the university. Histories of cluster development reveal that cluster emergence (Braunerhjelm and Feldman 2006) is an evolutionary process that requires an initial seeding or triggering event, followed by entrepreneurial activity that builds upon this event. This initial triggering event is frequently the result of serendipity, and can in no way be planned or anticipated.¹ A triggering event can also be part of a planned government initiative to stimulate cluster development. In the cases discussed in this chapter these triggering events are the discoveries that emerge from research conducted by the university.

In general the first stage of cluster evolution requires a seeding event which produces an economic opportunity, the presence of entrepreneurs who have the knowledge to discover this opportunity and are in a position to act upon it, and the existence of resources for new firm formation in the cluster that are available to the entrepreneur. Because universities continuously produce potential entrepreneurial opportunities for new firm formation, it is instructive to observe their success in promoting cluster development. In particular, studying university-based clusters over time allows for a comparative examination of the first stage of cluster development.

Although university-based clusters exist in other countries, these clusters were first noticed in the United States in the postwar period and are

most common in American settings.² As Scott Shane (2004) observed in his extensive review of university start-ups, World War II transformed American research universities, particularly with respect to federal government funding of research. Throughout the last half of the 20th century and into the 21st, real university R&D expenditures increased significantly both absolutely and as a percentage of total US R&D. The Bayh–Dole Act of 1980 giving universities (and other Federal contractors) the exclusive property rights to inventions certified and generalized a process of commercialization that had already been underway by that time (Mowery et al. 2004).³

This increase in entrepreneurial activity at US universities has been mirrored by an increased academic interest in the topic. A recent literature search of this topic (Rothaermel et al. 2007) indicated that 173 academic articles have been written on university-related entrepreneurship between 1981 and 2005, and that almost 75 per cent of these were published since 2000.⁴ What one finds in reviewing this literature is a very large number of articles investigating the relationship between the number and type of firms spun-off from the university, and the attributes of the university from which these firms arose, including attributes of the university's technology transfer office. Relative to the level of interest, surprisingly little research has been done on the founding and performance of these firms with respect to the locality in which they find themselves.

In this chapter the characteristics and attributes of university-based clusters in the United States are described, and the history and development of two such clusters, the University of Wisconsin-Madison (UW-M) and the University of Illinois at Urbana-Champaign (UIUC), is compared.

1 UNIVERSITIES AND KNOWLEDGE-BASED CLUSTERS

Research universities are producers and disseminators of knowledge. This knowledge is transmitted to society through multiple channels. The most common channel is through the university's role as educator. Research universities also produce knowledge which is transmitted through a variety of other channels including publication in professional and academic journals, hosting conferences, professorial consulting, and the mobility of university graduates (Stephan 2007). More recently, patents have become another form of transmitting this knowledge of society. A number of these transmission channels ensure that university knowledge is widely distributed geographically, that is, the knowledge is not necessarily confined to the region in which the university is located.

The academic literature suggests that even though much of this

knowledge is transmitted widely, certain, more tacit, knowledge may be most easily captured locally. This local capture occurs when students join local firms and professors are involved in consulting with nearby firms. It can also occur when knowledge becomes the basis of a new, locally-based start-up enterprise. Universities are recognized as an essential institution in many of the most celebrated innovative regions of the world (Etzkowitz 2004; Storper and Salais 1997). Indeed, the entire evolution and development of Silicon Valley has been profoundly influenced by the role of Stanford University and the University of California, Berkeley (Kenney 2000; Saxenian 1994).⁵ These two universities are the crucial educational institutions within Silicon Valley that observers have termed an 'ecosystem' (Bahrami and Evans 2000), a 'social structure of innovation' (Florida and Kenney 1990), or an 'incubator region' (Eisenhardt and Schoonhoven 1990).

Since the 1980s there has been a growing appreciation of the university's role in transferring the knowledge developed through public research to the larger society, particularly the private sector in the form of commercial ventures. Scholarly interest in this role has tended to focus on the university's direct role in promoting new firm formation on the basis of university inventions. In particular, this interest has centered on university spin-offs in high technology, science-based fields, such as biotechnology (Kenney 1986; Zucker et al. 2002) and, more recently, nanotechnology.

The existence of a permanent, externally supported research university committed to the promotion of entrepreneurship is the distinguishing feature of what we refer to as the university research-centric cluster. Because this type of cluster is based on the research of various disciplines within the university it is quite different from other clusters in one fundamental way. Industry-specific clusters react to the demands of the market as products and innovations are produced explicitly in response to the market. University research-centric-based clusters, on the other hand, are characterized by the technology push that comes from research in a wide variety of university academic disciplines. As a result the new firms that spin out of the university will be as varied in their product and technology as the research areas pursued by the university. It is not the case that firms entering on the basis of university inventions are not concerned with market demand. Clearly they must be. Rather it is the research conducted by the university, which produces opportunities for entry, that is not subject to the demands of the market.

The distinction between the university research-centric cluster described here, and industry-specific clusters characterized by specialization in a particular industry, is based on the source of entrepreneurial opportunities for new firm formation. In the university research-centric cluster, the university generates 'seeds' for high technology firm formation, but unless the region

in which these seeds are planted is a rich entrepreneurial environment a successful cluster manifesting external economies may not emerge. The entrepreneurial environment surrounding a university is not a prerequisite of cluster formation, but rather something that grows with new firms and the institutions that emerge to support them (Feldman and Francis 2004). Studies of the genesis of clusters have consistently shown that the attributes of successful, mature clusters maintain entrepreneurial support networks, such as venture capital, that were not in place when the cluster first emerged (Bresnahan et al. 2001). As will be shown by a comparison of two university research-centric clusters below, whether a university produces a cluster characterized by external economies and exhibiting new firm formation through spinoffs, or simply an agglomeration of local firms, depends on the evolution of an environment supportive of university entrepreneurship.

The unique attributes of the university research-centric cluster explain its initial formation, how it is maintained, and how learning occurs within it. Because this type of cluster is initially formed by start-ups based on university research, these firms will be established in close proximity to the university, usually in the university town, for two reasons. First, many of these firms will be founded by university faculty who will want to retain their position with the university. In addition, several studies have shown that there is a strong motivation for entrepreneurs to establish their start-ups locally to be near familiar surroundings, family, and friends (Stam 2007: 37; Dahl and Sorenson 2008). This tendency is particularly strong in the earliest stage of the start-up and is also based on consideration of access to capital and professional networks. Second, the tacit, or contextual, knowledge upon which the start-up is based will exert a strong centripetal force keeping the start-up close to the university as well. There is a large body of literature on the role of proximity in the transmission of tacit information, particularly in a university setting (see Audretsch and Stephan 1996, and Zucker et al. 1998).

Peter Maskell (2001), in his knowledge-based explanation of geographical clusters, argues that the advantages of multiple co-located firms pursuing the same activities arise from the knowledge obtained from running parallel projects. 'Co-localized firms undertaking similar activities find themselves in a situation where every difference in the solutions chosen, however small, can be observed and compared' (Maskell: 928–29). It is not just that the costs of input–output transactions among firms can be greatly reduced within a cluster, which Storper (1995: 201) refers to as the 'traded interdependencies' of a cluster. In addition there is a great advantage in having firms engaged in similar activities competing, and occasionally cooperating, with each other in the same location.

This ability to observe other firms pursuing the same activity in close

proximity is the basis of Brown and Duguid's observation that there is both a high level of knowledge in firms in Silicon Valley, and a high level of knowledge about firms (Brown and Duguid 2000: 20–23). This knowledge about firms is a function of proximity and shared practice, and explains Marshall's 'mysteries in the air' that is to be found in places like Silicon Valley. Shared practice is knowledge that is embedded in a social setting, a knowledge that comes from learning by being in the place where the knowledge is being used and having the opportunity to use it in that setting. Such a setting, where people working together produce a body of actionable, community-based knowledge, is a community of practice.

The concept of communities of practice can assist us in understanding the role of universities in initiating new firms and sustaining existing firms in the university research-centric district. In its early stages the start-up is basically an extrusion from the university laboratory, and the founders and original staff will most likely be drawn from this community. Initially a given start-up, and the cluster itself, is maintained by this interaction between the start-up and its university-based community of practice. Later in the development of the cluster entrepreneurs, in conjunction with the university, develop institutions and networks that advance their ventures and foster new firm formation.

The role of the university in sustaining common codes of communication and networks among actors has been noted by several authors. Miner et al. (2001: 144–45) argue that universities can play a key role in industry formation because they provide a neutral territory in which scientists can form relationships outside of the world of competition. Paniccia (2006) observes that universities, together with alumni associations and others, act as social as well as professional institutions within university-based clusters, where they act as centers of socialization and as arenas for the exchange of ideas and reputation building.

2 TWO EXAMPLES OF UNIVERSITY-BASED CLUSTERS

The dynamics of these clusters can be understood by examining case studies of two elite universities, the University of Wisconsin-Madison (UW-M), and the University of Illinois at Urbana-Champaign (UIUC). Both of these universities have experienced spin-offs and have conscious policies of encouraging cluster formation.

Both UW-M and UIUC are large, comprehensive, and highly rated universities. UIUC has top-tier computer science and engineering departments, and technologies that can be traced to UIUC are the basis of Lotus

Notes, the email program Eudora, and web browsers. Inventors coming directly from UIUC include those that founded firms such as Netscape and Paypal. However, these two very important start-ups were not founded in Champaign, but rather were founded in Silicon Valley some 2000 miles away. The importance of regional considerations in the start-up process is captured in the following statement by Marc Andreessen, the founder of Netscape, on why he did not consider Champaign as the location for Netscape in the mid 1990s: ‘there’s no infrastructure at all in Illinois for a start up company. It’s not there. No one does it. They just don’t know how to react to it.’⁶ In comparison Bill Linton, the founder of biotechnology firm Promega of Madison, said of the environment around UW-M in 1976: ‘A tradition of educational excellence has contributed to an environment of intellectual curiosity, exploring spirit, and intuitive visions – together they create a rich business development environment.’⁷

While these are only anecdotal observations, our research into the sources of firm foundings in these two university towns indicates that there has been and continues to be a difference between these two regions. UW-M has a much longer history of promoting new firm formation, going back to 1925 with the establishment of a private non-profit entity, the Wisconsin Alumni Research Foundation (WARF) to patent inventions and license technologies emerging from UW-M research. Several significant biotechnology firms have emerged in this cluster including Promega, PanVera, and Tomo Therapy, all of which were founded in Madison and not outside the region. The most significant firms that have been founded on the basis of UIUC research have located in Silicon Valley.

In this study all high technology firms that were founded in Madison and Champaign-Urbana, or founded by university personnel, including secondary spinoffs, were recorded going back to 1957 and 1958. In our examination of firm founders we found in both Madison and Champaign that the university was by far the largest source of entrepreneurship among these firms. But unlike Champaign, Madison has developed a biotechnology cluster that supports spinoffs from existing firms. That is, the firms themselves seed new firms, so that new generations of firms emerge that are not directly related to the university. This pattern of firm formation was not observed in Champaign.

3 GENESIS AND EVOLUTION OF TECHNOLOGY BASED CLUSTERS

While studies of clusters have increased in number in recent years, few have examined clusters from a dynamic perspective that appreciates that cluster

formation is a co-evolutionary process which reflects the joint development of institutions, technologies, and firms. This shortcoming has been recognized, and two recent works on biotechnology clusters (Owen-Smith and Powell 2006; Romanelli and Feldman 2006) have provided insight into the evolution of these clusters over time.⁸

Owen-Smith and Powell's study compared the development of the San Francisco Bay Area biotechnology cluster with the development of the Cambridge/Boston cluster from 1988 through 1999, with regard to network evolution among different cluster actors, particularly universities, venture capital firms, and pharmaceutical corporations. They observe that studies that rely on comparative statics may conclude that these clusters evolved in a similar manner. But in fact a consideration of their history reveals that their patterns of development diverge significantly, even though they share many attributes in their mature phase.

Romanelli and Feldman's study focused upon an entire industry, human biotherapeutics, rather than comparing regions. They recorded the history of the founders of 688 biotherapeutic firms from 1976 through 2003 to track cluster formation across all regions. Based on the sources of entrepreneurs of these firms and the emergence of biotherapeutic clusters over this time period, they came to the following conclusions.

First, the majority of firms were founded by entrepreneurs in the regions in which they resided, and most regions generated new firms by entrepreneurs out of local universities and research institutes at a fairly steady rate. Second, the largest clusters – San Diego, Boston, and San Francisco – exhibited growth by entrepreneurs leaving local, established firms to create local start-ups. Only regions in which this secondary firm formation occurred grew relative to the other clusters. Third, a significant number of entrepreneurs relocated from one region to another to found firms. This tertiary growth by immigration of entrepreneurs was pronounced in the largest clusters, and occurred late in their development (Romanelli and Feldman 2006: 108–10).

These observations imply a three-stage pattern of growth that can be examined by the examples of Madison, Wisconsin and Champaign-Urbana, Illinois. The first stage of cluster development occurs as a result of firm formation by local entrepreneurs based on perceived economic opportunities. A second stage of cluster development may occur as a result of secondary growth through the spinning off of start-ups from established firms in the cluster. Feldman and Francis (2004) observe that it is in this stage that entrepreneurs, by interacting with their environment, emerge as social actors within the cluster, establishing networks and institutions to support their ventures and address their concerns. Finally a third stage of cluster development is reached when a cluster becomes sufficiently well

established to attract entrepreneurs from other regions. These latter two stages, though, do not inevitably emerge from the first. The triggering event in cluster development is only the necessary first stage. The critical moment in cluster development occurs after this initial seeding event. In university research-centric clusters the potential initial triggering event occurs continuously through the research a university conducts.

4 DATA FOR THE UNIVERSITY RESEARCH-CENTRIC CLUSTERS OF UW-M AND UIUC

The data for this study was collected over 2006 and 2007, and is comprised of a census of all high technology firms founded in Madison, Wisconsin and Champaign-Urbana, Illinois from 1950 through 2006.⁹ Firms that were established by university personnel outside of the cluster were also included in this study. The data collection effort was based primarily on Internet sources, but was also based on direct contacts with university officials¹⁰ and an e-mail survey of Madison firms.¹¹

The Internet sources used in building this census were numerous, and included local development agencies, venture capital data, the local press, business associations, company websites, and of course Internet searches. Once firms were identified and screened to meet criteria for inclusion the names of the firm founders were established and their biographies obtained.

Only *de novo*, high technology firms were included in this census.¹² To be considered *de novo* a firm had to be founded locally, not be a spin-off from an existing firm, or be a subsidiary or branch operation. Very small firms of just one or two employees providing only services were also excluded, as were all exclusively retail establishments.

In determining which firms were high technology, and what type of technology category most accurately described them, the authors relied on consensus in classification by other sources whenever possible. These sources included the firm website, a description in the local or business press, a description by the university technology transfer office, or business association. The initial guidance for the technology classification used in this study was provided by the MG&E high technology directory of Madison, Wisconsin (Madison Gas & Electric Co. 2004).

All start-ups are assigned to one of five general technology categories: information technology, engineering, physical sciences, biological sciences, and medical sciences. Information technology includes all Internet and software firms as well as firms dedicated to computer systems and IT services. Engineering includes companies involved in the manufacture of

computers, scientific instruments, and machinery, while physical sciences includes firms involved in the manufacture of electronics and telecommunications. Biological sciences includes firms involved in the fields of biotechnology, veterinary science, and agriculture. Medical sciences includes all firms that are directly involved in medical instruments, equipment, and services, with the exception of biotechnology and pharmaceutical companies.

5 THE UNIVERSITY AS PLANTER OF SEEDS

Because the university is the primary source of knowledge within the university research-centric cluster, and because this knowledge is the basis for many of the new firms founded within the district, one would hypothesize that the characteristics of new firms would reflect the relative disciplinary excellence of the university.

In Tables 9.1A and 9.1B all start-ups founded by faculty, staff, and students at UIUC and UW-M respectively are tallied and grouped into five technological categories. The research and development expenditures by the universities for these categories are for the single year of 2004, while the rankings of university academic programs that fall into these categories are given for the years 2006 and 1995.¹³

UIUC and UW-M differ significantly in the types of firms that have spun off from the university. At UIUC, information technology and engineering start-ups account for almost two thirds of the total. Over the years, only seven start-ups based on the life sciences had UIUC founders. At UW-M, on the other hand, the life sciences account for over half of the total number of start-ups. Without reference to either the academic reputation of these universities, or the R&D expenditures by various programs, the differences in start-up technologies in these clusters would be difficult to explain.

In the case of UIUC we can see that there is an exact ordinal ranking match between the number of start-ups in each technology category and the rank of comparable university programs by R&D expenditures. UIUC's R&D expenditures on computer science (information technology) were the highest in the US in 2004, and this was the most important category of start-ups. Its second highest program in R&D expenditure rank was engineering, and this corresponds to engineering being its second most important category of start-ups. This ordinal match proceeds through the other categories. Further, this roughly parallels the academic ranking of these programs as well.

UW-M start-up technologies match up ordinally with R&D ranks

Table 9.1A University of Illinois Urbana-Champaign-Founder Start-ups

	Start-ups 1958–2006	R&D 2004 in \$1,000s (US rank)	2006 Program (US rank)	1995 Faculty rank
Information Technology	22 36.7%	113 320 (1)	5	8
Engineering	17 28.3%	120 032 (10)	4	5.5
Physical Sciences	14 23.3%	50 152 (17)		17.8
Biological Sciences	6 10.0%	61 911 (45)	24	31.3
Medical Sciences	1 1.7%	11 331 n.a.	no medical school	
UIUC Total	60			

Table 9.1B University of Wisconsin Madison-Founded Start-ups

	Start-ups 1957–2006	R&D 2004 in \$1000s (US rank)	2006 Program US rank	1995 Faculty rank
Information Technology	23 20.0%	13 457 (23)	10	10
Engineering	12 10.4%	94 860 (14)	15	15.6
Physical Sciences	15 13.0%	51 853 (14)		16.5
Biological Sciences	44 38.3%	155 682 (6)	12	10.0
Medical Sciences	21 18.3%	272 640 (11)	26	
UW-M Total	115			

Notes: The R&D expenditures, as well as academic and faculty rankings, of computer science are used for the category of information technology. The faculty ranks for biological sciences, physical sciences, and engineering are based on averages of fields within these categories. See note 13.

Sources:

University start-ups: Martin Kenney and Donald Patton. Data furnished on request by the authors.

R&D data: National Science Foundation (2006).

2006 program ranks: US News and World Report (2006).

1995 faculty ranks: National Research Council (1995).

and program ranks with the exception of information technology which appears to have too low an R&D ranking, and engineering which appears to have too high a program ranking, relative to the number of start-ups by UW-M faculty and staff. Basically, though, the rankings are congruent for both universities suggesting that the types of start-ups within each cluster mirror the relative strengths of the universities at their center. These results agree with empirical work on the characteristics of universities and their propensity to produce spinoffs (Di Gregorio and Shane 2003; O'Shea et al. 2005). In most studies the number of spinoffs per year are regressed on a variety of university level attributes. It is then found that the prestige of the university, measured by either the quality of faculty in science and engineering (O'Shea et al. 2005), or by overall graduate school ranking (Di Gregorio and Shane 2003), is positively and significantly related with the number of spinoffs per year based on university licensed technology.

Because the spinoff data of these studies was based on the Association of University Technology Managers (AUTM) surveys, the individual identities of the start-ups was suppressed, thereby restricting the analysis to the university rather than department level. The results, though, clearly show that university prestige, and therefore the quality of the ideas emerging from them, is directly related to the number of firms founded upon those ideas.

6 THE INSTITUTIONAL ROLE OF THE UNIVERSITY IN NEW FIRM FORMATION AND ENTREPRENEURSHIP

The extent to which universities extrude their knowledge into the larger economy through start-ups depends not only on the quality of the technology and ideas of their departments. It is also shaped by the offices of the university that attempt to promote entrepreneurship, and the institutions and social relations in which faculty are embedded. Kenney and Goe (2004), in their comparison of the electronic engineering and computer science (EE&CS) departments of UC Berkeley and Stanford found that Stanford faculty were significantly more involved in entrepreneurship than UC Berkeley faculty, and that the primary explanation of this difference lies in the historical legacies and cultures that developed at these two universities. Stanford had a history of encouraging entrepreneurship, while UC Berkeley did not.

This explains why two departments of equal prestige, and roughly similar proximity to Silicon Valley, produce a different number of spinoffs. The fact that Stanford produces many more EE&CS spinoffs than UC

Berkeley lies in the institutional differences in the universities. It was assumed that since the disciplines were held constant, the institutional context was the differentiating factor. Feldman and Desrochers (2004) argue that similar institutional factors are at work in explaining why Johns Hopkins University produces fewer start-ups than its reputation and size would predict.

Since the passage of the Bayh–Dole Act of 1980 which gave universities the property rights to federally funded inventions developed at their campuses, most universities have established technology licensing offices (TLOs) to expedite the licensing of university ideas and promote the founding of firms based on university technology. In addition, many universities have supplemented these efforts with university sponsored research parks and start-up incubators, as well as sponsored venture capital firms and other types of organizations aimed at providing support to university entrepreneurs.

For the University of Wisconsin, the Wisconsin Alumni Research Foundation (WARF) plays a unique and critical role in the UW-M ecosystem as an intermediary in the commercialization of university research. Established in 1925 as a non-profit patent organization funded initially by UW alumni and managed by a Board of Trustees composed of alumni, its independence allows it to operate in an entirely business-like fashion, separate from university politics and academic administration. WARF's primary purpose is to manage patents based on UW-M research, and since 1928 it has provided more than \$915 million to the university to support further research (WARF 2008).

WARF was established in 1925 as a vehicle to administer the discovery of UW-M Professor Harry Steenbock to prevent the bone disease rickets. Prof. Steenbock had developed a method of increasing the Vitamin D content of food products by ultraviolet irradiation, but since Steenbock could not secure the cooperation of the university Board of Regents he and other alumni founded WARF, which granted its first license using Steenbock's discovery to Quaker Oats in 1927 (Sobocinski 1999: 310–11). This patent and other later discoveries on the use of Vitamin D continue to provide between 60 to 70 percent of WARF's total income (Gulbrandsen 2003).

In addition to WARF, the university's Office of Corporate Relations (OCR), established in 1963, is a critical link from the university to small businesses and the larger economy. The role of the OCR is to act as a broker and counselor. Madison has also experienced a proliferation of small business incubators and business parks, the most important of which is the UW-M-sponsored University Research Park, established in 1984 (Sobocinski 1999: 306).

The University of Illinois has similar institutions to UW-M, but their experience is much more limited having been established only recently. The university's agent for technology transfer, the UIUC Office of Technology Management, was established in 1995, a full 70 years after the formation of WARF in Madison. Like UW-M, UIUC has established organizations to support entrepreneurs, but these too are of recent origin. The university-sponsored University Research Park only began construction in 2000, and the university venture capital fund, Illinois Ventures, was proposed as an entity in the same year. Another institution intended to provide mentoring to university entrepreneurs is the Technology Entrepreneur Center. Currently housed within University Research Park, it too was only recently established in 1999 (Technology Entrepreneur Center 2008). It is clear that UIUC is attempting to quickly develop university institutions to support technology transfer from laboratories through new firm formation.

7 THE ENTREPRENEURIAL ENVIRONMENT WITHIN THE CLUSTER

Although the university provides the initial seeding of firms within a potential cluster, this is just the primary stage of growth. For a cluster to thrive new firm formation must be based, at least in part, on the existing firms in the cluster. This secondary, or second generation, growth is the hallmark of vibrant clusters (Romanelli and Feldman 2006; Klepper 2001).

In Tables 9.2A and 9.2B all high technology start-ups associated with UIUC and UW-M are presented. The university-founded start-ups are combined with other start-ups founded within Champaign and Madison respectively. The first column presents the count of all start-ups founded within the university town by technology category, including all those founded outside the region by university faculty, staff, and students. The second column indicates the number of firms founded by university personnel, the third column indicates the number of forms founded by one or more individuals from other local high technology start-ups, and the fourth column gives the number of firms founded by university personnel outside the region. These columns are not mutually exclusive. Firms founded by individuals from other local firms may also have been founded by university faculty, and the fourth column is simply a subset of the second column.

Several observations can be made from this data. First, in both cases approximately half of all start-ups were founded by university personnel. This holds across technology categories with information technology having a somewhat smaller proportion of university start-ups for both

Table 9.2A *Champaign-founded and UIUC-founded combined*

	All start-ups 1958–2006	Founded by UIUC faculty/staff	Other local high tech founder	UIUC founded outside of region
Information Technology	46 39%	22 0.48	2 0.04	5 0.11
Engineering	28 24%	17 0.61	0	1 0.04
Physical Sciences	23 20%	14 0.61	0	5 0.22
Biological Sciences	11 9%	6 0.55	0	2 0.18
Medical Sciences	5 4%	1 0.20	0	0
Other	4 3%	1 0.25	0	0
Total	117	61 0.52	2 0.02	13 0.11

Table 9.2B *Madison-founded and UW-M-founded combined*

	All start-ups 1957–2006	Founded by UW-M faculty/staff	Other local high tech founder	UW-M founded outside of region
Information Technology	54 27%	23 0.43	4 0.07	1 0.02
Engineering	22 11%	12 0.55	2 0.09	0
Physical Sciences	27 14%	15 0.56	0	0
Biological Sciences	65 33%	44 0.68	12 0.18	0
Medical Sciences	26 13%	21 0.81	0	2 0.08
Other	6 3%	2 0.33	0	1 0.17
Total	200	117 0.59	18 0.09	4 0.02

Source: Martin Kenney and Donald Patton. Data furnished on request by the authors.

schools, while biological sciences and medical sciences at UW-M, and engineering and physical sciences at UIUC, have a greater proportion of university founders.

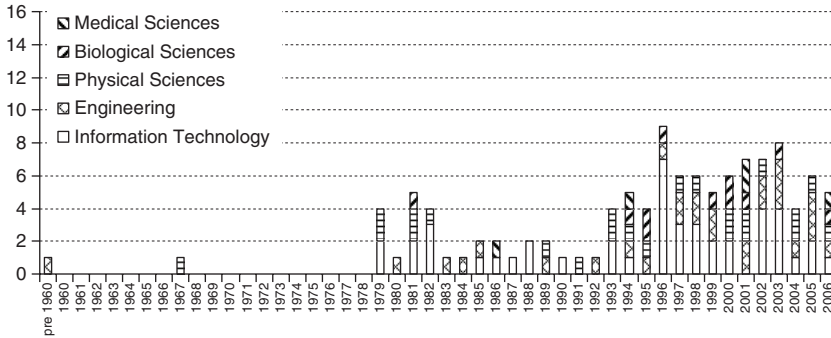
Second, the mix of technology of all start-ups parallels that of university start-ups. This is what one would expect if one believes that university-affiliated founders are only a portion of the channels of innovation within a locality. Third, the role of secondary foundings of firms is much greater in Madison than it is in Champaign. Just two start-ups in Champaign had founders who came from other local high technology start-ups. This indicates that in Champaign new firms have been established, but have thus far failed to produce secondary offspring by becoming a source of entrepreneurs in their own right.

The situation is quite different in Madison where approximately one in ten of all start-ups had founders from other, locally founded high technology firms. This proportion rises to almost one in five in the biological sciences, the area in which Madison excels. What this indicates is that in biotechnology Madison start-ups encourage the formation of secondary offspring. Although the university is the driver in Madison biotechnology, the resulting firms generated yet other firms, implying that they operate in a fertile entrepreneurial environment.

The generation of new firms, as measured by secondary spinoff activity, is an important measure of the vitality of the entrepreneurial environment within a cluster. Earlier we indicated that one of the best known spinoffs from UIUC, Netscape, was founded outside the region due in part to the shortcomings of the Champaign environment. This was not an isolated case.

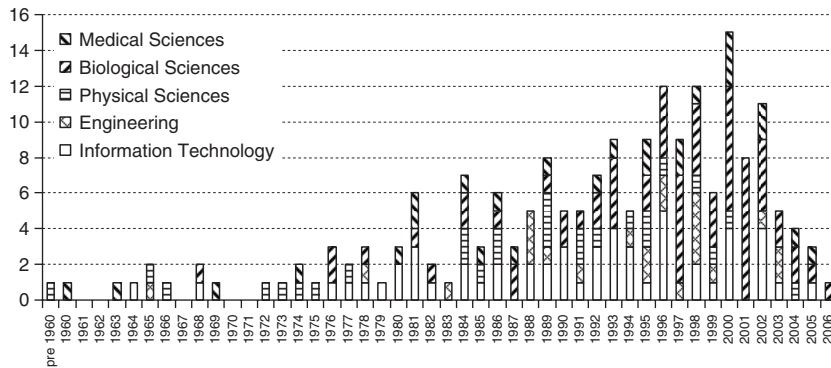
Slightly over one in five (13 out of 61) of all start-ups founded by UIUC personnel were founded outside the Champaign area. Silicon Valley has been a strong attractor of individuals from UIUC seeking to form start-ups, particularly in the field of information technology as seen in Table 9.2A, but this does not explain all of the firms founded outside of the Champaign region by UIUC personnel. Moreover, just five of these firms were founded in Silicon Valley. Another five were founded in Illinois and one each in Virginia, North Carolina, and Massachusetts. Because UIUC entrepreneurs have founded firms in other areas besides Silicon Valley, and in other technologies besides information technology, it seems clear that Champaign is not retaining all of its entrepreneurs.

In Madison all but four start-ups were founded in the Madison area. The question of whether this is a characteristic of the life sciences or the university is not entirely clear, but it should be noted that Madison retained start-ups in the physical sciences and information technology as well as the biological sciences.¹⁴



Source: Martin Kenney and Donald Patton. Data furnished on request by the authors.

Figure 9.1A Champaign-Urbana and UIUC Start-ups



Source: Martin Kenney and Donald Patton. Data furnished on request by the authors.

Figure 9.1B Madison and UW-M Start-ups

The observations that have been made to this point are based on the start-ups in these clusters around UW-M and UIUC over their entire history from the late 1950s through 2006. The dynamic nature of these clusters' development can be shown by time series data on new firm formation over time, as shown in Figure 9.1A and Figure 9.1B. In these figures two features immediately stand out. First, the cluster around UW-M started much earlier in its development than did UIUC, and second, the cluster in Madison is much larger than the one in Champaign.

Another consideration in comparing these two clusters is whether the

characteristics noted earlier remain constant if we examine their development over time. In particular, does the observed tendency of UIUC entrepreneurs to leave Champaign remain constant, or has this tendency declined as the cluster has developed?

The data indicates that entrepreneurs from UW-M founded start-ups outside of Madison in the 1980s only. Since that time all university entrepreneurs have found that Madison has a suitable business environment for start-ups. The situation in Champaign is quite different. Although Netscape was the most famous of the start-ups established outside of Champaign, it was just one of the first. The data indicates that 10 of the 13 firms that were founded outside the region emerged from the university during the current decade, the other three being founded before the year 2000. It would seem that efforts to encourage local entrepreneurship are failing to keep many of the new start-ups in town, even as the number of new firms being founded has remained quite high through the first decade of this century as shown in Figure 9.1A.

Without looking more closely into the motivations of individual entrepreneurs it is difficult to conclude much more from the data on start-ups within these two university research-centric clusters. To remedy this situation, two histories of innovation at these universities are discussed below. The first history considers the series of discoveries on the uses of Vitamin D at UW-M over many years, primarily by Professor Hector DeLuca and his associates. The second history is of the development of the first graphical Internet browser, Mosaic, at the National Center for Supercomputing Applications (NCSA) at UIUC in the early 1990s. Both of these innovations are chosen for their high profile and insight they provide into the operation of these clusters.

Hector DeLuca came to UW-M in 1951 and was the last graduate student to work under Harry Steenbock, the professor whose discoveries in Vitamin D research was directly responsible for the founding of WARF in 1925. DeLuca's subsequent work has resulted in both academic achievements and patent royalties of close to \$100 million for UW-M through WARF administration, as well as three university start-ups founded directly from his work; Lunar Corporation, Bone Care International, and Tetrionics (Sobocinski 1999: 294).

Prof. DeLuca and his research team synthesized calcitriol in 1971, a substance that increases calcium absorption and regulates blood calcium levels. Calcitriol has been used to successfully prevent osteoporosis, and it has been modified into vitamin D analogs. These vitamin D analogs are used to treat renal osteodystrophy, vitamin D resistant rickets, and parathyroid gland failure (Sobocinski 1999: 190). The production of these vitamin D analogs is the basis of the Madison start-up Bone Care

International, founded in 1984. Synthetic vitamin D pharmaceuticals were also the basis of the local start-up Tetrionics, founded in 1990.

The work of Prof. DeLuca and his colleagues has resulted in over 150 US patents files by WARF, many of which have been licensed to US and foreign corporations. Over the years Prof. DeLuca has established and maintained extensive networks of academics and entrepreneurs, effectively linking his laboratory to a set of firms within Madison and outside the region, as well as other university biochemistry departments. Such university entrepreneurs are not uncommon in Madison, and the richness of the networks and culture that have grown up are evident in the number of organizations that have been established precisely for the purpose of networking in the area, such as the Wisconsin Technology Network, the Wisconsin Angel Network, the Wisconsin Technology Council, and the Wisconsin Entrepreneurs' Network. These networks are embedded in both the business environment and the community of Madison, and are characteristic of the second stage of cluster development as described by Feldman and Francis (2004: 129).

The development of the Mosaic browser at UIUC is an important part of the history of the development of the Internet. Prior to the release of Mosaic in 1993, access to the Internet on the World Wide Web was limited to browsers that were based solely on text, ran on the Unix operating system, and were oriented towards academics and professional engineers rather than mainstream users (Naughton 1999: 236–7; Reid 1997: 4–5).

By early 1993 there were around 50 Web servers in the world, one of which was located at the National Center for Supercomputing Application (NCSA) at UIUC (Berners-Lee 1999: 67–8). Marc Andreessen, an undergraduate intern at the NCSA, together with Eric Bina, a full time employee at NCSA, developed a Unix version of a graphical browser called Mosaic that could be run on personal computers. Mosaic was released in January 1993 and soon became the standard browser in the rapidly emerging world of the Web, but its limitations required customer support which the development team at NCSA was unable to handle effectively. In addition, with Mosaic's great success, issues of ownership and control over the innovation began to arise at the NCSA.

Marc Andreessen decided to leave the area after it became obvious that he would not be the head of the Mosaic project at the NCSA after he graduated from UIUC. Andreessen initially took a position in Palo Alto, California with Enterprise Integration Technologies (EIT), a developer of Web security products. Although the firm was involved with the Web, Andreessen was not hired to extend the development of Mosaic. The fact that he received a good offer from EIT and was attracted to the region were his motivations in taking this job (Stark 1995). It was not until February

1994, several months after he started working for EIT, that Andreessen resumed his work on browser software, having received an offer from Jim Clark, the founder of Silicon Graphics, to build a firm based on the Web.

What this history suggests is that Marc Andreessen was not so much drawn to Silicon Valley to pursue his innovation of Mosaic, as he was pushed from the source of this innovation in Champaign. Andreessen's and Jim Clark's collaboration resulted in the founding of Mosaic Communications Corporation, later known as Netscape, in 1994. To obtain the talent needed to advance their venture Andreessen and Clark flew to Champaign in early 1994 and basically hired away the Mosaic development team from the NCSA.

Would there have been any conditions where Andreessen would have founded a firm based on Mosaic in Champaign, Illinois? It was certainly the case that Andreessen had at least thought of such an idea before he left for California (Reid 1997: 21). The main deterrence was the absence of an entrepreneurial infrastructure for new firm formation in Champaign. Jim Clark's start-up experience and financial means, coupled with his wide array of contacts into Silicon Valley entrepreneurial support networks, provided this infrastructure. Yet coming to Silicon Valley to found a company was not the motivation for Andreessen's move. Clearly chance was a factor in all of these decisions, yet the establishment of Netscape in Mountain View, California was due less to the pull of Silicon Valley than it was to the failure of institutions and networks in Champaign to retain the entrepreneurs that established the firm.

Consider this situation with that facing the university entrepreneur scientist Hector DeLuca at UW-M. When DeLuca came to UW-M in 1951 he worked as a graduate student under Harry Steenbock. By this time the model of the scientist researcher, whose work is directed to commercial applications, was well established. Indeed, it was Prof. Steenbock whose discoveries led directly to the establishment of WARF, and established the pattern, and the legitimacy, of professors taking the results of research from the university laboratory and extruding them into the larger economy through licenses issued by WARF and new start-ups. Not only was engaging in research that had direct commercial application not discouraged, but at UW-M it was seen as acceptable and a means to advance one's scientific reputation.

8 CONCLUSION

At the heart of a university research-centric cluster is a research university, a permanent, externally supported institution that is mandated to teach

and conduct research. Because such a cluster is based on the research of various disciplines within the university, it may be distinguished from other clusters in a number of ways. Other clusters achieve external economies by their market specialization. They are characterized by numerous competitors producing similar goods, resulting in deep horizontal and vertical relations. The management and technical expertise is steeped in industry knowledge and lore so that a new start-up can quickly attract key personnel. The founding of Netscape is a perfect illustration of the vitality of such clusters. In Silicon Valley Netscape quickly attracted seasoned managers and was able to draw upon the industry knowledge of the region. In Champaign these resources were simply not available, and in fact, there are few other places in the world where such a depth of information technology-related talent can be found.

University research-centric clusters, in comparison with industry-specific clusters, are characterized by technological innovations that come from a wide range of disciplines. As a result, the new firms that spin out of the university will be as varied in their product markets as the research areas pursued by the university. In the university research-centric cluster, the university generates 'seeds' for firm formation, but unless the region in which these seeds are planted is a rich entrepreneurial environment, a well functioning cluster may not emerge. Indeed, one of the primary differences between the two examples of university research-centric clusters discussed in this chapter is the vitality of the entrepreneurial settings in which the universities of Wisconsin and Illinois are located.

The cluster of firms found around UIUC has only the structural core of a university research-centric cluster, namely the presence of a large, highly ranked research university. UIUC satisfies the role of an institution which plants seeds for new firm formation. Yet a number of these seeds, such as Netscape and Paypal, took root in Silicon Valley rather than Champaign. The cluster around UW-M, on the other hand, has achieved a level of success where existing firms are the basis of second generation spinoffs. This secondary growth is a hallmark of vibrant clusters, and an indication that a cluster has entered a second stage of development from an initial seeding event (Feldman and Francis 2004: 129–30).

UW-M has several features that UIUC lacks. First, the university is deeply involved in the governance of the cluster through such long-standing organizations as WARF and the Office of Corporate Relations, among others. The efforts made by UIUC in promoting entrepreneurship are much more recent, going back only to the 1990s, and are much more modest in size and scope.

Second, the ties of networks among entrepreneurs in the community, and their counterparts in university laboratories, are deep and long-standing

in Madison. These ties are promoted by university organizations, and by private organizations that emerged from the entrepreneurial community in Madison. Such private organizations are almost completely absent in Champaign.

One finding from this investigation is that new firms in university-based clusters closely reflect the university strengths of the university at its core, at least in the case of UIUC and UW-M. Although this is a modest effort based on comparing two universities, it does suggest that academic excellence contributes directly to entrepreneurial opportunities in a locality in an unambiguous way. Given the level of interest in university entrepreneurship among researchers in economic geography and economic development, it seems clear that further studies of university-based clusters of this kind would yield valuable insights.

NOTES

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1. An important triggering event in the formation of Silicon Valley was the decision of William Shockley to locate his transistor firm in Palo Alto to be near his mother. Had he chosen the Boston area it seems likely that the history of Silicon Valley would have been quite different. Yet other high technology firms such as Varian and Hewlett-Packard were already in the area suggesting that it would have emerged as an important electronics cluster in any event (Sturgeon 2000).
2. The clusters of Oxford University and Cambridge University are notable examples of such clusters in the UK that have received considerable attention (Lawton Smith and Ho 2006; Proudfoot 2004; Garnsey and Heffernan 2005).
3. For a critique of Bayh–Dole as an encouragement of entrepreneurship, see Kenney and Patton (2008).
4. Rothaermel et al. 2007 is a literature analysis of articles explicitly focused on university entrepreneurship. These 173 articles cover four major research streams: (i) entrepreneurial research university, (ii) productivity of technology transfer offices, (iii) new firm creation, and (iv) environmental context including networks of innovation.
5. The influence of Stanford University through the role of Frederick Terman, department chair of the electrical engineering department and university provost, would be hard to exaggerate given his encouragement of William Hewlett, David Packard, and the Varian brothers to establish firms in the area.
6. As quoted in Scott Shane's study of university spinoffs (2004: 99).
7. As quoted in Randall Willis' report on Madison's biotechnology cluster (2004: 41).
8. Both of these articles appeared in *Cluster Genesis* (Braunerhjelm and Feldman 2006), a collection of studies directed towards examining the emergence of clusters as an evolutionary process.
9. In this study the regions around Madison and Champaign encompass all locations within one hours' drive by automobile, or around a 50 mile radius.
10. At UW-M the Office of Corporate Relations provided very valuable information on university start-ups, as did the Initiative for Studies in Technology Entrepreneurship

- at the Wisconsin School of Business. At UIUC the Office of Technology Management provided useful information on university start-ups. In addition we relied heavily on the High-Tech Directory published by MG&E (Madison Gas & Electric Co. 2004) and the text by Philip Sobocinski (1999) for data on Madison.
11. An e-mail survey of 103 Madison start-ups was conducted in February 2007. The following information was requested: the year and location of the firm founding, the names of the founders, what these founders did prior to the start-up, and the education of the founders. Out of 103 firms surveyed 47 responses were received. About 7 of these responses contained no information, so 40 out of 103 were actually informative.
 12. High technology is quite broadly defined. For example, a firm that produces equipment for biotechnology laboratories would be included as a high technology firm, while a firm that raises mice for laboratories would not.
 13. US News and World Report publishes an annual ranking of US graduate programs. They do not provide a rank for Physical Sciences as a graduate program. The 1995 faculty quality rankings are drawn from the National Research Council's 1995 review of US doctoral programs. The ranking of faculty quality for biological sciences is the average faculty rank of four biological fields: biochemistry and molecular biology; cell and development biology; ecology, evolution and behavior; and molecular and genetic studies. The ranking for engineering is based on four engineering fields: chemical, civil, electrical, and mechanical. The ranking of physical sciences is the average of four fields: chemistry, geosciences, mathematics, and physics. The NRC did not consider medical schools, so no faculty rank of medical sciences is provided.
 14. See Kenney and Patton (2005: 223–5) for a discussion of the impact of the university on the geography of different high technology start-ups.

REFERENCES

- Audretsch, D.B. and P.E. Stephan (1996), 'Company-scientist locational links: The case of biotechnology', *The American Economic Review*, **86** (3), 641–52.
- Bahrami, H. and S. Evans (2000), 'Flexible recycling and high-technology entrepreneurship', in M. Kenney (ed), *Understanding Silicon Valley*, Stanford, CA: Stanford University Press, pp. 165–89.
- Berners-Lee, T. (1999), *Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web by its Inventor*, New York: Harper Collins Publishers.
- Braunerhjelm, P. and M. Feldman (eds) (2006), *Cluster Genesis*, Oxford: Oxford University Press.
- Bresnahan, T., A. Gambardella, and A. Saxenian (2001), 'Old economy inputs for new economy outcomes, cluster formation in the new Silicon Valleys', *Industrial and Corporate Change*, **10** (4), 835–60.
- Brown, J. S. and P. Duguid, (2000), 'Mysteries of the region: Knowledge dynamics in Silicon Valley', in C.M. Lee, W. Miller, M. Hancock, and H. Rowen (eds), *The Silicon Valley Edge: A Habitat for Innovation and Entrepreneurship*, Stanford, CA: Stanford University Press, pp. 16–39.
- Dahl, M. S. and O. Sorenson (2008), 'The social attachment to place', electronic copy available at: <http://ssrn.com/abstract=1292224>, accessed 13 March 2009.
- Di Gregorio, D. and S. Shane (2003), 'Why do some universities generate more start-ups than others?', *Research Policy*, **32**, 209–27.
- Eisenhardt, K. and C. B. Schoonhoven (1990), 'Organizational growth: Linking

- founding team strategy, environment, and growth among U.S. semiconductor ventures, 1978–1988', *Administrative Science Quarterly*, **35** (3), 504–29.
- Etzkowitz, H. (2004), 'The evolution of the entrepreneurial university', *International Journal of Technology and Globalisation*, **1** (1), 64–77.
- Feldman, M. (2001), 'The entrepreneurial event revisited: Firm formation in a regional context', *Industrial and Corporate Change*, **10** (4), 861–91.
- Feldman, M. and P. Desrochers (2004), 'Truth for its own sake: Academic culture and technology transfer at the Johns Hopkins University', *Minerva*, **24**, 105–26.
- Feldman, M. P. and J. L. Francis (2004), 'Homegrown solutions: Fostering cluster formation', *Economic Development Quarterly*, **18** (2), 127–37.
- Florida, R. and M. Kenney (1990), *The Breakthrough Illusion: Corporate America's Failure to Move from Innovation to Mass Production*, New York: Basic Books.
- Garnsey, E. and P. Heffernan (2005), 'Clustering as multi-levelled activity; The Cambridge case', presented at the 4th European Meeting on Applied Evolutionary Economics, 19–21 May, De Uithof, Utrecht, The Netherlands.
- Gulbrandsen, C. (2003), 'WTN interview: Carl Gulbrandsen WARF – A unique and successful technology transfer organization', December 9, by M. Klein, Wisconsin Technology Network, <http://wistechology.com/article.php?id=416>.
- Kenney, M. (1986), *Biotechnology: The University–Industrial Complex*, New Haven, CT: Yale University Press.
- Kenney, M. (ed.) (2000), *Understanding Silicon Valley*, Stanford, CA: Stanford University Press.
- Kenney, M. and W.R. Goe (2004), 'The role of social embeddedness in professional entrepreneurship: A comparison of electrical engineering and computer science at UC Berkeley and Stanford', *Research Policy*, **33**, 691–707.
- Kenney, M. and D. Patton (2005), 'Entrepreneurial geographies: Support networks in three high-technology industries', *Economic Geography*, **81** (2), 201–28.
- Kenney, M. and D. Patton (2008), 'Reconsidering the Bayh–Dole Act and the current university technology licensing regime', Berkeley Roundtable on the International Economy Working Paper (draft).
- Kirzner, I. M. (1997), 'Entrepreneurial discovery and the competitive market process: An Austrian approach', *Journal of Economic Literature*, **35** (1), 60–85.
- Klepper, S. (2001), 'Employee start-ups in high-tech industries', *Industrial and Corporate Change*, **10** (3), 639–74.
- Lawton Smith, H. and K. Ho (2006), 'Measuring the performance of Oxford University, Oxford Brookes University and the government laboratories' spin-off companies', *Research Policy*, **35**, 1554–68.
- Madison Gas and Electric Company (2004), *2004 Greater Madison Wisconsin Area Directory of High-Tech Companies*, Madison, WI: Madison Gas and Electric Company.
- Maskell, P. (2001), 'Towards a knowledge-based theory of the geographical cluster', *Industrial and Corporate Change*, **10** (4), 921–43.
- Miner, A.S., D.T. Eesley, M. Devaughn, and T. Rura-Polley (2001), 'The magic beanstalk vision', in C.B. Schoonhoven and E. Romanelli (eds), *The Entrepreneurial Dynamic*, Stanford, CA: Stanford University Press.
- Mowery, D.C., R.R. Nelson, B.N. Sampat, and A.A. Ziedonis (2004), *Ivory Tower and Industrial Innovation*, Stanford, CA: Stanford University Press.
- National Research Council (1995), *Research-Doctorate Programs in the United*

- States: Continuity and Change*, Washington DC: The National Academies Press.
- National Science Foundation, Division of Science Resources Statistics (2006), *Academic Research and Development Expenditures: Fiscal Years 2004*, Arlington, VA: National Science Foundation.
- Naughton, J. (1999), *A Brief History of the Future: The Origins of the Internet*, London: Weidenfeld & Nicolson.
- O'Shea, R.P., T.J. Allen, A. Chevalier, and F. Roche (2005), 'Entrepreneurial orientation, technology transfer and spinoff performance of U.S. universities', *Research Policy*, **34**, 994–1009.
- Owen-Smith, J. and W.W. Powell (2006), 'Accounting for emergence and novelty in Boston and Bay Area biotechnology', in P. Braunerhjelm and M. Feldman (eds), *Cluster Genesis*, Oxford: Oxford University Press, pp. 61–83.
- Paniccia, I. (2006), 'Cutting through the chaos: Towards a new typology of industrial districts and clusters', in B. Asheim, P. Cooke, and R. Martin (eds), *Clusters and Regional Development: Critical Reflections and Explorations*, London: Routledge, pp. 90–114.
- Proudfoot, N. (2004), 'The biopharmaceutical cluster in Oxford', in C. Crouch, P. Le Gales, C. Trigilia, and H. Voelzkow (eds), *Changing Governance of Local Economies: Responses of European Local Production Systems*, Oxford: Oxford University Press, pp. 237–60.
- Reid, R.H. (1997), *Architects of the Web*, New York: John Wiley & Sons, Inc.
- Romanelli, E. and M. Feldman (2006), 'Anatomy of cluster development: Emergence and convergence in the US human biotherapeutics, 1976–2003', in P. Braunerhjelm and M. Feldman (eds), *Cluster Genesis*, Oxford: Oxford University Press, pp. 87–112.
- Rothaermel, F.T., S.D. Agung, and L. Jiang (2007), 'University entrepreneurship: A taxonomy of the literature', *Industrial and Corporate Change*, **16** (4), 691–791.
- Saxenian, A. (1994), *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Cambridge: Harvard University Press.
- Shane, S. (2004), *Academic Entrepreneurship: University Spinoffs and Wealth Creation*, Cheltenham, UK and Northampton, MA, USA: Edward Elgar.
- Sobocinski, P.Z. (1999), *Creating High-Tech Business Growth in Wisconsin*, Madison, WI: University of Wisconsin System Board of Regents.
- Stam, E. (2007), 'Why butterflies don't leave: Locational behavior of entrepreneurial firms', *Economic Geography*, **83** (1), 27–50.
- Stark, T. (1995), 'The Marc Andreessen interview page', May, <http://www.starkrealities.com/marca.html>.
- Stephan, P. (2007), 'Wrapping it up in a package: The location decision of new PhDs going to industry', in A. Jaffe, J. Lerner, and S. Stern (eds), *Innovation Policy and the Economy, Volume 7*, Cambridge, MA: MIT Press.
- Storper, M. (1995), 'The resurgence of regional economies, ten years later', *European Urban and Regional Studies*, **2** (3), 191–221.
- Storper, M. and R. Salais (1997), *Worlds of Production: Frameworks of Action in the Economy*, Cambridge, MA: Harvard University Press.
- Sturgeon, T. (2000), 'How Silicon Valley came to be', in M. Kenney (ed.), *Understanding Silicon Valley*, Stanford, CA: Stanford University Press, pp. 15–47.
- Technology Entrepreneur Center (2008), 'About TEC', http://www.tec.uiuc.edu/tec/about_tec.php, accessed 1 October 2008.

- U.S. News and World Report (2006), *America's Best Graduate Schools, 2006 Edition*. Washington DC: US News & World Report Inc.
- Willis, R.C. (2004), 'America's biotech heartland', *Modern Drug Discovery* (June), 41–46.
- Wisconsin Alumni Research Foundation (WARF), 2008, 'Our history', <http://www.warf.ws/about/index.jsp?cid=26>, accessed 12 October 2008.
- Zucker, L. G., M. R. Darby, and J. S. Armstrong (2002), 'Commercializing knowledge: University science, knowledge capture, and firm performance in biotechnology', *Management Science*, **48** (1), 138–53.
- Zucker, L.G., M.R. Darby, and M.B. Brewer (1998), 'Intellectual human capital and the birth of U.S. biotechnology enterprises', *The American Economic Review*, **88** (1), 290–306.