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"The most crucial aspect of Silicon Valley is its networks." There is no proposition so universally agreed upon and so little studied. We see two main reasons for this. The first is that the analysis of social networks has been mainly the province of sociologists, but only in recent years have they become interested in industrial organization. The second is that methods for systematic study of social networks are of very recent origin.[1]

Sociologists' earlier theoretical concerns led them to focus network analysis on small groups (like children in schools). But more recent work has treated larger groups and even entire industries (see, e.g., Granovetter and McGuire 1998). In this chapter we outline a project in progress, "Networks of Silicon Valley." Ultimately, we hope to achieve a systematic mapping of the Valley's networks and their evolution over time. This means also accounting for how networks of individuals literally outside the Valley's industrial activity, but playing a vital role, articulate with and sometimes become "insiders." The most obvious such groups are educators, venture capitalists, lawyers, headhunters, engineers, and industrial/civic associations and trade groups. Financial, commercial, educational, and political institutions are linked not only to information technology firms, but also to one another in this region, since industries do not arise and exist in a vacuum, but in a distinct institutional context. Variations in these contexts may well explain why the myriad attempts to replicate Silicon Valley in utterly different contexts, by copying only the features of its firms, are rarely fruitful. This broader account is essential for understanding how regional economies operate. The distinctive inclination of sociologists is to investigate how different institutional arenas mesh with one another, rather than focusing on the technical, economic, legal, educational, or political aspects of a situation. In Silicon Valley, where such linkages are an important and distinctive feature of economic success, this is an especially vital topic.

Thus, in this chapter we will introduce some key ideas about social networks, sketch some of the vital institutional sectors in Silicon Valley where they operate, and present an initial exploration of the formal analysis of how these sectors articulate with one another.

SOCIAL NETWORKS IN THE ECONOMY

A "social network" can be defined as a set of nodes or actors (persons or organizations) linked by social relationships or ties of a specified type. A tie or relation between two actors has both strength and content. The content might include information, advice, or friendship, shared interest or membership, and typically some level of trust. The level of trust in a tie is crucial, in Silicon Valley as elsewhere. Two aspects of social networks affect trust. One is "relational"—having to do with the particular history of that tie, which produces conceptions of what each actor owes to the other. The other is "structural": some network structures make it easier than others do for people to form trusting relationships and avoid malfeasance. For example, a dense network with many connections makes information on the good and bad aspects of one's reputation spread more easily.

An extensive literature shows the importance of social networks in the economy—from small start-up companies to large multinationals, from emerging industries such as biotechnology to traditional ones such as automobiles, from regional industrial districts such as Silicon Valley to national and supranational entities such as the European Union. (For a general review, see Powell and Smith-Doerr 1994.) In Silicon Valley, networks have special importance in the movement of labor, the evolution of influence and power, and the actual production of innovation.

Networks of Access and Opportunity

One of the most important aspects of Silicon Valley is the way its labor market works. Extensive labor mobility creates rapidly shifting and permeable firm and institutional boundaries and dense personal networks across the technical and professional population. The ability of Silicon Valley to restructure itself when conditions change through rapid and frequent reshuffling of organizational and institutional boundaries and members (which, in the Eastern European context, Stark [1996] has called a "recombinant" process) is one of the factors that underlie the dominance of Silicon Valley in the new economy.

Scholars have written extensively on the role of social networks in allocating labor (see Granovetter 1995a). Recruitment often occurs not through close friends, but from what Granovetter (1973) called the "strength of weak ties." Close friends know the same people you do, whereas acquaintances are better bridges to new contacts and nonredundant information. Firms benefit from employees' social networks, and employers are thus willing to pay monetary bonuses to them for successful referrals (Fernandez and Weinberg 1997; Fernandez, Castilla, and Moore 2000). Workers' social connections are considered resources that yield economic returns in the form of better hiring outcomes. Employees hired though social networks tend to quit less, experience faster mobility inside an organization, and perform better than those recruited through other means.

Commenting on Silicon Valley's exceptionally high rates of interfirm mobility, Saxenian (1994) has argued that "The region's engineers developed loyalties to each other and to advancing technology, rather than to individual firms or even industries" (28). The result of this unique culture and vast network of weak ties is that engineers in the Valley move frequently from one project or company to another. High mobility reinforces the dense networks, strengthening their role as channels through which technical and market information, as well as other intangibles—organizational culture and trust, for example—are diffused and shared among firms.

Engineers not only hop around firms in the same industry; they also move from one industry and/or institutional sector to another—from technical firms to venture capital firms or to university research centers—creating cross-institutional ties and loosely integrating different institutional nodes in Silicon

Valley. Many venture capitalists, for example, once worked in technical sectors of the Valley. Eugene Kleiner, the founder of the preeminent venture capital firm, Kleiner Perkins Caufield & Byers, had worked for Fairchild Semiconductor before moving on to finance. Similarly, John Doerr had been an Intel employee prior to his excursion into venture capital, and Regis McKenna had worked at National Semiconductor before founding his own, now famous, public relations firm.

Networks of Power and Influence

In addition to mediating labor flows, networks can also be an important source of power and influence. Research on interlocking directorates among financial and industrial corporations (e.g., Mintz and Schwartz 1985) shows how influence can flow from financial institutions to the industrial corporations to which they lend. In Silicon Valley, venture capitalists and lawyers play more than their conventional roles; they influence the structure and future development of their client companies. The lawyers are deal makers as well as counselors (Suchman 1994; Suchman and Cahill 1996). As deal makers, "Silicon Valley attorneys employ their connections in the local business community to link clients with various transactional partners" (Suchman 1994, 96). For example, lawyers help by providing connections to venture capital, giving Valley firms access to their accumulated knowledge about the region and high-technology industries, and offering general business advice, like conventional business consultants (100).

Venture capitalists not only provide necessary financial resources to start-ups and spin-offs, but often play the multiple roles of broker, management consultant, and recruiter. Their vested interest in the firms for which they provide financial resources makes them more likely to intervene in the operations of their start-ups. From the knowledge of high technology that they have accumulated from their broad portfolios of successes and failures, venture capitalists offer invaluable advice as to what does and does not work. Many start-ups and spin-offs are founded by engineers who are naive about management; venture capitalists can access an informal and formal network of experts to further the long-term viability of newly created firms. Further, venture capitalists often (re)organize the boards of directors of their start-ups, sometimes reducing the role of original founders and even severing the original founders from their own creation; Cisco Systems and Silicon Graphics were two famous cases.

Networks of Production and Innovation

Finally, social networks function as a distinct governance mechanism, a "social glue" that binds actors and firms together into a coherent system. In high-technology industries in particular, social networks help transmit information and knowledge among different firms and individuals and produce innovation. In Silicon Valley, getting the right product out at the right time has become crucial for the survival and growth of a firm in a rapidly changing environment. Networks enhance the capacity to do this by enabling people to mobilize capital, find relevant and reliable information quickly, and link to appropriate outlets. Innovation is so central to high-technology industry that it is not an exaggeration to say that effective social networks determine a firm's chance for survival.

Such a network governance structure is a typical way to regulate the interfirm alliance practices, such as collaborative manufacturing, found in industrial districts. Piore and Sabel (1984) argue that a new logic of production—"flexible specialization"—emerged as a challenge to mass production once markets for standardized goods were saturated, and higher quality and more specialized goods attracted consumers. Into this volatile environment have stepped flexible producers who can respond quickly to changing market conditions. To meet the demands of this changing marketplace, firms adopt new modes of organization that spread production across diversified interfirm linkages of suppliers, subcontractors, and end users. In the regions of north central Italy and southwestern Germany, for example, a complex division of labor among small and medium-sized companies has developed, supported by local political, financial, and educational institutions, which allows firms to produce a wide range of industrial products (Herrigel 1996).

Saxenian (1994) shows that Silicon Valley shares many of the characteristics of European industrial districts, and thus promotes collective learning among specialist producers of interrelated technologies. In this decentralized system, dense social networks and open labor markets encourage entrepreneurship and the ongoing mobilization of resources. Companies compete intensely, but simultaneously learn about changing markets and technologies through informal communications, collaborative projects, and common ties to research associations and universities. High rates of job mobility spread technology, promote the recombination of skills and capital, and aid the region's development. Silicon Valley companies, just as those in Germany and Italy, trade with the whole world, but the core of knowledge and production remains local. One way the Valley accomplishes this recombination of knowledge and capital is through spin-offs, which have contributed to the construction of dense social networks of entrepreneurs, inventors, and other institutional actors.

Part of the importance of these spin-offs is that most organizations resist changing their core technologies and structures (compare Stinchcombe 1965; Hannan and Freeman 1977; 1984). This resistance based on past success is what Clayton Christensen calls the "innovator's dilemma" (Christensen 1997). Thus, upgrading of a regional economy occurs especially through new organizations rather than through transformation of existing ones. While the founders of spin-offs explore new ideas and possibilities, they build upon the know-how they have gained from previous employment. In this regard, ties between new spin-offs and previous organizations through founders are an important way in which information and experience are transmitted, as we show in detail in the network analysis of the following section. Any region whose institutions or networks resist spin-offs or new entrants may face stagnation. Larson's (1992) and Nohria's (1992) research on the development of successful start-up companies stresses that social networks to other firms are a means for quick access to resources and know-how that cannot be produced internally.

NETWORKS AND INSTITUTIONS

In this part, we sketch the application of social network ideas and methods to some of the main institutional sectors of the Silicon Valley industrial district, including the region's educational, industrial, financial, and legal activities. We want to know how Silicon Valley's networks attained their current structure—what growth process took them from the modest and small-scale enterprise of

William Shockley's semiconductor laboratory in 1957, for example, to the world-dominating structures of the early twenty-first century? We address such questions by illustrating how formal techniques of network analysis can uncover patterns not easily found by casual inspection. Our emphasis will be not only on networks within a sector, but also on how networks from different sectors mesh with one another.

Networks and Genealogy: A Semiconductor Industry Case Study

Part of the legend of Silicon Valley is the story of how Shockley's company begat Fairchild Semiconductor via defection of the "Traitorous Eight," and how Fairchild later begat the many "Fairchildren" firms such as Intel, which in turn gave birth to still new generations of important firms. Many Silicon Valley firms have a "genealogy chart," first developed by journalist Don Hoefler and later maintained by the trade association SEMI, hanging in their lobbies, tracing their ancestry back to Fairchild. In this section, we undertake the first systematic analysis of the data in this chart, by techniques of network analysis and network visualization. By doing so we hope to illuminate the continuing significance of patterns laid down in the initial set of foundings and spin-offs that gave the Valley its distinctive industrial organization.

History of the semiconductor industry. In 1947, William J. Shockley and his collaborators at Bell Laboratories in New Jersey introduced the first successful transistor, which would eventually earn them the Nobel prize. This was important for Silicon Valley because Shockley, a Stanford graduate, with the encouragement of Frederick Terman, Stanford's legendary engineering dean and provost, decided to start his own company in his native Palo Alto to capitalize on the invention (Hoefler 1971; Riordan and Hoddeson 1997).

Shockley's ability to spot and recruit talented people contributed to the growth of what would eventually become Silicon Valley. Shockley Semiconductor Laboratories was founded in February of 1956. Drawing on established firms such as Raytheon, Motorola, and Philco, and on top engineering and science programs such as those at MIT and Cal Tech, Shockley soon had the core of the firm, and of the nascent semiconductor industry, in place. Robert

Noyce and Gordon Moore, both in their late twenties, would later go on to found Fairchild Semiconductor and Intel. In addition to Noyce and Moore, by mid-1956 Shockley had successfully recruited Jay Last and Sheldon Roberts from MIT and Dow Chemical Company, respectively.

Despite his ability to recruit, Shockley's eccentric and authoritarian managerial style did not match his Nobel laureate stature. Both Last and Roberts thus joined Noyce, Moore, Julius Blank, Jean Hoerni, Victor Grinich, and Eugene Kleiner to become the "Traitorous Eight" who left Shockley to form Fairchild Semiconductor in 1957, indelibly changing the future development of Silicon Valley's semiconductor industry. (For a full historical account, see Chapter 8.)

At Fairchild, the integrated circuit was first developed sufficiently for commercial production, with Noyce receiving the first patent in 1961. But the "Traitorous Eight" contributed more to Silicon Valley than a breakthrough in technology. Robert Noyce had a vision for this newly emerging industry that explicitly rejected the hierarchical East Coast corporate culture (Wolfe 1983). For example, there was no reserved parking at Fairchild, which was conceived of as a democratic community rather than a hierarchical workplace. And this new approach diffused as employees from Fairchild spun off to start their own companies. Everywhere the Fairchild émigrés went, they took the "Noyce approach" with them. It was not enough to start up a company; you had to start up a community in which there were no social distinctions. The atmosphere of the new companies was so democratic, it startled businessmen from the East. As Tom Wolfe reported:

> Some fifty-five-year-old biggie with his jowls swelling up smoothly from out of his F. R. Tripeler modified-spread white collar and silk jacquard print necktie would call up from GE or RCA and say, "This is Harold B. Thatchwaite," and the twenty-three-year-old secretary on the other end of the line, out in the Silicon Valley, would say in one of those sunny blonde pale-blue-eyed California voices: "Just a minute, Hal, Jack will be right with you." And once he got to California and met this Jack for the first time, there would be, the CEO himself, all of thirty-three years old, wearing no jacket, no necktie, just a checked shirt, khaki pants, and a pair of moccasins with welted seams the size of jumper cables. Naturally the first sounds out of Jack's mouth would be: "Hi, Hal." (1983, 360–61)

And, of course, there was the start-up culture. Fairchild engineers, even those who were among the founders, started their own companies—often in direct competition with their mother company. Fairchild spin-offs produced another round of spin-offs and spin-offs of spin-offs and so on. The spin-off of all spin-offs was founded in 1968 when Noyce and Moore, with Andy Grove, left Fairchild to start Intel. Their intention was not to compete with Fairchild and other already-established semiconductor firms, but to carve out a new niche, in semiconductor memory. Intel grew to become a company with sales of $66 million by 1973, employing more than two thousand workers (Wolfe 1983).

The early history of the semiconductor industry is replete with similar stories of spin-offs, some encouraged and some discouraged by parent companies. These spin-offs led to rapid technological breakthroughs created by networks of scientists and engineers building on the accumulated knowledge of their predecessors, and their experience in previous firms.

Social network analysis of the semiconductor industry. Although all accounts stress how crucial these spin-offs were for the spectacular stream of innovation that came from this region, there has been no systematic analysis of this spin-off process. Our own research on this is at an early stage, but it is interesting to see what can be gleaned from the well-known Semiconductor Genealogy Chart, originally developed by journalist Don Hoefler (with the concept by Jack Yelverton), and later maintained by the trade association Semiconductor Equipment and Materials International, or SEMI (updated information provided by H.T.E. Management). This chart indicates that more than 372 people started and built the semiconductor industry since 1947.

In the chart, we have identified 129 firms (including spin-offs, spin-offs of spin-offs, etc.) that existed between 1947 and 1986, after which the chart was no longer updated. In Figure 11.1 we plot the number of companies founded each year from 1947 to 1986.

We use a computer graphics program called MAGE (Richardson and Richardson 1992), which displays dynamic three-dimensional images to explore and evaluate the social structure of engineers, inventors, and entrepreneurs.[2] The resulting image represents the social network as a set of actors and the ties between them. Such a picture is like an X ray, laying bare the struc-

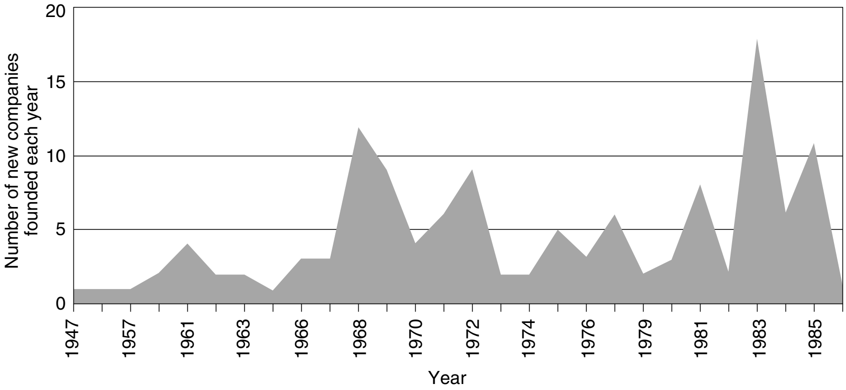

Figure 11.1. Number of new companies in the semiconductor industry founded each year, 1947–86.

ture of social ties, but needing a substantial amount of interpretation, and often raising more questions than it answers. Thus, social network analysts are "social radiologists," who use such pictures as heuristic devices to initiate more systematic probes of how structures arise and change over time, and as preludes to more complex quantitative analyses (such as those described in Wasserman and Faust 1994).

The graph of those who started and built the semiconductor industry in Silicon Valley is presented in Figure 11.2.[3] Each point (or "node") represents a person, and the lines connecting the points represent the ties. Since the presence of a tie between two people is coded from the semiconductor industry genealogy chart, it means that they were co-founders of at least one Silicon Valley semiconductor company. Thus, for any two persons in the sample, a tie is either present or absent.[4]

Not surprisingly, important actors in the semiconductor industry such as Jean Hoerni, Julius Blank, Eugene Kleiner, Jay Last, and Sheldon Roberts are the ones who are connected to more than ten people in the network. Shockley, on the other hand, appears with quite a low average number of co-founder ties. One important task is to discover how a person's position in a network may both reflect and confer or reinforce a position of influence. Roughly speaking, actors who are more central, in the sense of having more ties to others ("degree centrality"), or being crucial linkages that actors must go through to reach others ("betweenness centrality"), can often be shown to be more in-

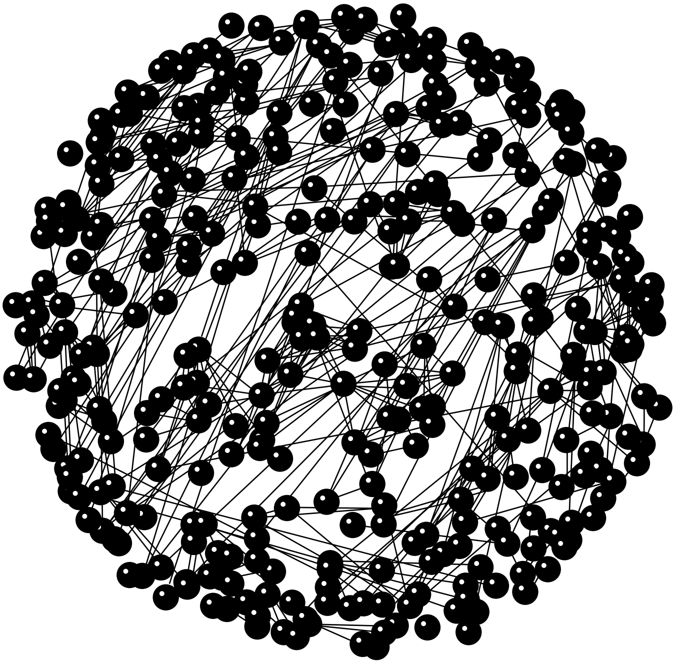

Figure 11.2. The founders of the semiconductor industry.
SOURCE: SEMI Semiconductor Industry Genealogy Chart. First conceived by Dan Hoefler, later maintained by SEMI.

fluential.[5] Jean Hoerni is the actor with the highest betweenness centrality in the network we computed from the genealogy chart. The analysis also highlights other less well known actors who appear to be quite central in the development of the semiconductor social network. Among these are Gifford, founder of companies such as Advanced Micro Devices in 1969 and later Maxim Integrated Products in 1983; Araquistain, Baldwin, Bower, Breene, Elbinger, Koss, Marchman, Valdes, and Wiesner, all founders of Rheem Semiconductor in 1959 (and some of whom also worked for Fairchild Semiconductor); and, finally, Weindorf, who had previously worked for Fairchild Semiconductor and Rheem Semiconductor. One virtue of network analysis is that in its impartial way it may point to the need to look more closely at individuals whose centrality has not been captured in the many impressionistic and journalistic accounts of Silicon Valley history.

The meaning of centrality, however, depends on a network's definition. In a network of ties computed at a single point in time, individuals with the highest centrality are quite likely to be powerful and influential by virtue of their position, because of which much vital information must flow through them before it reaches others. But the network we display here, where ties indicate co-founding, is quite different, as it spans nearly thirty years. Here, central individuals are those who provided vital linkages among industry sectors, making Silicon Valley the "small world" that it is. Though this was a crucial role in shaping the Valley's unique character, those who played it need not have been highly visible. Recent research on the "small world problem" (known to the general public as the issue of "six degrees of separation") shows that a remarkably small number of strategically placed ties can dramatically increase the connectivity of a network (see Watts 1999).[6]

Higher Education and University-Industry Networks: The Role of Stanford

To study the evolution of connectedness among industrial firms in Silicon Valley is already a challenge. But as we stress repeatedly, much of what is unique in this region and accounts for its "edge" is how industry relates to other sectors. In this section and the next, we choose two such sectors—education and venture capital—and discuss how the social networks within these sectors and with Silicon Valley industry helped shape outcomes. This is followed by an illustrative network analysis of IPOs that shows how the different sectors work together on a particular activity. A fuller account would treat other institutional sectors such as law, public relations, and real estate, and give much more extensive attention to connections. Here, however, we want simply to sketch out the issues.

The educational sector has been especially vital because the constant movement back and forth between industry and university has blurred the boundaries of both and created elaborate social networks that keep academic research focused on practical problems, and infuse industrial activity with up-to-date science. Though a number of educational organizations have been important in this way, we focus on the key actor in Silicon Valley's early history, Stanford University.

In the 1950s, two institutional innovations—the University Honors Cooperative Program and the Stanford Industrial Park—brought together university researchers and nascent industry interests. Stanford Industrial Park (now called Stanford Research Park), conceived by Stanford provost Frederick Terman and officially founded in 1951, was the first of its kind. No university had previously allotted large tracts of its own land for industrial uses (in part because few other universities had Stanford's more than 8,000 acres of land to allot). Varian Associates moved its R&D and administrative operations to Stanford in the late 1940s, and other companies such as General Electric, Eastman Kodak, Admiral Corporation, Hewlett-Packard, and Watkins-Johnson joined Varian. By 1962 there were 25 companies in the park (Saxenian 1994, 23–24). Although the park is still home to many influential players in the Valley, such as the law firm Wilson Sonsini Goodrich & Rosati and the legendary Xerox Palo Alto Research Center, Silicon Valley has outgrown its birthplace.

The Honors Cooperative Program, founded by Frederick Terman in 1953, made it possible for local companies to send their engineers and scientists to pursue advanced degrees at Stanford as part-time students while working full-time. The program "strengthened the ties between firms and the university and allowed engineers to keep up to date technically and to build professional contacts" (Saxenian 1994, 23).[7]

In addition, Stanford students and faculty formed new companies, such as Hewlett-Packard, Sun Microsystems, and Yahoo!, among many others, that were crucial to regional growth. As Silicon Valley matured, research and commercial interests proliferated and the business community came to assume the role of innovator, developing and commercializing innovations. The university's emphasis has shifted to maintaining its relations with already-established firms as the source of cutting-edge scientific knowledge and expert labor. Currently, innovative ideas produced at Stanford find their way to industries through licensing via the Stanford Office of Technology Licensing and various research centers that have proliferated over the past two decades. Further, given Stanford's prominent role in the evolution of Silicon Valley and its accumulated ties to the region's different sectors, Stanford is the one place where outsiders can gather information about Silicon Valley. It is also an important port of entry to the Valley for many high-technology firms from overseas through its various affiliates programs. Now foreign firms can send their employees to Stanford to study Silicon Valley for a nominal fee. In fact, one of Stanford's main current roles is to attract people from all over the world to the region, which is a crucial matter, as Silicon Valley start-ups are increasingly formed by nationals of foreign countries (see Chapter 12). It does so in part from its reputation as past midwife of successful firms, and in part from the international reputation of its engineering departments. The School of Engineering, typically rated at or near first in the United States, regularly provides the region with a highly skilled labor force and attracts top researchers from around the United States and the world.

One of the crucial links between the university and the surrounding Silicon Valley community is provided by its approximately 50 research centers, which provide for the university and the business community a forum in which they can maintain close contact. These centers also make it easier for foreign companies aspiring to learn the "Silicon Valley way" to introduce themselves into its sometimes arcane culture. The centers and programs are surprisingly informal and decentralized. Though they must be approved by the university administration, the university is not directly involved in their decision-making processes and their daily workings. They receive little financial support from the university, raising funds internally through corporate memberships.

The recruitment of firms to these centers occurs through already-established personal networks between professors or researchers and businesses. In particular, a research center director's role is to identify companies that are interested in the center's activities and to set up collaborations with the Stanford faculty. Usually a director has extensive experience working with both industry and universities. For example, the director of the Center for Integrated Facilities Engineering had worked both in industry and for various universities before joining Stanford University to set up the center, and had particular experience working in the area of university-industry collaboration.

Research centers are avenues through which information about the current state of research activities at Stanford flows to industry. Most member companies of research centers or affiliates programs work through particular faculty members as their liaisons to Stanford; through the liaisons they have early access to research reports. In addition, companies are invited to conferences held on campus and can have individual meetings when needed. They can set up courses geared specifically toward their design problems through the affiliates programs. This is a cost-effective way to tackle specific problems with the help of cutting-edge researchers and engineers. And some affiliates programs include opportunities to send their employees as corporate visiting scholars both to the programs and to an academic department. As a result, companies learn more about students and researchers who work on their problems, and some companies exploit this opportunity as a recruiting tool.

These centers and programs also provide funding opportunities for researchers in the Stanford community. Funding is used to support graduate students, to purchase equipment, and to support administrative assistants. Money is received from industry in the form of affiliates' fees, which do not go directly to the researchers, but through research centers. Compared to most government funding sources, the process of funding research is much more efficient and informal, and entails far less "overhead" cost than traditional grants.

The research centers provide a means by which university researchers can develop or commercialize their ideas. Here, researchers and faculty can legitimately pursue applied knowledge, which is at times difficult to do in an institution of higher education. This is not only allowed but encouraged, as the primary role of the centers and programs is to connect the university and industry. Through meetings such as annual affiliates days and other public events hosted by the centers, to which previous and current affiliates and individuals who have been involved in the program or centers are invited, industry and university come into direct contact with each other with the common purpose of university-industry cooperation. Student internship opportunities are provided through networks created in the research centers and programs. Professors can utilize concrete issues, topics, and materials brought to them by industry for their classes. Students enjoy and benefit from learning by doing.[8] This, in turn, helps departments to attract highly motivated students.

Key individuals move back and forth from industry to academic positions in research centers and affiliates programs. For example, a former director of one Stanford interdisciplinary research center, who now works for a high-tech company in the region, had also worked in industry before joining the center. As the industry liaison for the center, his past experiences and networks in industry were invaluable in developing its industry sponsorship program and in raising funds for the center.[9] Moreover, his career and current relationship with this center typify the evolving Stanford–Silicon Valley relationship. After receiving a Ph.D. in computer science, he joined a renowned research organization in Silicon Valley, and then a large industrial corporation. He subsequently started his own companies, one of which is now publicly traded on NASDAQ. Then he did consulting work for financial companies in the region. Years later, he joined the Stanford center to develop the affiliates program. Now back in industry, he still maintains an informal relationship with the center and can imagine returning some day.

Speaking more abstractly, the personnel of these research centers constitute "boundary spanning units" (Hirsch 1972), a category of organizational actor crucial in situations in which brokers must connect disparate institutional sectors.[10] The centers create social networks that ramify into every corner of the region's high-tech industry. Because of the proliferation of such boundary-spanning units, unusual in institutions of higher education, Stanford University continues to be a central forum for both academic and industrial researchers to benefit from the exchange of information.

Key Financial Institutions

It is widely agreed that the venture capital industry has been the financial engine of Silicon Valley. Harmon reflects a popular belief in asserting that

> the venture capitalists (VCs in finance parlance) are the new power brokers, banks, management providers, gurus, and mothers who hold the hands of the newbie idea-ites [the founders of new companies], taking them past the training wheels stage into rocket racers. It is smart money, the people and their capital. It has to be smart—there is no time to make the wrong moves in a world where every great idea has a dozen imitators in sixty seconds. (Harmon 1999, 3–4)

Wilson's 1985 study is probably the first systematic analysis of American venture capital. In his words, "Born in New York, nurtured in Boston, and almost smothered in Washington, venture capital did not really come of age until it moved to California and joined forces with the brash young technologists who were using bits of silicon to create an information revolution as profound as the industrial revolution a century earlier" (Wilson 1985, 31). With the formation of venture capital firms such as Draper, Gaither & Anderson, and Western Business Assistance Corporation in 1958, the basic foundations of today's venture structure were laid.

Experienced venture capitalists now manage billions of dollars. Half of the venture capital firms in the United States are now in Silicon Valley, which attracted $3.3 billion in venture capital funding in 1998 alone. This is about half of the venture capital invested in the top ten technology regions of the United States, which include Atlanta, Austin, Boston, Dallas, Denver, Phoenix, Portland, Raleigh-Durham, Salt Lake City, and Seattle (Joint Venture: Silicon Valley Network, "Index of Silicon Valley," various issues).

While Silicon Valley industry attracted venture capital firms, the presence of venture capitalists attracted entrepreneurs from all over the country and the world. Employment grew accordingly, and in 1998 Silicon Valley added an estimated 19,400 new jobs. The number of initial public offerings (IPOs) and mergers and acquisitions (M&As) in Silicon Valley indicates how successful entrepreneurship and companies are in the region. The Valley still produces the highest number of initial public offerings (IPOs) in the country (Joint Venture 1999). Sand Hill Road, in Menlo Park, California, is now the "*de facto* headquarters for venture capital activity on the West Coast" (Saxenian 1994, 40). Today it is probably the most powerful venture capital enclave in the country and a center of gravity for international venture capital.

Networks of engineers, entrepreneurs, and wealthy investors were crucial to the development of venture capital. These networks were fed by major inflows of technical entrepreneurs, venture capitalists, management talent, and supporting services from other regions. By the early 1980s, Silicon Valley venture capital was dominated by individuals who had migrated from industry rather than from backgrounds in finance (Wilson 1985, 50–51). For this reason, venture capitalists play a more active role in Silicon Valley than in other regions of the United States and the world (Saxenian 1994; Florida and Kenney 1987; Nohria 1992).

History of venture capital in Silicon Valley. In the 1950s, when the practice of venture capital did not yet have a name, the patterns for investment were established by rich men pursuing some risk investing in an informal but disciplined way. Three stand out among those who began to put risk capital on a more permanent institutional base. Laurance S. Rockefeller (third of the five sons of John D. Rockefeller Jr.) and John H. Whitney were rich, prominent prewar venture experimenters; and Georges F. Doriot, a French Harvard Business School professor, was very influential as teacher of a course about entrepreneurship and as president of the American Research & Development Corporation, founded in 1946. In the latter position, he organized capital and support for scientist-entrepreneurs in the Boston area. Government also stepped in by creating the Small Business Investment Company (SBIC) program in 1958, which "created hundreds of venture investors overnight" (Wilson 1985, 13), and later by reshaping the tax system to promote equity investing. One of the most successful pioneers was Frank G. Chambers. Chambers raised $5.5 million in 1959; his Continental Capital Corporation is believed to be the first SBIC in Northern California. Chambers and his brother, Robert, were greatly influenced by Doriot's teaching at Harvard, and started Magna Power Tools in San Francisco. "Chambers was already part of the informal luncheon-and-investment club that constituted San Francisco's venture capital community at the time, and he joined a few small investments" (Wilson 1985, 23). Aside from Chambers's SBIC, the only venture investment group of any magnitude in California was Draper, Gaither & Anderson in Palo Alto. DG&A was formed in 1958 by some of the biggest investors on the West Coast, William H. Draper Jr. (former vice president of Dillon, Read & Company), Rowan Gaither (founder of Rand), and Frederick L. Anderson (a retired Air Force general). DG&A had also raised money from the Rockefeller group.

An important Wall Street investment banker, Arthur Rock, moved himself and his "quiet passion for backing entrepreneurs" (Wilson 1985, 31) to San Francisco in 1961. His name is closely associated with the evolution of Silicon Valley. Rock played a significant role in the creation of Fairchild Semiconductor by the "Traitorous Eight" and accumulated considerable profits from his investments in companies like Scientific Data Systems, Intel, and Apple, among others. Rock's experiences in California convinced him that there was an important business investment opportunity in the West. In 1961 Rock and Tommy Davis, a lawyer who was president of Kern County Land Company, raised $3.5 million from several of the Fairchild Semiconductor founders, and opened an office in San Francisco. Davis and Rock and their principle—"back the right people"—became a model for later venture groups. The partnership between Rock and Davis lasted until 1968, when Davis started a partnership with Wally Davis to form the Mayfield Fund.

The "Boys Club" or "the San Francisco Mafia" (Wilson 1985) refers to a 1960s venture capital network that grew up in San Francisco. "One noontime each month they would troop up Nob Hill to the University Club for a meeting of the Western Association of Venture Capitalists, ideas and gossip flowing with the martinis. Deals were put together over lunch at Jack's or Sam's, venerable Financial District restaurants where the sole was dependable and the sourdough fresh. 'We'd get together and listen to the entrepreneur's story,'" recalls Reid Dennis, a charter member of "The Group" (Wilson 1985, 49).

During the 1970s, the Group moved down from the San Francisco Financial District to Sand Hill Road in Menlo Park, just a few miles from Stanford University. It is then that Silicon Valley became the most powerful venture capital enclave in the country. Venture capitalists were sharing the same physical space, now close to the inventors and entrepreneurs and to many of the young technology companies near Stanford.

Simultaneously, the number of venture capital firms increased enormously, as a result of spin-offs and new venture capital firms started by managers and engineers of companies in the computer industry. The evolution of the venture capital industry followed a pattern similar to that of new high-technology companies. Proliferation by spin-offs from preceding generations was prevalent in both industries. Some of the prominent examples of spin-offs in the venture capital industry are documented by Florida and Kenney (1987, 20–21). For example, Reid Dennis and Burton McMurtry founded Institutional Venture Associates (IVA) in early 1974. Out of IVA, two new important venture firms were built in the 3000 Sand Hill Road complex. Dennis's Institutional Venture Partners raised $22 million and invested successfully in Seagate Technology, a firm making disk drives for personal computers; and David F. Marquardt joined McMurtry and James J. Bochnowski to form Technology Venture Investors (TVI) which raised $24 million. McMurtry later brought in Pete Thomas from Intel, James A. Katzman from Tandem Computers, and Robert C. Kagle from the Boston Consulting Group. TVI had a chance to invest $1 million in Microsoft, which had been founded in 1975 by Harvard sophomore Bill H. Gates and Paul Allen.

Donald Valentine, formerly head of marketing at Fairchild, moved to Sand Hill Road in 1972 and formed Capital Management Services (which later became the important venture capital firm Sequoia Capital). "Everybody in the Valley knew Don Valentine, and if Valentine did not know them, he usually knew somebody who did" (Wilson 1985, 59–60). Valentine's connection to Fairchild Semiconductor salesmen led him to invest in Atari, entering the home video game industry. In 1976 Atari was bought by Warner Communications, which brought large returns to Sequoia. The founder of Atari, Nolan Bushnell, subsequently referred Steve Jobs, who worked for Atari, to Valentine. Jobs approached Valentine in 1977 in his quest to found Apple Computer; though Valentine passed on this funding opportunity, he did connect Jobs to his ultimate financial supporters.

In 1972, the first venture capital team taking up residence at 3000 Sand Hill Road was Thomas J. Perkins and Eugene Kleiner, predecessor of the now top-ranked firm Kleiner Perkins Caufield & Byers. Sandy Robertson, founder of an investment banking firm on San Francisco's Montgomery Street, was the matchmaker for this successful venture fund. Perkins was an engineer from MIT, had been a Harvard Business School MBA student who took classes with Georges Doriot and had worked for David Packard. Kleiner, one of the "Traitorous Eight," was a mechanical engineer from Brooklyn Polytechnic Institute who moved to California to work at Shockley Semiconductor Laboratory. Kleiner and Perkins decided to go into venture capital and to take an active role in designing and building the companies they backed. But they went a step further, encouraging their associates and partners to start companies of their own, such as Tandem Computers, Genentech, and Hybritech. This made Kleiner and Perkins not only a venture capital firm, but also a group of entrepreneurs able themselves to start and run their own companies.

Social network analysis of West Coast venture capital firms. Ultimately we aim not only to describe the historical development of the networks, but also to show how the particular structure of social networks in Silicon Valley stimulated higher growth and development compared to other regions. But the historical evolution of venture capital networks during the key period from 1958 to 1983, if narrated in full detail, would be too confusing and complex for our more modest purpose here. Our first goal has been to identify all early venture capital firms that contributed to the development of the West's venture capitalism. We compiled our data from the second well-known Silicon Valley firm "genealogy chart": "West Coast Venture Capital—25 years," created by the Asset Management Company (AMC) in 1984. This chart indicates that more than three hundred people in more than a hundred companies built West Coast venture capital in the 25 years between 1958 and 1983.[11]

We have identified 129 venture capital organizations (including spin-offs) in the Western region between 1958 and 1983. In Figure 11.3 we plot the cumulative number of such firms by year. The rate of founding remained relatively stable until 1967–68, after which it grew rapidly. An explanation for this trend is that during the late 1960s, the limited partnership became a common form of organization, and even large financial institutions became willing to invest as limited partners. After 1983 (not displayed), the number of venture capital firms in the Western region of the United States continued to grow, mainly as a result of spin-offs from existing venture capital firms.

Next we provide a preliminary glimpse into the network of venture capital firms.[12] As with the semiconductor industry, we use the computer program MAGE to illustrate the connections. In the semiconductor genealogy graph of Figure 11.2, each point (or "node") represented a person; here, each point represents a firm, and the lines connecting the points represent the ties between these organizations. In this case, the presence of a tie between two firms indicates that they share at least one founder.

There are 129 firms (or nodes), and 232 lines.[13] Unlike Figure 11.2, in which the nodes are more or less uniformly connected, Figure 11.4 shows two clear-cut clusters of venture capital firms.[14] One, on the upper right, is composed of 57 firms that are highly interconnected with each other. In this cluster, we find some of the oldest and still the most central and influential VC firms in Silicon Valley today, such as Kleiner Perkins, Crosspoint Venture Partners, Hambrecht & Quist Venture Capital, Institutional Venture Partners, and Mayfield Fund. It is remarkable how many of these firms have common founders, which indicates how close-knit this collection of firms was. We expect that the enormous influence of these firms derives not only from their early position of dominance, but also from the dense network of contacts they maintained among themselves. This network would have provided important conduits of information and flows of resources including advice, gossip, and referrals of opportunities that a given firm could not take advantage of at a

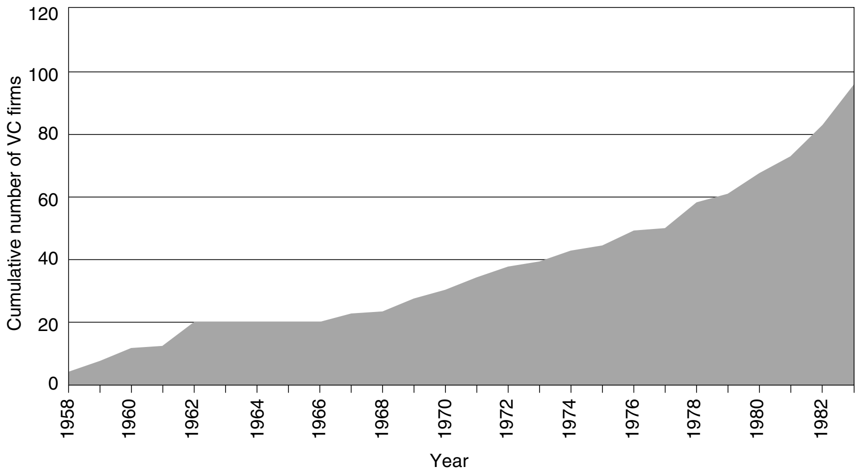

Figure 11.3. Cumulative number of venture capital firms per year, 1958–83.

given moment. In this clique, however, are also firms of more recent (1980s) origin, such as Melchor Venture Management and Lamoreaux & Associates. These newer firms appear to have gained their influence as spin-offs of the older and more influential ones.

The second cluster is a group of individual firms with very few or even no co-founder links among themselves. They are more or less randomly connected when connected at all, and include many "isolates"—which in this context means firms whose founders neither came from other VC firms nor started any new ones. Some of the firms in this incoherent cluster are nevertheless influential, such as Davis and Rock, and Sierra Capital.

This picture belies the idea that connections in Silicon Valley are dense everywhere and that everyone is connected to everyone else. The very different structure of these two distinct and completely disconnected groups of firms also suggests that there are at least two different strategies by which venture capital firms exercise their influence. Moreover, at least for venture capital, firms that are not involved in spin-offs or in dense networks of other such firms may find other ways to make their mark. Further research will be required to suggest what these ways are, but one possibility is that firms in the second cluster, appearing isolated in their absence of co-founder relations to other firms, may have other kinds of personal relations to fellow venture capital firms, and

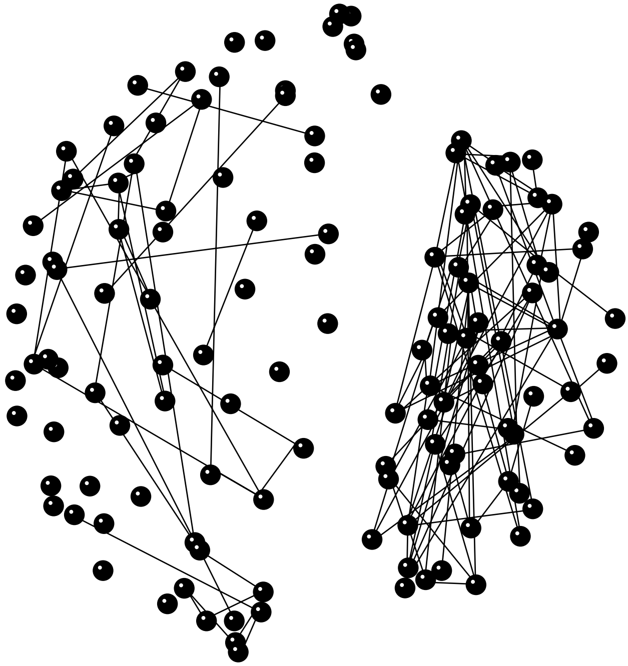

Figure 11.4. Connections among venture capital firms.
SOURCE: Asset Management Company's Genealogy Chart, 1958–83.

be more tightly integrated than the first cluster with firms *outside* the venture capital sector, such as law and accounting firms, educational institutions, and the technical sector itself.

Finally, although we do not show the figure here, we have also examined the social network of venture capitalists who started and built the venture capital industry in the Western region. There are 348 people involved in the construction of venture investing, according to the AMC's genealogy chart, and over 2,200 ties.[15] The average number of ties per person is 6.41, which means that each person in the network is connected as a co-founder of a venture capital firm to 6 other people in the network on average. This corroborates, once again, the importance of networks of human relations for Silicon Valley venture capital.

One of the interesting findings in the network analysis of individuals is that actors such as Arthur Rock, Tommy Davis, Eugene Kleiner, and Frank Chambers, who historically had important roles in the institutionalization of venture investing in Silicon Valley, are not necessarily as central as one would have expected. The most central actors in the co-founder network of venture capitalists all appear to have worked in the 1970s and early 1980s for venture capital funds started by important U.S. and regional banks (such as Citicorp Venture Capital Ltd., Bank of America Capital Corporation, Wells Fargo Investment Company, and Western Bancorp Venture Capital Company). These "venture capital" banks are not only "training grounds for inexperienced venture capitalists" (Kenney and Florida 2000), but also excellent places for them to expand their personal networks. Most of these venture capitalists, after learning about venture financing by working for a bank, left and started their own limited partnership or joined a more prestigious existing venture capital fund.[16]

An analysis of the network of companies confirms that employees of venture banks such as Bank of America Capital Corporation and Citicorp Venture Capital Ltd. founded a large number of new firms. Likewise venture capital firms such as Small Business Enterprises, Westven Management Company, and Fireman's Fund were also quite central to the development of the industry. The venture capital funds such as Hambrecht & Quist, Institutional Venture Partners, Interwest Partners, and Kleiner Perkins and their current venture fund descendants are among the firms that were and still are the most central and influential VC firms in the financing of companies, not only in Silicon Valley, but also elsewhere in the United States, where new investment opportunities are emerging. There are also venture partnerships that were started during the mid- to late 1980s (e.g., Menlo Ventures, and Burr, Egan, Deleage & Company, among many) or even earlier (Sierra Capital) that have become central in the current structure of venture capital.

Institutional Infrastructure: An Analysis of the Silicon Valley Regional Economy

Dense networks not only within but between sectors of engineers, educators, venture capitalists, lawyers, and accountants are important channels for the diffusion of technical and market information. Although we have frequently mentioned the importance of such cross-institutional ties, and have given important qualitative examples, we have not yet attempted systematic analysis of this phenomenon.

Mapping the relationships among different institutional sectors in the Valley is a must for a systematic understanding of the regional economic system, but it presents daunting challenges. Many domestic as well as foreign attempts to imitate the success of Silicon Valley have failed because the Valley's results depend on its particular institutional configuration rather than on the features of particular firms. But it is not obvious how to explore systematically the way different institutional sectors articulate with one another.

As a first step in developing such exploration by network analysis, we chose to study the case of IPOs. IPO deals allow us to observe the infrastructure of the economy at work, since at least five firms from four different institutional sectors take part: the new industrial firm itself (the "issuer"), a lead underwriting investment bank (usually as part of a syndicate), the issuer-side law firm, the underwriter's law firm, and an auditing accounting firm.

To illustrate the kind of analysis we believe will be fruitful, we take a small special case: the data on California firms involved in 1999 IPOs in a single four-digit SIC code, SIC 7375—"information retrieval services"—which includes such familiar firms as Ask Jeeves, Inc., Broadband Sports, Inc., and McAfee.com Corporation. In SIC 7375, the total number of issuer firms that filed for IPO in the United States in 1999 was 148, of which 19 came from California. In these 19 IPOs, 14 different law firms, 9 lead investment banks, and 6 accounting firms participated. The difference between the number of law firms and the number of accounting firms reflects the difference in industry concentrations. The audit industry is highly concentrated, and the Big Six (Arthur Andersen, Ernst & Young, Bailey, Mark & Co., KPMG, Lumer, Marc & Company, and PricewaterhouseCoopers) take up a disproportionate share of the audit market.[17]

We define two firms as having a network tie when both are involved in the same IPO. The structure of connections among the different companies involved in the filing of IPOs is presented in Figure 11.5, computed with the MAGE program previously described. The issuer firms themselves do not appear in the picture, only the infrastructural firms that supported the IPOs. Law firms, investment banks, and accounting firms are each represented. Firms are connected by lines if they participated together in at least one of the nineteen IPOs, and the length of the line is inversely proportional to the number of co-

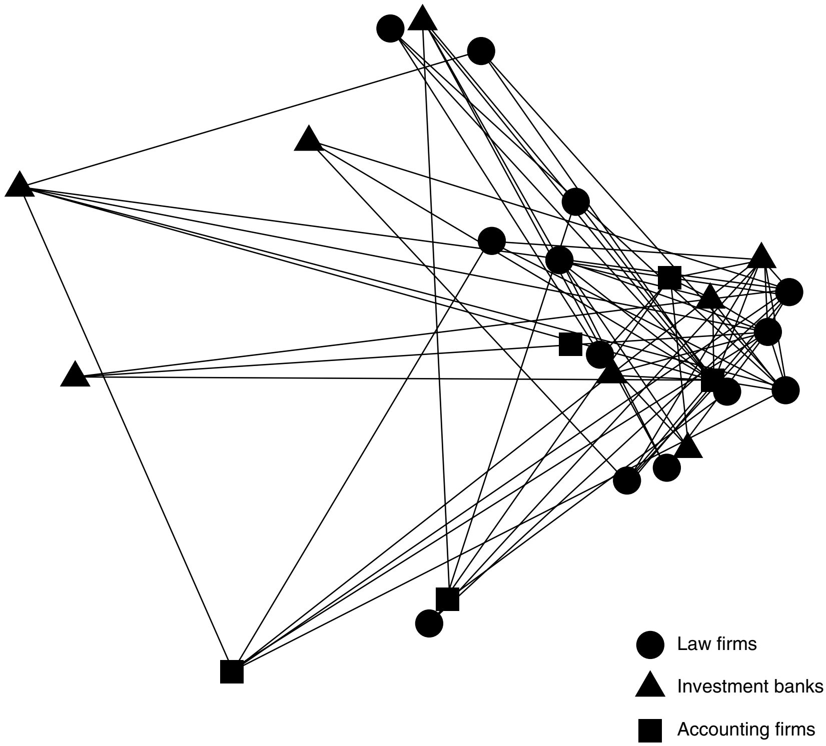

Figure 11.5. Network of IPO deals in the information retrieval services industry in California.
SOURCE: 1999 IPO deals from www.ipodata.com

participations; we may think of this as a measure of the "strength" of the tie—the longer the tie, the weaker the relationship.[18]

Although the network as a whole is densely connected, one can single out a group of eight firms (with the highest score in all centrality measures such as nodal degree, closeness, and betweenness) that are relatively more densely connected to one another: three law firms (Wilson Sonsini Goodrich & Rosati, Brobeck Phleger & Harrison, and Cooley Godward), three investment banks (Goldman, Sachs & Co., Morgan Stanley Dean Witter, and CS First Boston), and two accounting firms (PricewaterhouseCoopers and Ernst & Young).[19]

We note some interesting findings in the graph. First, there is a status dimension to this collection of firms. All eight firms are leading firms in their own industries (see Podolny 1993 for the status hierarchy of the investment banking industry and Han 1994 for the audit market). Both the investment banks and the accounting firms are well-recognized firms. While legal practice is more localized by state-level licensing, the three law firms are all big, corporate law firms. Wilson Sonsini has long been an institution in its own right in the Valley. Both Brobeck Phleger & Harrison and Cooley Godward are San Francisco–based law firms with branches around the country, employing hundreds of lawyers.

Second, although the profile of investment banks and accounting firms suggests the national scope of the markets for financial services and audit services, the market for legal services appears to be distinctively local. Although legal practice is circumscribed by state-level licensing, the emergence of national law firms (with branches in multiple states) and international law firms means that the market does not necessarily need to be as localized as it appears in this analysis. And the high concentration of legal services in our data departs from the more general national pattern. For example, the law firm of Wilson Sonsini Goodrich & Rosati participated in nine of our nineteen IPOs, either from the underwriter's or from the issuer's side.

Given that there are fourteen law firms in the data, this is a remarkable figure, equaled only by the accounting firm PricewaterhouseCoopers. But there are only six accounting firms in the data, reflecting the domination of the audit market by a small number of national firms. By contrast, concentration in law, compared to other service industries, is normally quite low. We do not have good recent data, but Galanter and Palay (1991) show that in 1982, percentages of total receipts were .9 percent and 3.6 percent for the four and twenty largest law firms, respectively, compared to 16.9 percent and 34 percent for the largest accounting firms. We do not have reason to think that these national patterns have changed dramatically. Yet in our data, the three most central law firms appeared twenty times in the nineteen deals. This is out of a possible 38 showings (since there are two law firms for each deal, one for the issuer and one for the underwriter), and thus these three occupied more than 50 percent of the slots in these deals—an extraordinarily concentrated market, far different from the national pattern for legal services.

From our preliminary study of IPO deals within a single SIC code, we begin to see the contours of the institutional articulation of the economy and can point to the local aspect of this configuration. It is this background of financial, commercial, and legal institutions linked to each other that characterizes Silicon Valley. Results for a single SIC code in a single year can only be illustrative. Differences in outcomes between years and industrial sectors would help us see why different sectors evolve in different ways. We would like to know, for example, whether the high concentration of legal services is a regional effect, an industry effect in this particular SIC code, or a temporary blip in a less concentrated pattern over time. We plan to explore many different permutations of this type of analysis in our effort to understand how Silicon Valley industrial and nonindustrial infrastructure has interacted and fitted together.

The development of Silicon Valley was highly dependent on this particular institutional context, which cannot easily be replicated in other regions. Our analysis also suggests that attempts to merely copy the structure and features of firms, as though they were independent actors, cannot be fruitful. Understanding how the networks of Silicon Valley have been built and are interrelated is essential for understanding regional differences in development.

CONCLUSION

This chapter has had two aims. First, we tried to describe and explain the crucial importance of social networks for the functioning of the Silicon Valley regional economy. Our emphasis has been not only on the important networks within institutional sectors, but also on the flow of people, resources, and information among sectors. It is our view that these intersectoral flows are what make Silicon Valley unique, and that in the history of the world's economy, the ability to leverage value by shifting resources among previously separated sectors has always provided a vital edge for regions able to do so.

Because of the enormous attention paid to this highly successful region, the general idea that networks are important has attained widespread currency, and so our emphasis will not surprise even casual observers. But we have also tried to connect this theme to the large and growing academic literature on the sociology of the economy, which indicates that Silicon Valley is not unique in having its outcomes derive from social networks. Instead, these networks underlie the economic structure of many regions, including some that are far less successful and have drawn much less attention. This means that the interesting problem is not whether networks are important in a region, but what kinds of networks are associated with what kinds of outcomes.

The literature on industrial organization has begun to consider this question. Saxenian (1994) presented a systematic argument that network structure in Silicon Valley was quite different from that in the Route 128 corridor of the Boston metropolitan area, for a variety of historical, economic, and cultural reasons, and that this difference translated into what she called, in her book's title, a distinct "regional advantage" for the Valley. Increasingly, when analysts question network interpretations of economic outcomes, they turn not to non-network stories, but to different and more refined network accounts. Thus, several recent studies challenge the idea that the "Third Italy" produces uniformly successful outcomes in its textile industry through elaborate networks of ties among small firms, outcompeting previously dominant but now ponderous and slow-moving large firms. Locke (1995) proposes that such outcomes are in fact quite variable, because only some regions have the institutional infrastructure to support such elaborate networks; and Lazerson and Lorenzoni (1999) point to situations where what really matters is what kind of ties connect networks of small firms to larger firms that can in turn connect them to global partners and suppliers. In such a scenario, the analytic problem shifts from whether large or small firms will triumph, to how the regional economy links firms of various sizes and competencies together, and with what results.

Such an emphasis should be important in Silicon Valley as well, because although most attention has gone to the network of small firms and connections among them, it is amply clear that the Valley's success also depends crucially on the Hewlett-Packards, the Intels, and the Cisco Systems. These firms do not compete to the death with small firms, but instead have an elaborate and complex relation to them that has been a source of vitality not yet adequately charted.

The second goal of this chapter, and of the project from which it reports, is to develop systematic methods to analyze the networks of Silicon Valley, and to enable us to make the distinctions between network structures that lead to stronger or weaker outcomes. The important work in industrial organization that has pointed to the centrality of networks cannot progress further without an adequate toolkit of methods for clear and detailed analysis of the complex data presented by the actual networks in particular regions and industries. We present here exploratory analyses from the beginnings of a long-term project.

As in most fields, methods lag behind theory, and at present, our technology and computer programs are a patchwork of materials borrowed from other settings, which need to be further developed and integrated. We believe that the network studies reported here show the promise of such further development, without establishing the definitive results that systematic analysis aspires to. But we also believe that such analysis is an indispensable step in developing a more sophisticated understanding of this and other industrial economies. In studying Silicon Valley's networks, we are probing its deepest and most enduring source of vitality, which will determine whether its world-dominating position can survive very far into the twenty-first century.

10. William Spencer, personal communication.
11. Douglas Jackson, personal communication.

CHAPTER 11, CASTILLA ET AL.

1. For a detailed historical account, as well as a comprehensive inventory of current knowledge, see Wasserman and Faust 1994.

2. MAGE was developed as a device to be used in molecular modeling. It produces three-dimensional illustrations that are presented as interactive computer displays. Transformations of these displays are immediate. Images can be rotated in real time, parts of displays can be turned on or off, points or nodes can be identified by picking them, and changes between different arrangements of objects can be animated. For more information on MAGE, see Freeman, Webster, and Kirke 1998, or visit http://www.faseb.org/protein/kinemages/kinpage.html to learn about and download the MAGE program. One of the difficulties of presenting network diagrams in printed form is that the dynamic capabilities of the program generating the pictures cannot be displayed; only static cross-sections can be presented.

3. For their indispensable help in developing methods and compiling data to construct this visualization, we are grateful to Dimitris Assimakopoulos (Hull University Business School, United Kingdom) and Sean Everton (Stanford University).

4. There are 372 people (or nodes) and more than 1,500 lines, out of a possible 69,006 ($[n \times (n-1)]/2$). Each person in the network is connected to four others, on average.

5. Centrality can be measured in several ways, each of which is associated with a different substantive interpretation. A person's "degree centrality" is simply the number of other people to whom the given person is tied. Degree is typically used as a measure of an actor's involvement in a network (Freeman 1979). In this sense, a person tied to two other people is said to be twice as involved as a person with only one link. In contrast, "betweenness centrality" is usually interpreted as a measure of an actor's power. A person gains power over any two other actors when she lies on the shortest path between the two in a given network of relations. In a network of N actors, an actor obtains the highest possible "betweenness" score when all N –1 other actors are tied only to that person. In this case the focal person would lie on all the shortest paths in the network and would be called a "star." The relative betweenness of a point is a ratio that measures the extent to which a point in a network approaches the betweenness score of a star (Freeman 1979). A person's relative betweenness can vary from a minimum of 0, when it lies on no shortest paths, to a maximum of 1, when the person is in fact a star. We calculated the degree and the relative betweenness of each person on the semiconductor industry genealogy chart.

6. A separate analysis with the companies as nodes, connected if they shared a founder, indicates that Fairchild Semiconductor and Amelco (founded in 1961 by Hoerni, Kleiner, Last, and Roberts) were the most central companies in the semiconductor network. Full results of the network analysis using the program UCINET 5 are available upon request.

7. At the present time, the Honors Cooperative Program has been integrated into the regular engineering curriculum.

8. Faculty interview.

9. Personal interview.

10. See Paul Hirsch's 1972 discussion of the importance of "boundary spanning units" or "contact men" in locating talents and marketing new products for organizations in cultural industries. We argue here that members of research centers and programs who have worked both in industry and at universities broker and facilitate the interaction between the university and industry to the benefit of both.

11. There are some omissions, such as Tom Flowers, Bud Moose, and Ray Lyon, who started early SBICs and were leaders of the old Western Association of Small Business Investment Companies (WASBIC). These people were not included since they primarily did real estate deals. WASBIC was the predecessor of today's Western Association of Venture Capital (WAVC). The information is current from 1958 up to December 1983, to the best of Asset Management Company's knowledge. West Coast offices of venture firms based elsewhere are not included as West Coast firms unless they joined the Western Association of Venture Capital (WAVC). Only those individuals whose principal occupation has been venture capital are coded in the genealogy chart, together with some investment bankers who were included when direct venture capital investment was a significant part of their business. We have done additional research to verify and complete some of the information contained in the chart whenever possible. In addition, we have sought to identify other firms and connections.

12. Our findings are tentative; data collection and analysis are still in progress.

13. This is out of the possible 8,256 lines ($[n \times (n-1)]/2$).

14. Figure 11.2 represents people rather than firms. But the comparable network graph for semiconductor firms, although not as densely connected as that for people, is quite different from Figure 11.4, and does not break down into clear components.

15. This is out of the possible 60,378 ties ($[n \times (n-1)]/2$).

16. Among the central actors who followed this pattern are David G. Arscott, who started Arscott, Norton & Associates in 1978 and worked for the previous ten years in Citicorp Venture Capital Ltd.; Dean C. Campbell, who also worked for Citicorp Venture for a year early in the 1980s and then for Institutional Venture Partners; Walter Baumgartner, who worked for Bank of America Capital Corporation from 1975 to 1979, and in 1979 moved to Capital Management Services, Inc; and Lawrence G. Mohn Jr., who worked for Bank of America Capital Corporation from 1975 to 1980 and left to work for Hambrecht & Quist. Kirkwood Bowman, the venture capitalist with the highest degree centrality in the whole network (connected to 32 people in the industry—five times the average nodal degree) also worked for Bank of America Capital Corporation from 1975 to 1979, then worked for WestVen until 1981, when he started working for Hambrecht & Quist.

Fuller results of the network analysis are available upon request. Our cautionary note in the section above on the semiconductor industry genealogy analysis, on the different meanings of centrality in networks with differently defined ties, also applies here.

17. Because this study is only illustrative, we have left in the data for California firms not located in Silicon Valley. Our preliminary analysis suggests that confining ourselves to Silicon Valley firms would not significantly change the results.

18. An interesting complementary analysis would be to study the network of industrial firms that are related by virtue of having had the same law firms, accounting firms, and investment underwriters on their IPOs. Such firms are tied to one another in the sense that they talk to the same partners in other institutional sectors, and thus might be expected to receive simi-

lar or related advice, information, and perhaps personnel flow into the firms or their boards of directors. One interesting issue would be to see whether such linked firms were more likely to pursue similar strategies than pairs of firms not linked. For a related argument, that board overlaps lead to similar anti-takeover strategies, see Davis 1991.

19. Full results of the network analysis are available upon request.

CHAPTER 12, SAXENIAN

1. For an account of the postwar growth of the Silicon Valley economy, see Saxenian 1994. For more data on immigrants in Silicon Valley, see Saxenian 1999.

2. Interview, Lester Lee, July 1, 1997.

3. Ironically, many distinctive features of the Silicon Valley business model were created during the 1960s and 1970s by engineers who saw themselves as outsiders to the mainstream business establishment centered on the East Coast. The origins of the region's original industry associations like the American Electronics Association were an attempt to create a presence in a corporate world that Silicon Valley's emerging producers felt excluded from. In the early days, these organizations provided role models and support for entrepreneurship similar to those now being provided within immigrant communities. See Saxenian 1994.

4. This list includes only professional associations whose focus is technology industry. It does not include the numerous Chinese and Indian political, social, and cultural organizations in the region; nor does it include ethnic business or trade associations for nontechnology industries.

5. This parallels Granovetter's (1995b) notion of balancing coupling and decoupling in the case of overseas Chinese entrepreneurs.

6. The following discussion is based on interviews with K. Y. Han and Jimmy Lee.

7. In 1996, 82 companies in the Hsinchu Science Park (or 40 percent of the total) were started by returnees from the United States, primarily from Silicon Valley, and there were some 2,563 returnees working in the park alone. Many other returnees work in PC businesses located closer to Taipei.

8. Institute for Information Industry, Market Intelligence Center (III-MIC), Taipei, 1997.

9. Interview, Ken Hao, April 15, 1997. See also Miller 1997.

10. Interview, Ken Tai, May 16, 1997.

11. Interview, Radha Basu, October 1, 1997.

12. Similarly, when Texas Instruments set up the first earth station in Bangalore, it entailed a long-winded process that included breaking or removing 25 government regulations.

PART III, INTRODUCTION

1. Calculations based on data from *San Jose Business Journal Book of Lists*, 1989 and 1999.

2. The geographic scope of the region shown here includes all of Santa Clara County and extends into adjacent zip codes in Alameda, San Mateo, and Santa Cruz counties. This is consistent with Joint Venture: Silicon Valley's 2000 Index (see Joint Venture: Silicon Valley 2000,

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