Economy and Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713685159

The role of venture capital firms in Silicon Valley's complex innovation network

Michel Ferrary [a]; Mark Granovetter [b]
[a] Ceram Business School, Rue Dostoievski - BP 85, Sophia Antipolis Cedex, France [b] Stanford University, Department of Sociology, Stanford, California, USA

Online Publication Date: 01 May 2009

To link to this Article: DOI: 10.1080/03085140902786827
URL: http://dx.doi.org/10.1080/03085140902786827

Economy and Society Volume 38 Number 2 May 2009: 326–359

The role of venture capital firms in Silicon Valley's complex innovation network

Michel Ferrary and Mark Granovetter

Abstract

We still poorly understand why Silicon Valley has originated so many breakthrough innovations and large companies. The durability of Silicon Valley's innovative competence over the last seventy years also needs more explanation. The failure of several policy-makers around the world to reproduce the Silicon Valley cluster reveals the misunderstanding of the innovative dynamic in Silicon Valley. This study uses complex network theory – CNT (Barabási, Newman & Watts, 2006; Jen, 2006; Thompson, 2004a) – to analyse the complex innovative capability of Silicon Valley and to understand the heterogeneity of agents and the multiplexity of ties that support creation and development of high-tech start-ups. As proposed by Barabási (2002, p. 200), we view the economy as a complex network, whose nodes are companies and whose links represent the various economic and financial ties connecting them. Innovation and entrepreneurship are understood as resulting from the interactions of numerous economic agents.

In a systemic perspective, by definition, the presence of a specific agent in a network induces specific interactions with other agents that could not take place if this agent were not there. Thus, the diversity of agents influences the dynamics of the system. The presence of venture capital (hereafter VC) firms in an innovative cluster opens potential specific interactions with other agents in the network (universities, large companies, laboratories) that determine a particular dynamic of innovation. In this perspective, what is distinctive about Silicon Valley is its complete and robust complex system of innovation supported by social networks of interdependent economic agents in which the VC firms have a specific function. Our perspective examines five different contributions of VC firms to Silicon Valley:

Michel Ferrary, Ceram Business School, Rue Dostoievski – BP 85, 06902 Sophia Antipolis Cedex, France. E-mail: Michel.Ferrary@Ceram.fr
Mark Granovetter, Stanford University, Department of Sociology, Stanford, California 94305-2047, USA. E-mail: mgranovetter@stanford.edu

ISSN 0308-5147 print/1469-5766 online
DOI: 10.1080/03085140902786827

financing, selection, collective learning, embedding and signalling. These five functions are different ways for the VC firms to interact with the other members of the complex network of innovation and to support the robustness of the system.

Keywords: social networks; innovation; cluster; complex network theory; venture capital.

Introduction

How best to improve industrial competitiveness based on innovation is a major public policy issue around the world. Innovation sustains economic growth and competitiveness and generates employment (Miller & Côté, 1985; Rosenberg, 2002). Since Schumpeter (1911), innovation and entrepreneurship have been understood as resulting from the action of a single agent: the entrepreneur. Several studies have pointed out that innovation-based competitiveness does not result from a single economic agent but from a complex process in which several geographically localized agents interact (Powell, Koput & Smith-Doerr, 1996; OECD, 1999, 2001; Porter & Stern, 2001). Different theoretical frameworks have been used to describe this process. Concepts like 'industrial district' (Marshall, 1890; Piore & Sabel, 1984; Becattini, 2002), 'cluster' (Porter, 1998), 'habitat' (Lee, Miller, Hancock & Rowen, 2000), 'business ecosystem' (Iansiti & Levien, 2004) and 'networks of innovation' (Saxenian, 1994) have been used to analyse geographically localized innovative environments.

Silicon Valley is a privileged object of research in the effort to understand industrial clusters and innovation. Numerous innovative high-tech enterprises have been founded in this region and have created thousands of jobs. Hewlett Packard, National Semiconductor, Intel, AMD, Oracle, Apple, Cisco Systems, Yahoo! eBay and Google, just to mention the best known companies, were founded and are based in Silicon Valley. In 2005, there were 1.15 million jobs and 22,000 companies in Silicon Valley (Joint Venture, 2008). Historically, this region is characterized by a high rate of start-up creation. From 1990 to 2000, 2100 high-tech companies were founded annually on average (Zhang, 2003). In terms of number of patents registered, eleven of the top twenty cities in the United States in 2006 were located in Silicon Valley (Joint Venture, 2008).

In spite of huge journalistic coverage and numerous books, we still poorly understand why Silicon Valley has originated so many breakthrough innovations and large companies. Only a few academic articles offer theoretically grounded analyses of the innovativeness of Silicon Valley.[1] The understanding of radical technological innovations that sustain new industries is a theoretical and a practical issue. The durability of Silicon Valley's innovative competence over the last seventy years also needs more explanation. The failure of several policy-makers around the world to reproduce the Silicon Valley cluster reveals the misunderstanding of the innovative dynamic in Silicon Valley.

This study analyses Silicon Valley as an innovative cluster, not as an industrial one. An industrial cluster is characterized by its capacity to generate and develop incremental innovations that reinforce its excellence and its competitiveness in a specific industrial domain. For example, the finance industry in Wall Street, the film industry in Hollywood or the wine industries in Napa Valley qualify as industrial clusters. By contrast, an innovative cluster is characterized by its capability to generate and develop breakthrough innovations that create new industrial domains and to redesign radically its industrial value chain. The competitive advantage of an innovative cluster is based on its capability to nurture the founding of start-ups developing breakthrough technologies that underpin new industrial sectors rather than on incremental innovations that improve an established competitiveness in a specific industrial sector.

Regarding Silicon Valley as a durable innovative cluster instead of an industrial cluster raises the question of the durability of its innovative capability. What explains its durable innovativeness? How did Silicon Valley cope with economic crises and new competitors in the last decades? What are the structure and the dynamic of an innovative cluster?

The mainstream in research on innovation generally focuses on the innovation process inside the firm. By contrast, we analyse innovation as the result of inter-firm interactions supported by social networks. This study uses complex network theory (Newman, 2003; Barabási, Newman & Watts, 2006; Jen, 2006; Thompson, 2004a) to analyse the innovative capability of Silicon Valley. Complex network theory (CNT) is a new perspective in mathematics, biology and physics that can be useful in understanding industrial clusters. CNT is useful to explain a phenomenon (biological, technological, sociological etc.) that does not result from simple interactions between a reduced number of agents in a linear relation but results from multiple interactions between numerous and diverse agents characterized by the non-linearity of their interactions (Newman, 2003; Barabási, 2005). We consider the innovativeness of Silicon Valley as an economic phenomenon supported by a complex network. The understanding of innovation requires analysis of this network and CNT offers an original framework to explore this economic phenomenon. The innovation dynamics of Silicon Valley are sometimes reduced to the action of only one agent (for example Stanford University or Hewlett-Packard) and sometimes to the interactions of a few agents (universities, research laboratories and large companies). Actually, there are many more different agents involved in the innovation dynamics of Silicon Valley and CNT can be useful to describe its complexity. As proposed by Barabási (2002), we view the economy as a complex network, whose nodes are companies and whose links represent the various economic and financial ties connecting them. Innovation and entrepreneurship are understood as resulting from the interactions of numerous economic agents.[2]

First, the complexity is due to the numerous decentralized interactions between a large diversity of economic agents. Further, these economic agents foster multiplex ties by holding different social roles (student, citizen, parent, neighbour, member of associations, etc.) and the economic interactions that generate innovations are embedded in the non-economic interactions. Agents interact on different social levels and this influences the economic level. For example, two agents linked by friendship (social tie) can become business partners to create a company (economic tie). This has been the case for companies like Hewlett-Packard, Apple, Cisco, Yahoo! and Google. Second, CNT emphasizes the robustness (or resilience) of systems more than their stability to explain how a system can or cannot cope with external radical changes and competitive shocks (Dodds, Watts & Sabel, 2003; Newman, 2003; Jen, 2006). It also allows exploration of the robustness of the Silicon Valley complex network of innovation that has withstood several external competitive shocks in the last decades. Silicon Valley has suffered several crises but has been able to re-create and reinforce its innovative capability (Kenney & Von Burg, 2000). Explaining this robustness is the main purpose of this study.

As a complex system, Silicon Valley is made up of networks of heterogeneous, complementary and interdependent agents. A systemic understanding of innovative clusters emphasizes that the efficiency of each particular agent depends on the presence of other agents. Due to this interdependence, the absence of one agent weakens the efficiency of others and, ultimately, the efficiency and the robustness of the entire system. Innovation results from a complete network and the entire system is less efficient if only one agent is missing.

But some agents contribute more than others to the robustness of a complex network of innovation. As mentioned by Thompson (2004a), there is a tendency for networks to create hubs that provide more stability and robustness. We argue that venture capitalists are a major (and underestimated) source of robustness of the innovative complex network of Silicon Valley. Two facts justify exploring the contribution of venture capitalists to Silicon Valley. First, a minority of high-tech start-ups are funded by venture capitalists at the seed stage (9 per cent on average; out of 2,100 high-tech companies created per year, around 200 got seed stage funding). On the other hand, almost all the large high-tech firms in Silicon Valley have been backed by venture capital (VC). Thus, it seems that VC firms back the seed stage of the most successful start-ups. Second, international studies of high-tech clusters point out that the main difference between Silicon Valley and other high-tech clusters around the world is not the size of universities, the presence of large companies or the quality of research laboratories but the huge presence of VC firms (Lee, Miller, Hancock & Rowen, 2000). In 2006, the National Venture Capital Association counted 180 VC firms in Silicon Valley (and 650 in the US). From 1995 to 2005, $111 billion was invested in Silicon Valley by venture capitalists. This represents 32.48 per cent of VC investments made in the US in this period ($341 billion)[3] and almost as much as was invested in Europe ($119 billion).[4] A comparison of VC investment per capita between Silicon Valley and other parts of the world highlights the difference (see Table 1). In 2005, $3341 was invested in Silicon Valley per capita. That is thirty-two times more than in England ($105 per inhabitant), 120 times more than in France ($28), 156 times

Table 1 Venture capital investment

	Population	2005	1995–2005	$/hab 2005	$/hab 1995–2005
USA	295,160,302	2,276,7838,500	341,683,941,700	77	1158
Silicon Valley	*2,429,000*	*8,115,032,800*	*110,982,715,200*	*3341*	*45,691*
Europe	460,726,436	15,205,351,200	119,270,100,392	33	259
England	59,934,290	6,278,076,000	35,238,551,362	105	588
Germany	82,500,849	1,518,696,000	19,947,691,200	18	242
France	60,561,200	1,686,326,400	16,354,860,000	28	270
Belgium	10,445,852	136,015,200	3,178,764,000	13	304
Denmark	5,411,405	1,003,342,800	2,637,802,800	185	487
Finland	5,236,611	179,773,200	1,906,075,200	34	364
Italy	58,462,375	531,048,000	8,027,442,952	9	137
Netherlands	16,305,526	592,894,800	8,651,653,200	36	531
Portugal	10,529,255	234,854,400	1,122,337,200	22	107
Spain	43,038,035	922,562,400	7,818,085,519	21	182
Switzerland	7,415,102	379,682,400	2,189,430,000	51	295
Sweden	9,011,392	1,034,575,200	5,678,336,400	115	630
Norway	4,606,363	395,365,200	2,555,592,000	86	555

Source: National Venture Capital Association and European Venture Capital Association

more than in Spain ($21), 181 times more than in Germany ($18) and 368 times more than in Italy ($9). The comparison of venture capital investments made from 1995 to 2005 points out the same difference. During this period, $45,691 per capita was invested in Silicon Valley, compared to $588 in England, $270 in France, $242 in Germany, $182 in Spain and $137 in Italy.

But, rather than emphasizing the amount of venture investment in Silicon Valley, we focus on other contributions of VC firms to the dynamics of the complex network of innovation. Several studies have pointed out the contribution of venture capitalists to the start-ups they fund (MacMillan, Kulow & Khoylian, 1988; Hellmann & Puri, 2002). Our study, based on more than forty non-directive interviews with entrepreneurs, venture capitalists, lawyers, journalists, consultants, bankers and professors in Silicon Valley, explores the interactions of VC firms with the other agents of Silicon Valley (such as universities, large companies, lawyers, consulting firms, and investment banks) in order to present VC's contributions to the innovative cluster and to the robustness of the system.

The presence of VC firms in an innovative cluster creates potential specific interactions with other agents in the network (universities, large companies, laboratories) that determine a particular dynamic of innovation. In this perspective, what is distinctive about Silicon Valley is its complete and robust complex system of innovation supported by social networks of interdependent economic agents in which the VC firms have a specific function. We examine five different contributions of VC firms to Silicon Valley's complex innovation network: financing, selection, collective learning, embedding and signalling.

First we summarize complex network theory and the concept of robustness and describe the innovative cluster of Silicon Valley as a complete and robust complex network of innovation. The complex network that sustains innovation in Silicon Valley has not been built all at once but results from a progressive aggregation over decades. This justifies an historical and longitudinal understanding of the situation (Pettigrew, 1990). We present the history of the VC industry in Silicon Valley in order to explain the progressive aggregation of the complex network, followed by a discussion of five specific contributions of VC firms to the innovative cluster to point out that CNT is a helpful framework to conceptualize the complexity of innovation and entrepreneurship. In conclusion, we point out that the duplication of a robust complex system of innovation depends on the completeness of the created system and, more specifically, on the inclusion of VC. We also suggest some theoretical contributions of our research to CNT.

An analysis of innovative clusters based on complex network theory

Physics, mathematics, computer science, biology and the social sciences have recently broadly used the concept of the 'complex network' (Newman, 2003; Thompson, 2004a; Jen, 2006; Barabási, Newman & Watts, 2006). This theoretical framework, which Watts (2004) called 'the new science of networks', is also helpful in the analysis of industrial and innovative clusters. Newman (2003) mentions that a set of vertices joined by an edge is only the simplest type of network; there are many ways in which networks may be more complex. For instance, there may be more than one different type of vertex in a network, or more than one different type of edge and vertices or edges may have a variety of properties. Taking the example of a social network of people, the vertices may represent men or women, people of different nationalities, locations, ages, incomes, or many other things. Edges may represent friendship, but they could also represent professional acquaintance or geographical proximity. A detailed overview of CNT is presented below and then used to analyse the innovative cluster of Silicon Valley.

Complex network theory

Network agents are heterogeneous and multiplex

A network is complex if it is made up of numerous interacting agents (Barabási, 2002) who may be heterogeneous, i.e. with different competences and different functions in the network. For example, Novaro, Funes & Walker (2005) show that the dispersion of palm seeds in Brazil's Maraca Island involved several agents: tapirs, deer, peccaries, primates and rodents. Agents of a complex network are also multiplex, i.e. the same agent can fulfil different functions and optimize different kinds of interest (Jen, 2006). For example, in a biological ecosystem, the same agent can be prey and predator. In a social system, the same person can be father, husband, employee, member of a political party and member of a sports association. Each of these roles corresponds to a set of functions in the system and to specific interests.

Interactions of the network are multiplex and self-organized

CNT is consistent with a systemic perspective. Networks are made up of agents that interact without formal hierarchy. Stark (1999) defines complex networks as 'heterarchies', which Jen (2006) describes as interconnected, overlapping, often hierarchical networks with individual components simultaneously belonging to and acting in multiple networks, and with the overall dynamics of the system both emerging from and governing the interactions of these networks.

A group of agents becomes a system when these agents interact. Interaction between heterogeneous actors is the second feature of complex networks. The probability of interactions between agents is higher when their interdependency is high. Watts & Strogatz (1998) point out that the structure of a network (diversity of agents and degree of connectedness) influences its dynamics. For example, the spread of epidemics depends on the connectedness of populations (Kretschmar & Morris, 1996). In social systems, the degree of agents' embeddedness impacts on the circulation of information (Granovetter, 2005).

CNT emphasizes the systemic dimension of the agent's efficiency. Results of agents depend on their intrinsic competencies but also on their interactions with their environment. There is a systemic interdependence between the agents of the network. The viability of the entire system and the viability of each agent depend on the diversity of agents and the degree of their connectedness.

The robustness of complex networks

The significance of complex networks lies more in their robustness than in their stability. Jen (2006) defines robustness as the ability of a system to maintain certain features when subject to internal or external perturbations. The persistence of a network is the result of its robustness (Allen, 2001). Resilience is another term used to describe the ability of a system to experience disturbance and still functionally persist (Newman, 2003). Conversely, the weakness of a network is its inability to face large perturbations. The palaeontologist D. Erwin (2005) describes how some ecosystems have been robust by resisting radical natural changes like climatic fluctuations, sea-level changes, volcanos or meteorites while other ecosystems disappeared.

The organizational architecture of the network plays a role in its robustness (Dodds, Watts & Sabel, 2003). Outcomes of networks depend on resources owned by agents and on the way these agents transform and exchange their resources. For example, the robustness of a biological ecosystem depends on the completeness and the continuity of the food chain (Montoya & Solé, 2002), and the robustness of the Web depends on its connectedness (Albert, Jeong & Barabási, 1999).

Robustness is a by-product of the completeness of the network and of the quality of the interactions between its agents. Interactions of heterogeneous agents favour mutations that ensure the survival of the system. Interactions enhance robustness by producing and maintaining the persistence of vital functions. Robustness supposes a complete set of heterogeneous and complementary agents and a dense network (Hartman, Garvik & Hartwell. 2001). The absence of one agent can weaken the entire network. A system is robust when it is able to reconfigure itself to face external shocks (Callaway, Newman, Strogatz & Watts, 2000). The robustness depends on the capability to evolve towards new functionalities, to integrate learning capabilities, to redesign its problem-solving processes and to promote creativity.

Capabilities of anticipation, learning and innovation as sources of robustness

The reaction of a complex network to a shock determines its chance of survival (Dodds, Watts & Sabel, 2003). Robustness is often thought of as reflecting the ability of a system to withstand perturbations in structure without change in function (Jen, 2006). The robustness is due to the capabilities of the complex network collectively to anticipate, learn and innovate in order to react to major internal or external changes. The learning process is a set of dynamic interactions with feedback across multiple scales and in multiple dimensions on multiple networks (Jen, 2006). A change entails interpretation and action by agents that induces feedback from the environment.

In reaction, networks may develop new functionalities unanticipated in their original design. Complex networks can generate innovative solutions to maintain and to reinforce themselves. Their robustness may depend on the capacity of the system to generate new agency or to connect itself to another system. Many significant evolutionary innovations occur in discrete bursts which fundamentally reorganize pre-existing ecological relationships (Erwin, 2005). Complex networks are rarely in a stable situation because of a permanent adaptation to perturbations. The dynamics of interactions entails non-linear and sometimes chaotic changes (Barabási, Newman & Watts, 2006).

Silicon Valley: an innovative cluster supported by complex social networks

According to CNT, Silicon Valley can be qualified as 'complex' because of the heterogeneity and the multiplexity of its agents. It can be qualified as a 'network' due to the decentralization of decision and to the importance of social ties to coordinate economic agents (Saxenian, 1994; Castilla, Hwang, Granovetter & Granovetter, 2000; Ferrary, 2003a). The complexity of these networks is due to the heterogeneity of agents and to the interplay of their organizational and human dimensions. Complex networks of organizations interact with complex networks of individuals in a continuous process of embedding and of decoupling (White, 1992). Social ties and organizational ties are intertwined. Social ties create and coordinate organizations, and then organizations decouple from social ties and create new social ties that help found new organizations. Following CNT terminology, as nodes, two agents may have two kinds of complementary professional competences (one is an IT person, the other a business person) and they may be tied by multidimensional links, being friends and business partners, if they create a start-up together. The density of social ties matters in an innovative milieu because important elements of the knowledge used for innovation are tacit (Nonaka, 1994). Social interactions underlie the circulation of knowledge among individuals and organizations (Granovetter, 1985). Dense social ties determine the creation of knowledge. As mentioned by Thompson (2004b), uncertainty and tacit knowledge entail the incompleteness of contracts and imply handshake transactions and regular face-to-face contact to make economic exchanges possible. Regular face-to-face contacts justify the geographical clustering of agents. The clustering density is an important property of complex networks (Newman, 2003) and Silicon Valley is characterized by high clustering density in which ethnic ties, university ties, friendship ties, past professional ties and current professional ties are intertwined to sustain innovation and entrepreneurship (Saxenian, 1994).

The definition of high-tech clusters is often reduced to the presence of and the cooperation between universities, large companies and research laboratories (Etkowitz & Leydesdorff, 1997). Several studies of Silicon Valley point out the importance of Stanford University, of large companies like Hewlett-Packard, Fairchild Semiconductor or Sun Microsystems and of research laboratories like the Stanford Research Institute or the Xerox/Parc to explain the dynamic of innovation in this region. However, if these three kinds of organizations are essential in a high-tech cluster, they do not suffice completely to explain the creation and the development of innovative companies. Silicon Valley is a complex network of innovation made up of heterogeneous and multiplex agents that interact at different levels. Beside universities, large companies and laboratories, there are also law firms (Suchman, 2000), VC firms (Hellman, 2000; Kenney & Florida, 2000), consulting groups, recruiting groups and other service firms (Bahrami & Evans, 2000) that contribute to the creation and the development of innovative start-ups. Thus, CNT may be a useful theoretical framework to conceptualize the interactions of the heterogeneous and multiplex agents that underlie innovation in Silicon Valley.

At least twelve different agents are involved in the creation and the development of successful start-ups: universities, large firms, research laboratories, VC firms, law firms, investment banks, commercial banks, certified public accountants (CPA), consulting groups, recruitment agencies, public relation agencies and media. Each of these twelve agents contributes in different ways to the life-cycle of start-ups that create innovation. For example, the creation of Google involved Stanford University, where the founders were PhD students (and also friends before becoming business partners; this is at least a three dimensional link); later the university provided the company with employees and continues to test new services developed by Google. Two major VC firms in the region, Sequoia Capital and Kleiner, Perkins, Caufield & Byers (KPCB), funded the start-up. The law firm Wilson, Sonsini, Goodrich & Rosati, located in Palo Alto, was in charge of the legal dimension of the venture. Yahoo! (funded by Sequoia Capital) and AOL (funded by KPCB) were the two first clients of Google. Local newspapers like *The San Jose Mercury News*, *The San Francisco Chronicle* and the *Red Herring* publicized the company. Hambrecht & Quist and CSFB, two San Francisco investment banks, organized Google's IPO. By 2006 Google had become one of the largest firms of Silicon Valley and contributed to the complex system by acquiring start-ups in the region, e.g. YouTube (funded by Sequoia Capital). In Silicon Valley, there are ten universities, about forty private or public research centres, 8718 large companies with over 100 employees, 180 VC companies, 3152 legal firms specializing in company law and legal areas related to company activity, 329 recruitment companies, 1913 chartered accounting firms, 311 public relations companies, nearly 700 merchant banks, 47 investment banks and about 100 newspapers employing approximately 500 journalists devoted to the high-technology environment of Silicon Valley.

These twelve agents interact with each other during the start-up life-cycle. For example, a professor of computer science can recommend to a VC firm one of his students who wants to create a company, a VC firm can employ a professor of computer science to evaluate the technological aspect of a project, a CPA can deal with the start-up's lawyer to prepare a new round of funding, a journalist can interview a consultant who has worked for the start-up, and so on. Based only on economic interactions, in the simplest design that we can imagine, the twelve agents can potentially have sixty-six types of dyadic interactions ((12*11)/2) in the course of the creation and the development of a single start-up.[5] Due to the number of potential ties, Figure 1 offers a suggestive diagram that shows the complexity of networks that support the innovativeness of Silicon Valley. It illustrates the complex nature of networks in Silicon Valley in a form regularly used by network theorists to visualize their analysis (Newman, 2003). Based on Baran's typology (Barabási, 2002), it aims to point out that the structure of networks of Silicon Valley is distributed more

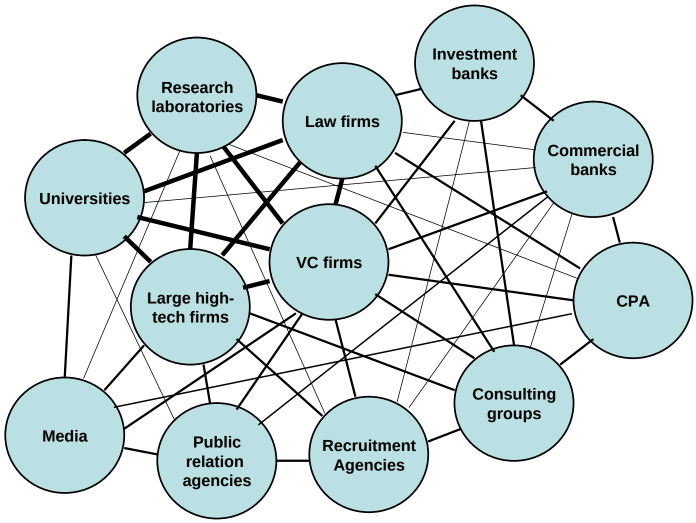

Figure 1 The complex network of innovation of Silicon Valley

than centralized or decentralized. Some agents interact more frequently than others. This induces stronger ties between some agents (Granovetter, 1973). For example, universities, large firms, research laboratories, VC firms and law firms have more interactions among themselves than with others.

There is a virtuous self-reinforcing dynamic of creation of high-tech start-ups. Several large firms that currently contribute to the complex network of Silicon Valley have previously been high-tech start-ups founded in the region (Oracle, Apple, Cisco Systems, Yahoo!) and have been developed with the support of other agents of the system. Another positive effect of the regional innovative dynamic is that large foreign high-tech firms (Nokia, Siemens, Alcatel, Samsung) open branch offices in the region and reinforce the system.

Identifying the complete set of agents that interact and underlie the virtuous dynamics of the complex network of innovation is an important task. Going from a conceptual definition of an innovative cluster as a set of heterogeneous and interacting agents to a comprehensive list of these agents is a valuable contribution to understanding Silicon Valley. An exhaustive identification is important because of the interdependence of agents. The robustness of Silicon Valley (i.e. its sustainable innovativeness) lies in the completeness of its networks. The entire system is weakened if only one of its members is missing. All members are not equally important but all of them contribute to the system. According to CNT, these agents may play different roles and contribute in several ways to the innovative cluster. They can contribute directly or indirectly to the creation and to the development of high-tech start-ups. For example, a direct contribution is when a legal firm helps a start-up to secure its intellectual property, when a consulting group provides its expertise or when an investment bank underwrites the start-up's IPO. An indirect contribution is when universities nurture entrepreneurs or when future entrepreneurs accumulate social ties as employees of large firms. Some agents contribute involuntarily to the creation of start-ups. For example, some entrepreneurs nurture their projects as employees in research laboratories or large firms and they leave their employers to create start-ups. In this way large organizations involuntarily nurture start-ups. Also, when start-ups recruit from large firms, these firms contribute involuntarily to the development of start-ups. Lastly, some agents, such as PR agencies, consulting groups or recruitment agencies contribute to the network in innovative clusters by connecting agents. They organize social events or meetings where people create social ties. For these reasons, innovation in Silicon Valley results from a complex network. Numerous heterogeneous agents (nodes) are involved with multiplex functions and these agents have multi-dimensional ties (professional, friendship, familial). The coordination between these agents is completely decentralized. There is no central agent (or central node) that coordinates the others. The innovativeness is a by-product of this complex network. Agents of the Silicon Valley innovative cluster and their formal and informal functions may be summarized as in Table 2.

The economic success of a start-up does not result only from the quality of the entrepreneur and its innovation, but also from its embeddedness in complex social networks. The more connected an entrepreneur is, the better is his access to financial resources, to advice, to partners and experts. Conversely, an isolated entrepreneur would have more difficulty mobilizing the resources needed. According to CNT, the quality of interactions between agents determines the success of each agent and, finally, the achievement of the entire system. In the case of Silicon Valley, a start-up can interact with a complementary agent only if the latter belongs to the cluster. The dynamics of innovation depends on the completeness of the environment. Accordingly, the innovative capability of Silicon Valley is a product of completeness of the set of its interdependent and heterogeneous agents. We argue that some other high-tech clusters are less innovative because of their networks' incompleteness.

Silicon Valley can be characterized as a robust system because of its capacity to generate radical innovations in the long run, to support new industries and to face major industrial disruptions. CNT is particularly useful to qualify and to understand the specific robustness of Silicon Valley. Jen (2003) insists on the difference between stability and robustness. Stability describes the system's capacity to survive by returning to the same position after a shock. Robustness describes the system's capacity to survive a shock by radically reorganizing itself and restabilizing in a new configuration. Silicon Valley was originally based on the semiconductor industry, with companies like Fairchild Semiconductor, National Semiconductor, Intel, AMD and Cypress. This industry was shaken in the early 1980s by the strong Japanese and Taiwanese competition. According to CNT, Silicon Valley would be a stable system if the region were to stay the leader of a semiconductor industry configured in the same way. Actually, Silicon Valley has shown its robustness for two reasons. First, the

Table 2 Economic functions of agents of Silicon Valley

Agents	Formal functions	Informal functions
Universities	Nurture innovations Accumulate expertise Provide trained workers	Incubate start-ups Socialize agents
Large firms	Nurture innovations Develop innovations Accumulate expertise	Incubate start-ups Acquire start-ups Partner with start-ups Provide trained workers Socialize agents
Research laboratories	Nurture innovations Accumulate expertises	Incubate start-ups Socialize agents
VC firms	Finance start-ups	Select start-ups Accumulate entrepreneurial knowledge Embed start-ups Signal start-ups Network the cluster
Law firms	Accumulate legal expertise Handle legal issues	Embed start-ups Network the cluster
Recruitment agencies	Favour labour market	Network the cluster
Public relations firms	Publicize start-ups	Network the cluster
Media	Circulate information	Publicize start-ups Sustain an entrepreneurial culture
Consulting groups	Accumulate business expertises Supply expertise to start-ups	Provide trained workers
CPAs	Accumulate accounting expertise Handle accounting issues	
Investment banks	Organize IPO of start-ups Organize acquisitions of start-ups	Signal start-ups
Commercial banks	Enable financial transactions	

Source: Compiled by Michel Ferrary and Mark Granovetter.

Californian semiconductor industry radically redesigned the value chain of the sector by focusing on the design of semiconductors and outsourcing the production to Asia. Second, the region got involved in new industrial sectors such as personal computers (Apple) and software (Oracle, Sun Microsystems, Symantec, Electronic Arts, Intuit). Later, Silicon Valley gave rise to telecommunication equipment start-ups (Cisco System, Juniper Networks, 3Com) and finally to the internet industry (Netscape, Excite, eBay, Yahoo!, Google). Each new industry was supported by the previous industries. The semiconductor industry enabled the computer industry and the software industry. These industries supported the telecommunication equipment industry. Finally, all these industries enabled the internet sector. Each new mature industry reinforced the innovative capacity of the cluster and improved the robustness of the complex network. The complex network of innovation generates agents with new competences that interact with the former agents and reinforce its innovative capability. More recently, Silicon Valley has radically redesigned its role in the software industry. The competition from India and China based on cheap software engineers is a major challenge for the Californian innovative cluster. In reaction, Silicon Valley radically changed its role by becoming a coordinator of the international software industry (Friedman, 2005; Saxenian, 2006). This move, which made sure that Silicon Valley retained its central position in the industry, highlights the robustness of region's innovative capability. This evolution illustrates the general growth model of complex networks described by Newman (2003) in which networks are resilient because they are able to add new links and new nodes in order to survive.

The completeness and the embeddedness of heterogeneous and interdependent agents are sources of the innovativeness of Silicon Valley. Different studies have emphasized the contributions to innovation by universities, research laboratories and large high-tech firms. The next section highlights the contribution of another agent: VC firms. It does not argue that VC firms by themselves explain the innovative capability of the Silicon Valley, but rather that their presence in the complex network enables specific interactions between agents and contributes to its completeness. These specific interactions sustain the robustness of the complex network of innovation.

VC firms as a source of robustness in Silicon Valley's complex innovation network

The founding date of Silicon Valley is a matter of debate. Some scholars believe that the industrial region was born in 1891 when Stanford University was founded (Adams, 2005). According to others, the creation of the Federal Telegraph Company in 1909 initiated the regional dynamics of innovation (Sturgeon, 2000). Some consider the establishment of Hewlett-Packard in 1939 as the main factor. Finally, some date it to 1955 when William Shockley founded the first semiconductor company in Palo Alto.

A longitudinal and historical analysis (Pettigrew, 1990) of the innovative complex network of Silicon Valley points out that it was not built all at once, but over decades by a progressive aggregation of heterogeneous and complementary agents. This gradual aggregation initiated a virtuous dynamic of endogenous growth that led to the entry of new agents who reinforced the complex network of innovation and nurtured the creation of new high-tech start-ups.

Stanford University was the first agent in the system of innovation. It has incubated a number of groundbreaking technologies and notable entrepreneurs and has trained many workers for the region. Byers, Keeley, Leone & Parker (2000) estimate that more than 2000 Silicon Valley companies have been created by Stanford alumni or faculty. Historically, a network of agents aggregated around Stanford has improved the system of innovation and made it more complex. In the 1930s, numerous non-Californian firms established branches in Palo Alto: General Electric, Eastman Kodak, Lockheed, IBM. Private research laboratories were established, such as the Stanford Research Institute (1946) and the Xerox/Parc (1970). At the same time, other agents of the complex network aggregated in the region. In 1968, an investment bank, Hambrecht & Quist, was established in San Francisco to underwrite initial public offerings (Hambrecht, 1984). Robertson & Coleman, another investment bank, was founded in the same period. Later, investment banks from Wall Street, such as Goldman Sachs, JP Morgan and Citicorp implanted offices in the region. The 1980s were characterized by the development of legal firms working with the high-tech industry: Wilson, Sonsini, Goodrich & Rosati, Ware & Friedenrich, Fenwick, Davis & West (Suchman, 2000).

If one considers the number of new start-ups as revealing the innovativeness of a cluster, then, in the 1940s, Silicon Valley was not very innovative. The region did not create many start-ups or high-tech jobs despite the presence of universities, large firms and the support of the state. We argue that the incompleteness of the network at that time explains the weakness of innovation. Adams (2005) points out that in 1939, when Hewlett-Packard was created, electrical and radio firms employed only 464 people in the San Francisco Bay Area (by 1963 there would be 17,000) and only 243 high-tech companies were created in this region between 1960 and 1969. The acceleration of the endogenous growth of Silicon Valley came with the development of the semiconductor industry in the late 1950s and the early 1960s. This was also when the Californian VC industry began to develop. In 1958, Draper, Gaither and Anderson created the first Californian VC firm. In 1961, in San Francisco, Arthur Rock and Tommy Davis established Venrock Associates, the first VC firm adopting limited partnership as the legal structure. Later, this legal structure became common in the VC industry (Kenney & Florida, 2000). The most prominent VC firms were created in the 1970s. In 1969, the Mayfield Fund was founded; Sequoia Capital and Kleiner, Perkins, Caufield & Byers followed in 1972. By 1975, more than thirty VC firms were located in the Bay Area.

The first Silicon Valley high-tech start-ups were funded by individuals or large firms. Shockley Semiconductor was backed by a large firm in 1955 (Beckman Instruments), and Fairchild Semiconductor was funded by Fairchild Corporation in 1957, but the later semiconductor start-ups were supported by venture capitalists. In 1968, Intel was backed by Venrock Associates. Cypress Semiconductor, Teledyne and AMD got funding from Sequoia Capital. In 2006, twenty-eight of the thirty largest high-tech employers of Silicon Valley (including Intel, Sun Microsystems, Apple, Oracle, Cisco Systems, eBay, Yahoo!, Google)[6] had been funded by VCs when they were created or shortly after. Out of these twenty-eight companies backed by VC firms, twelve were backed in the year of their founding, nine the year after, two two years later and five three or more years after their creation (see Table 3).

The fact that, in the mid-1960s, the high-tech endogenous growth in Silicon Valley and the development of the VC industry in this region coincided in time leads one to inquire about the contribution of VC firms to the innovative cluster. Before the 1960s, Silicon Valley was not really innovative, partly because of its incompleteness. CNT is particularly useful to explain the change. Silicon Valley was an incomplete network of heterogeneous agents (nodes) that was able in the 1960s to attract a new agent (node) that has generated new interactions (links) with existing agents that have created growth and sustained innovation.

The contribution of VC firms to Silicon Valley

The complex network of Silicon Valley is made up of heterogeneous agents that contribute in different ways to innovation and start-ups' creation. This research focuses especially on the VC firms' functions, but these functions become real only through the VCs' interactions with the other agents of the network. VC firms do not have a value by themselves but because they interact with others. This grounds the interdependency of agents in Silicon Valley's complex innovation network. This is a crucial point for regions or countries that think they can reproduce Silicon Valley's experience simply by developing VC as a stand-alone enterprise. CNT highlights the importance of heterogeneity and completeness to explain the weakness or the robustness of a network. The systemic dimension of Silicon Valley is such that the VC firms do not sustain by themselves the robust innovativeness of the region but, on the other hand, that without them the system would be less innovative. VC firms are complex agents that handle multiplex functions through multiplex interactions with the other agents of the networks. We define five different functions.

Financing function

The best-known economic function of VC is, of course, funding the creation and the development of start-ups (Gompers & Lerner, 2004). There is a stage in the life-cycle of high-tech start-ups when they need external funding because they do not generate sufficient revenues. VC funding is crucial at this stage. VC firms get equity shares in the start-ups in return for their funding. The financial risk of VC investment is very high. Commercial banks do not lend money to high-tech start-ups because of the high risk. Lacking assets or a proven cash flow, start-ups are unable to raise capital from conventional sources, such as commercial banks or the public market. Beside 'angel'

Table 3 Initial VC funding of large high-tech companies

Company	Employees	Founded	First funding	Investors
Adobe Systems	5734	1982	1982	JP Morgan Partners
Advanced Micro Devices	9860	1969	1969	Sequoia Capital, Bixby Associates, Bank of America
Agilent Technologies	21,000	1999	*	*
Apple Computer	14,800	1977	1978	Sequoia Capital, Venrock Associates, Arthur Rock
Applied Materials	12,576	1967	1969	Partech International, Adler & Co., Frederick Adler, General Electric Venture Capital
Atmel	8076	1984	1987	Institutional Venture Partners
Cadence Design Systems	4900	1988	1988	TA Associates
Cisco Systems	38,413	1984	1984	Sequoia Capital, Stanford University, Indosuez Ventures, Vencap, Inc.
Cypress Semiconductor	5100	1982	1983	Sequoia Capital, Mayfield Fund, Stanford University, KPCB, Merrill, Pickard, Anderson & Eyre, Dietrich Erdmann, Whitney & Co., Sevin Rosen Funds
eBay	22,000	1995	1997	Benchmark Capital
Electronic Arts	6819	1982	1982	Sequoia Capital, KPCB, Sevin Rosen Funds
Google	5680	1998	1999	Sequoia Capital, KPCB
Hewlett-Packard	150,000	1938	*	*
Intel	99,900	1968	1968	Venrock Associates, Grinnell College
Intuit	7000	1983	1989	KPCB, Warburg Pincus LLC, Technology Venture Investors, Sierra Ventures
Juniper Networks	4145	1996	1996	KPCB, Wilson, Sonsini, Goodrich & Rosati
KLA-Tencor	5500	1989	1994	Sprout Group, DLJ Merchant Banking Partners

Table 3 (*Continued*)

Company	Employees	Founded	First funding	Investors
Komag	6141	1983	1983	CIVC Partners, Hambro International Equity, Merrill, Pickard, Anderson & Eyre
LSI Logic	4322	1980	1981	Sequoia Capital, Menlo Ventures, KPCB, 3i, Bryan & Edwards, Institutional Venture Partners, Mayfield Fund, Merrill, Pickard, Anderson & Eyre, Sutter Hill Ventures, Technology Venture Investors
Maxim Integrated Products	7980	1983	1983	Adler & Co., Albion Ventures, Bessemer Venture Partners, Brentwood Associates, Cardinal Partners, GC&H Partners, L Squared Ltd. Partners, Merrill, Pickard, Anderson & Eyre
Maxtor	13,656	1982	1982	Bay Partners, Lefcourt Group
National Semiconductor	8500	1959	1967	Electronics Capital
Oracle	49,872	1977	1978	Sequoia Capital
Sanmina-SCI	37,021	1985	1985	Menlo Ventures, Morgan Stanley Venture Partners
Seagate Technology	44,000	1979	1980	Institute for New Enterprise Development, Institutional Venture Partners, Jamieson & Co., Oak Investment Partners
Solectron	57,000	1977	1984	Citibank, Cornerstone Management, Hambro International Equity, Manufacturers Hanover Venture Capital Corporation, Okabena Partnership, Prudential Capital Group, Robert Fleming Venture Capital Unit

Table 3 (*Continued*)

Company	Employees	Founded	First funding	Investors
Sun Microsystems	31,000	1982	1982	West Coast Venture Capital, Technology Venture Investors, U.S. Venture Partners
Symantec	6500	1982	1983	KPCB
Synopsys	4756	1986	1987	Austin Ventures, Brentwood Associates, First Venture Corporation, General Electric Venture Capital Corp., Harris Corp., Menlo Ventures, Merrill, Pickard, Anderson & Eyre, Oak Investment Partners, Technology Venture Investors, Xerox New Enterprises
Yahoo!	9800	1994	1995	Sequoia Capital

Source: Venture One.

investors who contribute smaller amounts, VC firms have a monopoly in funding seed and early stages of high-tech start-ups. Capital venturing is a dynamic and creative process by which capital investments in emerging enterprises are made, managed and developed (Kozmetsky, Gill & Smilor, 1985). A number of fledgling companies will fail because they cannot obtain adequate risk capital, particularly during the early critical stage. According to Batterson (1986), major risk capital is presently available only from VC firms. VC investments sustain and accelerate the growth of start-ups (Hellmann & Puri, 2002). Later, the funding of high-tech start-ups depends on self-financing, on initial public offerings or on acquisitions by larger firms (Gompers & Lerner, 2004).

VC firms fund start-ups directly and other agents of an innovative cluster indirectly. A start-up partly uses its funding to pay for the services of law firms, consulting groups, PR agencies and recruiting agencies (see Figure 2). Through the funding of start-ups, VC investments sustain different service providers. Start-ups also use their funding to recruit employees trained in local universities. Thus, indirectly, VC funds the labour market of the cluster. The creation of start-ups is thus a business activity that involves different agents that are indirectly paid by VC money. For this reason, VC investment is more than just the funding of start-ups; it is, more broadly, a source of funding for the entire innovative cluster. To make a parallel with the power network (Watts & Strogatz, 1998) and by considering money as the energy of the network economy, a VC firm empowers the network by creating a financial tie with a

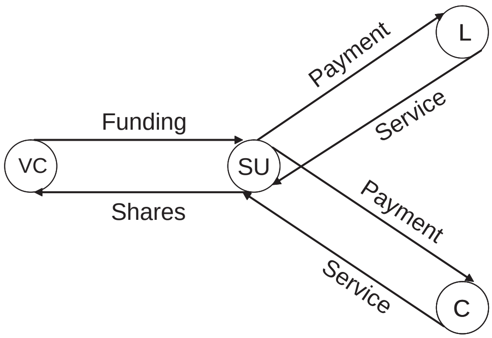

Figure 2 Financing function

Note: Start-up (SU), VC firm (VC), Consulting group (C), Law firm (L).

start-up. The financial flux coming from the VC firm enables the start-up to create business ties by paying other agents of the network (lawyers, consultants, experts etc.).

Selection function

Venture capitalists fund three or four start-ups out of more than 500 business plans received per year (Perez, 1986). They try to pick the most promising projects because their earnings depend on the performance of their investments. Twenty per cent of the returns on their investment come from carried interest (Gomper & Lerner, 2004). A venture capitalist typically evaluates three kinds of risk before any investment: the risk related to the technology, the risk related to the market and the risk related to the entrepreneur.

A traditional economics perspective attributes the function of selecting enterprises to the market. Evolutionist theory (Nelson & Winter, 1982) argues that natural selection of the best products is due to the customers' choice. In this perspective, the rise of a new technology that becomes a 'dominant design' results from market competition. A company disappears if it does not have enough customers (Schumpeter, 1911). In Silicon Valley, the life cycle of start-ups is different. VC firms select companies before the market has a chance to do so. At the seed stage, when a VC firm considers its business plan, a start-up typically has no or very few clients. Some start-ups do not face the market for several years after they get VC funding. Thus, they are highly dependent on VC investments. The survival probability of a start-up is very low if it does not receive VC money to fund its development. VC firms do not fund all start-ups created in Silicon Valley. Just 9 per cent of the high-tech start-ups created in Silicon Valley are backed by VC firms at the seed stage. From 1990 to 2000, out of the 2100 high-tech companies created per year (Zhang, 2003), around 200 got seed-stage VC funding.[7] Literature on VC focuses mainly on consequences for start-ups of getting VC funding and ignores the consequences when start-ups do not get this funding. Basically, without VC funding, a start-up can barely create business ties with agents of the complex network of innovation because it cannot pay them.

In Silicon Valley, VC firms specialize in certain sectors (telecommunication equipment, software, biotechnology). They receive business plans in their area of specialization because their reputation is well-established in the cluster. Some of them receive virtually no business plans outside their area of specialization. The investor can evaluate and compare all the start-ups before picking the best one with the right technology and the best people. VC firms implicitly decide the survival and the death of start-ups by choosing which of them to fund. Venture capitalists are well connected to each other. Thus, if a prominent one refuses to invest in a start-up, the information is quickly spread in networks and it become very difficult for the start-up to raise funding from other VC firms. A comment by a partner of a VC firm specializing in telecommunication technologies illustrates this selection process:

> In Silicon Valley, everybody knows the potential market opportunities for new technologies. For example, there is a huge potential market related to the possibility to do secured electronic payments on mobile phones. Banks and telecommunication companies are looking for such technology. Currently, in Silicon Valley, there are several entrepreneurs who are developing a project related to this prospective market. In the region, I am clearly identified as a specialized VC in telecommunication technologies and it is well known that I am close to a large commercial bank. Thus, I received almost all the business plans related to electronic payment on mobile phone. Entrepreneurs directly send me their business plan or VC firms that do not specialize in this domain redirect them to me. I got almost forty business plans. I will compare their technology, their understanding of the market and their teams. At the end, I will only invest in the best start-ups.

Such pre-market selection saves resources in the innovative cluster. The specific venture capitalist's competence is to evaluate the business opportunity of a start-up. Venture capitalists can often judge the potential of an innovation better than entrepreneurs. VC firms eliminate start-ups by refusing to invest in some of them at the seed stage. VC funding determines what start-ups will be connected, or not, to the complex network of innovation (see Figure 3). If one believes that VC firms are the most qualified to evaluate the business plan for a start-up then they implicitly save resources (entrepreneurs, service providers, employees) before market selection. By selecting start-ups, the VC firms implicitly prevent the other agents in the complex network of innovation from collaborating with start-ups that do not get VC funding. It could be argued that potential valuable innovations have never reached customers because they did not get VC funding to get connected to the network, but the data to evaluate this possibility would be difficult to acquire.

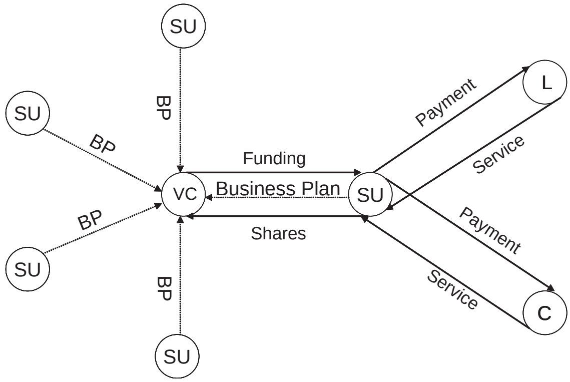

Figure 3 Selection function
Note: Start-up (SU), VC firm (VC), Consulting group (C), Law firm (L).

Signalling function

Working for a start-up is risky. Service providers such as law firms, recruitment agencies and consulting groups are not necessarily able to evaluate the risk that the start-up that uses their services will not pay. The level of risk can prevent some service providers from working with start-ups. Workers face the same issue when they consider working for a start-up. An engineer who resigns from a large high-tech company to work for a start-up risks losing his job if the company goes bankrupt. This risk is even higher if his compensation is largely based on stock options. Finally large firms face the same risk when they consider possible contracts with start-ups.

This uncertainty is a crucial issue in an innovative cluster. The risk of dealing with start-ups is so high that some economic agents may refuse to do business with them. There is a potential vicious circle where high-tech start-ups fail because other agents refuse to deal with them. Ultimately, the entire system can collapse because of the reluctance of some interdependent agents to interact with each other.

Funding by a VC firm, especially a prominent one like Sequoia Capital, KPCB, Menlo Ventures or Benchmark Capital, gives a positive signal to other agents of Silicon Valley, where it is common knowledge that the main competence of VCs is to evaluate start-ups. When a top-tier VC firm invests in a start-up, it does not guarantee success, yet it gives a positive signal. Podolny (1994) points out that economic agents tend to collaborate with agents having the same status when they face uncertainty. In an uncertain environment, high-status agents tend to aggregate and to exclude low-status agents. Newman (2003) generalizes this finding by mentioning that it is a common phenomenon in many social networks that we tend to associate preferentially with people who are similar to ourselves in some way. The propensity to homophily is exacerbated in an uncertain environment. Therefore, agents of the complex network of innovation, especially high-status ones, are more likely to create ties with start-ups that have previously been able to connect with high-status VC firms. A connection with a high-status VC firm signals the high status of the start-up and encourages other agents to link to it.

Conversely, a negative signal is sent if a start-up raises funding from an unknown VC firm or, even worse, does not raise any venture capital. Many of the agents of Silicon Valley want to know the VC investors in a start-up before deciding on collaboration. A prominent head-hunter describes the signalling function of VC firms:

> I specialize in recruitment of chief financial officers. Basically, I know everybody in finance departments of high-tech companies. I have a huge database on financial officers. I know the good ones and the bad ones. On the other hand, recruitment of a talented CFO is crucial for start-ups, especially when they consider going public. In Silicon Valley, I have a pretty good reputation for finding good CFOs. I receive more than twenty requests per month from companies that want to recruit financial officers. I can only handle two or three of them at the same time. Thus, I have to choose between the requests. My issue is to choose those coming from start-ups that will be able to pay me. The bankruptcy rate is very high among start-ups. It is even more important if I agree to be paid by stock-options of the company instead of cash. I make my choice based on the VC firms that have backed the start-ups. I accept the request if Sequoia Capital or another top-tier VC funded the start-up, otherwise I refuse. I don't want to take the risk.

Funding by VC firms signals the quality of start-ups to other agents (see Figure 4). In effect, VC firms do risk evaluation for the complex network. By investing or refusing to do so they signal the level of risk for each start-up and indirectly modify the risk evaluation and the behaviour of the other agents of the system. They encourage other agents to collaborate with the most promising start-ups and to avoid involvement with more fragile companies. By funding promising start-ups, VC firms contribute heavily to the capabilities of anticipation and of innovation that characterize a robust complex network in complex network theory (Dodds, Watts & Sabel, 2003; Jen, 2006).

Collective learning function

The persistence of innovative capability underlies the robustness of the complex system of Silicon Valley. In spite of competition from new high-tech clusters in the US and abroad, Silicon Valley keeps creating high-tech start-ups. Many high-tech companies have been created over the last fifty years, but many of them have disappeared. Migration of workers from the US and from abroad has fluctuated. Each new high-tech growth attracts a wave of immigrants and each crisis entails emigration. The VC industry is a source

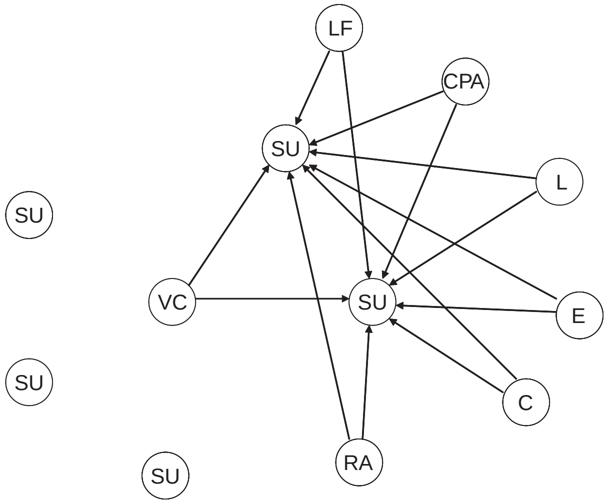

Figure 4 Signalling function

Note: Start-up (SU), VC firm (VC), Recruitment agency (RA), Consulting group (C), Employees (E), Law firm (L), Certified public accountant (CPA), Large firm (LF).

of stability in the midst of these changes. The prominent VC firms of the 2000s were created in the 1970s and the 1980s (Sequoia Capital, KPCB, Menlo Ventures, Mayfield Fund). Moreover, founders of these VC firms often made their entire careers in the firm they created. For example, all the founders of Kleiner, Perkins, Caufield & Byers worked for the firm from 1972 till retirement. Byers still works for the firm. John Doerr was recruited in 1980. At Sequoia Capital, Don Valentine, the founder of the firm in 1972, is still an active partner. Six general partners of the firm have seniority over fifteen years. H. Dubose Montgomery founded Menlo Ventures in 1976 and is still an active partner; two of his associates have worked in the firm for over twenty years.

This durability of venture capitalists ensures that over the years they accumulate tremendous knowledge on creation and development of high-tech companies. Senior venture capitalists have evaluated thousands of projects and funded and accompanied dozens of start-ups. They have a deep understanding of industrial, technological, legal and managerial issues. Venture capitalists are, moreover, strongly involved in the management of the start-ups they have backed (Gorman & Sahlman, 1989). They meet the entrepreneurs at least monthly at board meetings and sometimes daily. In some cases, the venture capitalist becomes a temporary worker for the start-up or the entrepreneur is housed in the VC offices. The structure of social networks affects the spread of information (Granovetter, 1973; Newman, 2003); therefore connections to VC firms give access to entrepreneurial knowledge.

Some entrepreneurs have entrepreneurial experience before founding a start-up but the majority of them do not. For example, graduate students such as the founders of Google or Yahoo! rarely have business and entrepreneurial experience. Pierre Lamond, a general partner at Sequoia Capital since 1981, gives us example of such transfer of knowledge:

> In 1984, Sequoia Capital funded Cisco Systems, a telecom equipment start-up founded by Len Bosack and Sandy Lerner, two employees of Computer Operations staff at Stanford University. They did not have competence in finance matters. At some point, at the end of the 80s, it became crucial to monitor the cash burning rate of the company. For some months, I became the chief financial officer of Cisco Systems to bring my competences. Then they recruited a permanent CFO.

An entrepreneur gets access to the venture capitalist's knowledge by being funded by a VC firm. For example, a start-up backed by Sequoia Capital would benefit from entrepreneurial knowledge related to companies like Apple, Intel, Oracle, Electronic Arts or Yahoo! This contribution is reinforced by two facts. First, venture capitalists are often former entrepreneurs and have personal entrepreneurship experience to share. Second, general partners of the same VC firm share their knowledge. Partners can always ask their associates for advice on an issue they face in one of their start-ups.

An entrepreneur gives an example of knowledge transfer by venture capitalists:

> I faced an issue when I got my first clients. I had to implement a billing process. I did not know what to do. I hesitated between outsourcing and insourcing it. I mentioned this issue to my VC. He came up with a great solution. Several start-ups funded by his firm had previously faced the same issue. One of them had outsourced its billing process to a company in India. The solution proved to be efficient and all other start-ups backed by my VC firm outsourced their billing to this Indian company. Following the advice of my VC, I did the same.

By financing start-ups, venture capitalists accumulate entrepreneurial knowledge. They are the memory of the complex network of the Silicon Valley. They share with the entrepreneurs the best and the worst entrepreneurial practices they know. As a new generation of venture capitalists arrives in the prominent VC firms of Silicon Valley (for example, six new partners have been recruited by Sequoia Capital in the past four years and nine by KPCB), the coexistence of the two generations of venture capitalists ensures the knowledge transfer between partners.

CNT emphasizes the learning capability of robust complex networks (Jen, 2006). In the perpetually changing environment of Silicon Valley's networks, the VC firms are perennial agents that accumulate and diffuse entrepreneurial knowledge through different life-cycles of technological industries (see Figure 5). By accumulating this knowledge during the maturation of an industry (for example, the semi-conductor industry) and by transferring it to an emerging one (for example, the software industry), the VC firms sustain the reconfiguration that ensures the survival of the complex network when an industry declines.

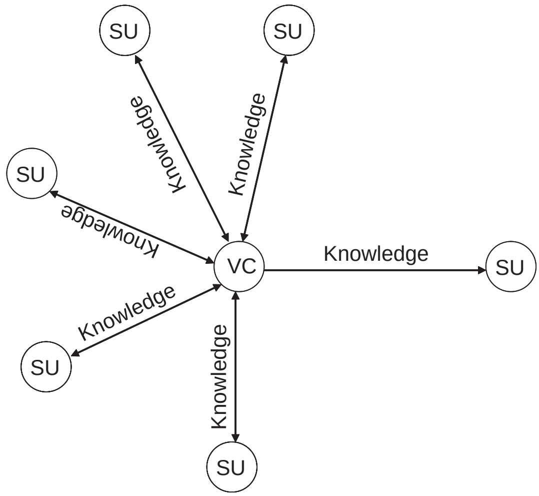

Figure 5 Collective learning function
Note: Start-up (SU), VC firm (VC).

Embedding function

The embeddedness of entrepreneurs in the complex networks of Silicon Valley is a major factor determining the success of start-ups. Several studies point out that in Silicon Valley social networks matter in the circulation of knowledge and the business coordination of agents (Saxenian, 1994; Castilla, Hwang, Granovetter & Granovetter, 2000). The social ties between economic agents, or the ease of creating them, strongly affect the start-ups. An entrepreneur who is poorly embedded in the complex networks gets few resources from the agents of the cluster and may compromise his success. This raises a specific issue for the network theory about the embedding process of agents. A large set of researches points out the influence of the social network structures on agents. Conversely, few researches analyse how agents become embedded in a specific network. The case of Silicon Valley points out that embeddedness can result from the strategic behaviours of agents. Agents are active nodes that influence the structure of networks. Watts (1999) mentions that CNT considers mainly networks of passive agents, but that social networks deal with active agents in the sense that the network is a device to be manipulated consciously for an agent's own ends. It is well established by CNT that networks are not randomly structured (Newman, 2003; Barabási, Newman & Watts, 2006); rather, the structure of the network results from the behaviour of the nodes because agents are 'networkers' (Granovetter, 2003). Silicon Valley highlights the latter situation. Some entrepreneurs of Silicon Valley are already embedded before they found a company. They may have worked for a long time in a large local company. Some of them grew up in the region or graduated from a university in the Bay Area.

For example, one can imagine that when Jim Clark founded Healtheon in 1996, as a former Stanford professor and founder of Silicon Graphics and Netscape, he was deeply embedded in social networks of Silicon Valley. Yet, the majority of entrepreneurs are less embedded and some of them could be isolated from business networks. This applies especially to new immigrants. However, Saxenian (2002) reports that many founders of Silicon Valley firms are immigrants. The embedding of isolated potential entrepreneurs is a major issue for the dynamics of innovation. Entrepreneurs behave strategically to embed themselves. The VC firms also embed the start-ups they fund in the complex networks of Silicon Valley. As mentioned in Table 2, VC firms are not the only embedding agents. More or less all the agents have an interest in embedding a start-up that they support. However, they first try to connect them with a VC firm to get access to their networks. For an entrepreneur, it is more strategic to be connected with a VC firm than with, for example, a CPA. A VC firm can more easily create a tie between a start-up and a CPA than the other way round.

Venture capitalists are deeply embedded in the social networks of Silicon Valley. They have resided in the region for several years. They have worked in different large high-tech firms of the region. They belong to several boards of directors of start-ups or even of large firms. They frequently interact with universities as speakers or advisers. They graduated from local universities. They are partly recruited for their social network. Kevin Fong, a Mayfield Fund partner, is a good example of an embedded agent. He graduated from Stanford University and UC Berkeley. He has worked for Nortel, Hewlett-Packard and David Systems. In 1988, he joined Mayfield Fund. According to the Mayfield Fund's website, Kevin Fong invested in Alantec, Crescendo Communications, Legato, Latitude, Mobile 365, Redback Networks and Tasman Networks. He currently sits on the boards of 3PARdata, Cemaphore Systems, Fultec, Hammerhead Systems, Lattice Power, Mendocino Software, ONStor and Velocity11.[8] He was formerly on the board of the Western Association of Venture Capitalists, and he is currently on the boards of Community Foundation Silicon Valley and the Palo Alto Medical Foundation. He is the co-founder of Silicon Valley Social Ventures (SV2) and is an invited member of the American Leadership Forum. He frequently gives lectures at Stanford University.

The deeply embedded venture capitalists are embedding agents for the isolated entrepreneurs they back (see Figure 6). VC firms are the main hubs between entrepreneurs and the complex networks of Silicon Valley. They enable interactions between interdependent economic agents. They do this because the profitability of their investments depends on these interactions. Entrepreneurs have access to information, resources, service providers and business partners through their investors. For example, the two first clients of Google were Yahoo! and AOL. These two companies had been funded by the same VC firms that backed Google: Sequoia Capital and KPCB.

A French entrepreneur in Silicon Valley illustrates the embedding function of VC firms:

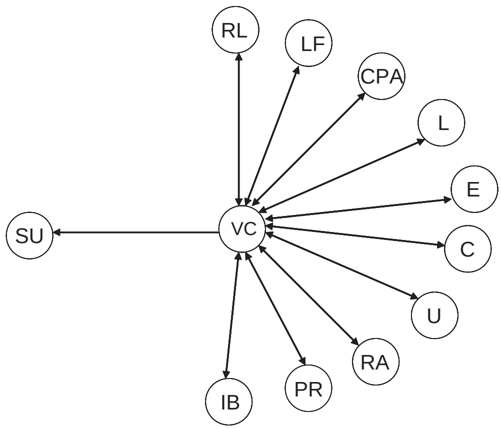

Figure 6 Embedding function

Note: Start-up (SU), VC firm (VC), Investment bank (IB), Public relations firm (PR), Recruitment agency (RA), University (U), Consulting group (C), Employees (E), Law firm (L), Certified public accountant (CPA), Large firm (LF), Research laboratory (RL).

> I was a graduate student at Stanford when I got the project to create an internet start-up. At that time, I had nobody to help me. Through the French community of Silicon Valley, I met a French venture capitalist working for Benchmark Capital. He decided to fund my company. He brought me lots of contacts. He introduced me to a prominent law firm and to a recruitment agency. He recruited a talented and well-connected CEO for the company. He put me in touch with Doubleclick to sell my software.

All agents of the innovative cluster want to be connected with VC firms because venture capitalists nurture strong ties with their entrepreneurs and get inside information. A close relationship with a VC firm is a way to get private information on start-ups it has invested in. Some large firms invest in VC funds as limited partners in order to get access to inside information. The relationship between Cisco Systems and Sequoia Capital is a good illustration. Cisco Systems is famous for its acquisitive strategy to get new products and new technologies. Cisco Systems has bought ten start-ups funded by Sequoia Capital. The close relationship between the two companies (Sequoia Capital funded Cisco, D. Valentine is vice-chairman of Cisco, Cisco invests in Sequoia's funds) underlies these acquisitions (Ferrary, 2003b). Venture capitalists integrate the innovative cluster socially by creating ties between interdependent agents. By connecting people, they contribute to a better coordination inside the complex network.

CNT points out the multiplexity of interactions in complex networks. By embedding entrepreneurs, the VC firms build the multiplexity that sustains the Silicon Valley's complex innovation network. As one of the main hubs between start-ups and complex networks of innovation, the VC firms are one of the agents (or nodes) that supports the robustness of the complex network. CNT points out that some nodes are more important for the resilience of the network because of the non-randomness of complex networks (Barabási & Bonabeau, 2003; Newman, 2003). Out of the 180 VC firms of Silicon Valley, the destruction of the ten most prominent of them might strongly affect the connectivity of the cluster and, then its innovativeness, because these prominent firms are network 'hubs' with far more ties than other nodes.

Conclusion

First, innovation and entrepreneurship have been understood as resulting from the action of a unique agent: the entrepreneur (Schumpeter, 1911). Second, they have been analysed as a by-product of simple organizational networks involving mainly three agents: universities, large companies and research laboratories or government (Rosenberg, 2002; Etzkowitz, 1999). More recently, different researches, notably on Silicon Valley, have pointed out the implication of a large variety of agents that give a more complex picture of innovation and entrepreneurship. This complexity needs a theoretical framework to be conceptualized.

CNT is useful for understanding the innovativeness of Silicon Valley because this region is a complex network of innovation. With respect to the definition of a complex network, 1) Silicon Valley is a network of heterogeneous and multiplex agents; 2) interactions between agents are multiplex and self-organized; 3) Silicon Valley is a robust system that has evolved to resist different industrial and technological shocks to maintain its innovativeness; and 4) this robustness is due to the anticipating and learning capabilities of the system, mainly supported by venture capital firms.

The use of CNT to analyse innovative clusters emphasizes the systemic dynamics of innovation. The exploration of the complex networks of Silicon Valley points out the specific functions of VC firms and their contribution to the robustness of the system. Beyond the funding of start-ups, the VC firms select the most promising projects of the region, signal the best start-ups to the business community, accumulate and spread entrepreneurial knowledge in the cluster and embed the interdependent agents of the network. VC firms depend on other agents of the complex network of innovation and vice versa. Due to this systemic interdependence, the absence or the presence of only one type of agent can weaken or reinforce the entire system. By emphasizing the heterogeneity and the interdependence of agents (the nodes), the analysis of Silicon Valley has implications for complex network theory. CNT is more focused on the structure of ties (links) than on the nature of the agents (nodes) to explain properties of complex networks. The example of the scale-free networks of the Internet (Faloutsos, Faloutsos & Faloutsos, 1999) or the one of power grids (Watts & Strogatz, 1998) points out that the network may be weakened by the removal of a few highly-connected nodes. The importance of the node depends on the number of ties (links) it gets and not on its intrinsic nature. In the case of the complex network of Silicon Valley, the removal of

VC firms would also weaken the entire system because of the specificity of their competencies. When the complexity of a network is due to the heterogeneity of its nodes as much as the structure of its ties, then the consequences of the removal of one node depend on its intrinsic nature as much as its connections.

The analysis of Silicon Valley based on CNT can be used to understand public policies that try to reproduce the same kind of innovative clusters elsewhere, and offers new research perspectives. Some countries do not fully understand the complexity of innovation and the specific functions of VC firms in Silicon Valley's complex innovation network. For example, France has been trying to create innovative clusters for more than thirty years. In the 1970s, the French state tried to create nearly twenty 'technopoles'. This generated few high-tech start-ups and no endogenous growth. In 2006, the French government reactivated its effort to sustain innovative clusters. Sixty-seven '*pôles de compétitivité*' were identified and got the support of the state. In 2006, as in the 1970s, the French policy-makers defined an innovative cluster as 'a localized grouping of universities, research laboratories and large high-tech companies'.[9] The definition does not mention VC and the policy-makers do not intend to include any VC firms in these clusters. In France, 95 per cent of the VC firms are in Paris and 85 per cent of these new clusters are not in the Paris area. Furthermore, the French state has created a public administration (OSEO) with an office in almost every new cluster to support potential start-ups financially. Clearly, the French administration imagines the function of VC firms to be financing alone, and does not take into account more informal functions such as selecting, signalling, learning and embedding. On the other hand, some countries do understand the broader functions of VC firms in innovative clusters and try to create a VC industry. VC firms belong to the innovative cluster located around Cambridge in England, for example. The Taiwanese administration helped to attract VC firms to the innovative cluster of Hsinschu. More recently, the Indian and the Chinese authorities supported the rise of a VC industry in their clusters. Some prominent VC firms of Silicon Valley have opened offices in these countries. For example, Sequoia Capital recently opened offices in Beijing, Hong Kong and Bangalore. KPCB has opened offices in Beijing and Shanghai.[10]

It thus appears that understanding Silicon Valley's complexity and the hidden functions of VC firms can help policy-makers who try to create innovative clusters. Future comparative research would do well to consider how the success of such new clusters is related to the extent and significance of VC in their organization and functioning. Another theoretical perspective is to define the complexity of an innovative network by the large diversity of functions or competences needed to generate innovation, then to identify which agents (nodes) fulfil these functions and how they interact with each other (the network structure). Then complex networks of innovation may differ depending on which agent carries out which function (or competences). For example, the selecting, signalling, learning and embedding functions handled by VC firms in

Silicon Valley could be carried out by other agents, depending on the particular history and institutional arrangements in a particular setting.

The analysis of Silicon Valley points out that the complexity and the robustness of a network depend on the intrinsic nature and the diversity of its nodes as much as the structure of its ties. Nodes get different 'attractiveness[es]' (Bianconi & Barabási, 2001) that depend on their nature and that shape the structure of the network by explaining the links supported by nodes.

The 'robustness' of a complex network is a relatively new concept for CNT. Dodds, Watts & Sabel (2003) have modelled robustness but its analysis is mainly carried out in non-human networks like computer, neuronal, molecular or ecological networks (Jen, 2006). This article is a contribution to the analysis of robustness in inter-organizational and social networks.

Notes

1 Research reported by Ebsco points out that no article on Silicon Valley has been published in journals like the *American Economic Review*, *Quarterly Journal of Economics*, *Journal of Political Economy*, *Academy of Management Review*, *Academy of Management Journal*, *Administrative Science Quarterly* or *Strategic Management Journal*. Academics' articles on Silicon Valley have mainly been published in *California Management Review* and *Industrial and Corporate Change*.
2 Actually, Barabási (2002) mentions Silicon Valley as an example of complex social networks without elaborating his analysis.
3 The source for this is the Money Tree Survey, PriceWaterhouseCoopers.
4 This figure comes from the European Venture Capital Association.
5 Due to the lack of space, an example of each possible interaction cannot be given here.
6 The two companies that have not been backed by venture capitalists are Hewlett-Packard, founded in 1938 before the existence of VC, and Agilent Technologies, which is a 1999 spin-off from Hewlett-Packard.
7 Figures from PriceWaterhouseCoopers.
8 Barabási (2002) emphasizes the study of boards of directors to identify social networks in business
9 Definition by the French Ministry of Industry.
10 The information on the presence of VC in different high-tech clusters around the world is preliminary data collected as part of an ongoing research project run by the OECD.

References

Adams, S. (2005) Stanford and Silicon Valley: Lessons on becoming a high-tech region. *California Management Review*, *48*(1), 29–51.
Albert, R., Jeong, H., & **Barabási, A. L.** (1999). Diameter of the world-wide web. *Nature*, *401*, 130–1.
Allen, P. M. (2001). A complex systems approach to learning, adaptive networks. *International Journal of Innovation Management*, *5*(2), 149–180.
Bahrami, H. & Evans, S. (2000). Flexible recycling and high-technology entrepreneurship. In M. Kenney, *Understanding Silicon Valley* (pp. 165–189). Stanford, CA: Stanford Business Books.
Barabási, A.-L. (2002). *Linked*. New York: Plume Books.

Barabási, A.-L. (2005). Taming complexity. *Nature Physics*, *1*, 68–70.

Barabási, A.-L. & Bonabeau, E. (2003). Scale-free networks. *Scientific American*, May, 50–9.

Barabási, A.-B., Newman, M., & **Watts, D.** (2006). *The structure and dynamics of networks*. Princeton, NJ: Princeton University Press.

Batterson, L. (1986). *Raising venture capital and the entrepreneur*. Englewood Cliffs, NJ: Prentice Hall.

Becattini, G. (2002). Industrial sectors and industrial districts: Tools for industrial analysis. *European Planning Studies*, *10*(4), 483–93.

Bianconi, G. & **Barabási, A.-L.** (2001). Competition and multiscaling in evolving networks. *Europhysics Letters*, *54*, 436–42.

Burgelman, R., Maidique, M. & **Wheelwright, S.** (2001). *Strategic management of technology and innovation*. New York: McGraw-Hill.

Byers, T., Keeley, R., Leone, A., & **Parker, G.** (2000). The impact of a research university in Silicon Valley: Entrepreneurship of alumni and faculty. *Journal of Private Equity*, *4*(1), 7–15.

Callaway, D., Newman, M., Strogatz, S., & **Watts, D.** (2000). Network robustness and fragility: Percolation on random graphs. *Physical Review Letter*, *85*, 5468–71.

Castilla, E., Hwang, H., Granovetter, E., & **Granovetter, M.** (2000). Social networks in Silicon Valley. In C. Lee, W. Miller, M. Hancock & H. Rowen (Eds.), *The Silicon Valley edge* (pp. 218–47). Stanford, CA: Stanford Business Books.

Dodds, P., Watts, D., & **Sabel, C.** (2003). Information exchange and the robustness of organizational networks. *Proceedings of the National Academy of Sciences*, *100*, 12516–21.

Erwin, D. (2005). Seeds of diversity. *Science*, *308*, 1752–3.

Etzkowitz, H. (1999). *The triple helix: MIT and the rise of entrepreneurial science*. London: Gordon & Breach.

Etkowitz, H. & Leydesdorff, L. (Eds.) (1997). *Universities and the global knowledge economy: A triple helix of university-industry-government relations*. London, New York: Pinter.

Faloutsos, M., Faloutsos, P., & **Faloutsos, C.** (1999). On power-law relationships of the internet topology. *Computer Communications Review*, *29*, 251–62.

Ferrary, M. (2003a). The gift exchange in the social networks of Silicon Valley. *California Management Review*, *45*(4), 120–38.

Ferrary, M. (2003b). Managing disruptive technologies life cycle by externalizing the research: Social network and corporate venturing in the Silicon Valley. *International Journal of Technology Management*, *2*(1–2), 165–80.

Friedman, T. (2005). *The world is flat: The globalized world in the twenty-first century*. London: Penguin Books.

Gompers, P. & **Lerner, J.** (2004). *The venture capital cycle*. Cambridge, MA: MIT Press.

Gorman, M. & **Sahlman, W.** (1989). What do venture capitalists do? *Journal of Business Venturing*, *4*, 21–248.

Granovetter, M. (1973). The strength of weak ties. *American Journal of Sociology*, *78*, 1360–80.

Granovetter, M. (1985). Economic action and social structure: The problem of embeddedness. *American Journal of Sociology*, *9*(1–3), 481–510.

Granovetter, M. (2003). Ignorance, knowledge, and outcomes in a small world. *Science*, *301*, 773–74.

Granovetter, M. (2005). The impact of social structure on economic outcomes. *Journal of Economic Perspectives*, *19*(1), 33–50.

Hambrecht, W. (1984). Venture capital and the growth of Silicon Valley. *California Management Review*, *26*(2), 74–82.

Hartman, J. L., Garvik, B., & **Hartwell, L.** (2001). Principles for the buffering of genetic variation. *Science*, *291*, 1001–4.

Hellmann, T. (2000). Venture capitalists: The coaches of Silicon Valley. In C. Lee, W. Miller, M. Hancock & H. Rowen, *The Silicon Valley edge. A habitat for innovation and entrepreneurship* (pp. 276–294). Stanford, CA: Stanford Business Books.

Hellmann, T. & **Puri, M.** (2002). Venture capital and the professionalization of start-up firms: Empirical evidence. *Journal of Finance*, *58*(1), 169–97.
Iansiti, M. & **Levien, R.** (2004). *The keystone advantage: What the new dynamics of business ecosystems mean for strategy, innovation, and sustainability.* Cambridge, MA: Harvard Business School Press.
Jen, E. (2003). Stable or robust? What's the difference? Working Paper, Santa Fe Institute.
Jen, E. (2006). *Robust design: A repertoire of biological, ecological, and engineering case studies.* Oxford: Oxford University Press.
Joint Venture (2008). *Index of Silicon Valley.* San José, CA: Joint Venture Editor.
Kenney, M. & **Florida, R.** (2000). Venture capital in Silicon Valley: Fueling new firm formation. In M. Kenney, *Understanding Silicon Valley* (pp. 98–123). Stanford, CA: Stanford Business Books.
Kenney, M. & **Von Burg, U.** (2000). Institutions and economies: Creating Silicon Valley. In M. Kenney (Ed.), *Understanding Silicon Valley.* Stanford, CA: Stanford Business Books.
Kozmetsky, G., Gill, M., & **Smilor, R.** (1985). *Financing and managing fast-growth companies: The venture capital process.* Lexington, MA: Lexington Books.
Kretschmar, M. & **Morris, M.** (1996). Measures of concurrency in networks and the spread of infectious disease. *Mathematical Biosciences*, *133*, 165–95.
Lee, C., Miller, W., Hancock, M., & **Rowen, H.** (2000). *The Silicon Valley edge: A habitat for innovation and entrepreneurship.* Stanford, CA: Stanford Business Books.
MacMillan, I. C., Kulow, D. M., & **Khoylian, R.** (1988). Venture capitalists' involvement in their investments: Extent and performance. *Journal of Business Venturing*, *4*, 27–47.
Marshall, A. (1890). *Principles of economics.* New York: Macmillan.
Miller, R. & **Côté, M.** (1985). Growing the next Silicon Valley. *Harvard Business Review*, July–August, 114–23.
Montoya, J. M. & **Solé, R. V.** (2002). Small world patterns in food webs. *Journal of Theoretical Biology*, *214*, 405–12.
Nelson, R. & **Winter, S.** (1982). *An evolutionary theory of economic change.* London: Belknap Press.
Newman, M. (2003). The structure and function of complex networks. *SIAM Review*, *45*, 167–256.
Nonaka, I. (1994). A dynamic theory of organizational knowledge creation. *Organization Science*, *5*(1), 14–38.
Novaro, A., Funes, M., & **Walker, S.** (2005). An empirical test of source-sink dynamics induced by hunting. *Journal of Applied Ecology*, *42*(5), 910–20.
OECD (1999). *Boosting innovation. The cluster approach*. OECD Proceedings. Paris: OECD.
OECD (2001). *Innovative networks. Co-operation in national innovation systems.* OECD Proceedings. Paris: OECD.
Perez, R. (1986). *Inside venture capital.* New York: Praeger.
Pettigrew, A. (1990). Longitudinal field research on change theory and practice. *Organization Science*, *1*(3), 267–92.
Piore, M. & **Sabel, C.** (1984). *The second industrial divide*. Cambridge: Basic Books.
Podolny, J. (1994). Market uncertainty and the social character of economic exchange. *Administrative Science Quarterly*, *39*(3), 458–83.
Porter, M. (1998). Clusters and the new economics of competition. *Harvard Business Review*, November–December, 77–90.
Porter, M. & **Stern, S.** (2001). Innovation: Location matters. *MIT Sloan Management Review*, *42*(4), 8–36.
Powell, W., Koput, K, & **Smith-Doerr, L.** (1996). Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. *Administrative Science Quarterly*, *41*, 116–45.
Rosenberg, D. (2002). *Cloning Silicon Valley.* London: Pearson Education.
Saxenian, A. (1994). *Regional advantage*. Cambridge, MA: Harvard University Press.
Saxenian, A. L. (2002). *Local and global networks of immigrant professionals in Silicon Valley.* San Francisco: Public Policy Institute of California.

Saxenian, A. L. (2006). *The new argonauts. Regional advantage in a global economy.* Cambridge, MA: Harvard Business Press.
Schumpeter, J. (1911). *The theory of economic development*. Cambridge: Transaction Books.
Stark, D. (1999). Heterarchy: distributing authority and organizing diversity. In J. H. Clippinger (Ed.), *The biology of business: Decoding the natural laws of enterprise* (pp. 153–179). San Francisco: Jossey-Bass.
Sturgeon, T. (2000). How Silicon Valley came to be. In M. Kenney (Ed.), *Understanding Silicon Valley* (pp. 15–47). Stanford, CA: Stanford Business Books.
Suchman, M. (2000). Dealmakers and counselors: Law firms as intermediaries in the development of Silicon Valley. In M. Kenney (Ed.), *Understanding Silicon Valley* (pp. 71–97). Stanford, CA: Stanford Business Books.
Thompson, G. (2004a). Is all the world a complex network? *Economy and Society*, *33*(3), 411–24.
Thompson, G. (2004b). Getting to know the knowledge economy: ICTs, networks and governance. *Economy and Society*, *33*(4), 562–81.
Vise, D. (2005). *The Google story.* New York: Bantam Dell.
Watts, D. (1999). Networks, dynamics, and the small-world phenomenon. *American Journal of Sociology*, *105*(2), 493–527.
Watts, D. (2004). The new science of networks. *Annual Review of Sociology*, *30*, 243–70.
Watts, D. & **Strogatz, S.** (1998). Collective dynamics of 'small-world' networks. *Nature*, *393*, 440–2.
White, H. (1992). *Identity and control. A structural theory of action*. Princeton, NJ: Princeton University Press.
Zhang, J. (2003). *High-tech start-ups and industry dynamics in Silicon Valley.* Berkeley, CA: Public Policy Institute of California.
Zider, B. (1998). How venture capital works. *Harvard Business Review*, November–December, 131–9.

Michel Ferrary earned a master's degree in economics at EHESS, a master's degree in sociology at Paris University and a PhD in business administration at HEC (France). He is professor in human resources management at Ceram Sophia Antipolis (France). He has been visiting professor for two years at the Department of Sociology at Stanford University and has published several articles in the *Journal of Socio-Economics*, *Revue Française de Sociologie* and *Cahiers Internationaux de Sociologie*.

Mark Granovetter earned an AB at Princeton University and a PhD at Harvard University. He is currently the Joan Butler Ford Professor in the School of Humanities and Sciences at Stanford University and was formerly the department chair of sociology. He has previously worked at Northwestern University, the State University of New York at Stony Brook and Johns Hopkins University. He is the author of the book *Getting a job*: *A study of contacts and careers* (University of Chicago Press, 2nd updated edition 1995) and he has published several articles in *American Journal of Sociology*, *American Sociological Review* and *Journal of Economics Perspectives.*