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THE ROLE OF FOUNDER TIES IN THE
FORMATION OF SAN DIEGO'S "WIRELESS VALLEY"

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Abstract

The wireless telecommunications industry was widely dispersed across North America, but during the 1990s a cluster of wireless firms emerged in San Diego. This paper describes interim results of an ongoing study of firm creation in this cluster. By examining founder career affiliations, we show the role of educational and military institutions in incubating the "Wireless Valley" cluster.

Keywords: cellular communications, regional economies, innovation clusters
JEL codes: O18 (Regional, Urban, and Rural Analyses), L96 (Telecommunications)

1. Introduction

Silicon Valley is the global exemplar for geographical agglomeration effects in technology-intensive industries. Given its success, it has been frequently studied by social science researchers and journalists, having a major impact not only on the U.S. economy, but also on theory and practice of regional economic development.

There is a risk of deriving all our theoretical knowledge of high-technology clusters from a single exemplar. The Northern California cluster has played an important role in the U.S. semiconductor, PC software and Internet industries. But beyond these segments, regional agglomeration effects have been largely absent from U.S. industries based on Information & Communication Technologies.

In particular, the birth and early growth of wireless telecommunications equipment was broadly dispersed throughout North America. However, with the shift from analog to digital cellular telephony, in the late 1990s a new cluster dubbed “Wireless Valley” emerged in San Diego, centered in part on Qualcomm and its CDMA technology.

This paper describes interim results of an ongoing study of firm creation in the Wireless Valley cluster. It begins by briefly reviewing prior research on technology clusters, discusses the history of Wireless Valley, and then presents preliminary results from a dataset of more than 300 firms created during the period 1980-2000. In particular, we show how a few central firms were essential in the subsequent growth of firms in the cluster. Finally, we offer preliminary implications for the economics and sociology of regional industry clusters.

2. Research on Technology Clusters

The work of Marshall and his successors have identified the economic benefits created by industry clusters. These include localized knowledge spillovers, economics of agglomeration and specialization and more recently the role of university research and development (Marshall 1919; Porter 1990, 1998).

In economics, the geographic concentration has been explained in terms of “agglomeration advantages”. Once a firm has located in a specific region, a path-dependent process attracts more firms to the region (Arthur, 1990). Knowledge spillovers foster innovation that fuels firms creation (Scherer 1982; Saxenian 1994; Powell et al 1999). Firms also benefit from pools of skilled labor specialized for the cluster industry (Zucker, Darby & Brewer, 1998). Geographic concentration and industry specialization also facilitate information flows to venture investors, reducing uncertainty and increasing the availability of capital (Sorenson & Audia, 2000; Robinson and Osnabrugge, 2000). The region thus develops an industry-specific technical culture, with a complex web of relations between local institutions (Maskell and Malmberg 1999).

In the 1980s, the rapid rise of the U.S. personal computer industry focused attention on the role of one industry cluster dubbed “Silicon Valley.” The cluster demonstrated a high rate of firm creation and diffusion of knowledge through high job mobility; these firms were supported by local institutions including universities and venture capital investors (Rogers and Larsen, 1984; Saxenian, 1994). With the economic growth generated by these high technology firms, “the model of Silicon Valley became the Holy Grail of economic development” (Sturgeon, 2000: 15).

Despite the highly visible and oft-studied Silicon Valley exemplar, there is still considerable disagreement over which institutional actors were essential to its success — and whether this success can be replicated. Some authors point to the importance of university-industry interfaces;

for example, Stanford University played an important role in the regional development of Silicon Valley (Kenney, 2000). Others point to spillovers from military-related research & development or support by local public agencies (Leslie, 2000). Another frequently mentioned factor is the role of venture capital firms in funding start-up companies (Kenney, 2000; Leslie, 2000).

One way to get at those central organizations in Wireless Valley's evolution is to look at the career histories of the founders of wireless organizations. Where do these entrepreneurs come from? The myth of the Silicon Valley entrepreneur has led to great interest, stories, and speculation about which types of individuals were likely to form new firms and what their backgrounds were (Kaplan, 1999).

An individual's career history shapes the stock of accumulated human capital (knowledge and skills) (Becker 1962), and has been shown to impact subsequent decision making activities (Dearborn and Simon, 1958). Indeed, founders may need to tap in those social networks accumulated at other firms in order to access key resources such as financial capital, knowledge, and information. Research on personal characteristics of founders has emphasized that a lack of founder experience in specific skills often leads to firm failure (Mayer and Goldstein, 1961; Boswell, 1972). Other studies have developed measures of human capital and tested its relationship to organizational survival (Bates, 1985; Bruderl, Preisdorfer, and Zielgler, 1992). While we do not in this paper measure the human capital of San Diego's wireless founders, we acknowledge that their past organizational ties have contributed to this capital. Hence, the most frequently mentioned organizations in career trajectories are likely to be the most significant source of knowledge (human capital) leading to subsequent foundings of wireless organizations. Founder's career backgrounds also impact their social capital (Stinchcombe, 1965; Coleman, 1988). Past organizational affiliations also bring social capital in the form of informal connections that may provide resources in founding a firm. Social capital consists of those social relationships which are available to individuals at any given moment to draw resources from which facilitate action (Coleman, 1988). In Silicon Valley, such social capital can be found around Stanford University (and other regional research institutions), venture capital organizations, business networks and their supporting organizations (Cohen and Fields, 2000). In the case of Silicon Valley, the benefits of being affiliated with these institutions extend beyond the time of formal affiliation in the form of informal networks.

Therefore, by investigating the past organizational attachments of Wireless Valley high-tech founders, one can determine which organizations were central in building human capital (knowledge and skills) and social capital (connections) that are likely to be crucial in the decision to found an organization.

3. San Diego's Wireless Valley

In the late 1990s cluster of telecommunications firms sprouted up in San Diego to form what promoters termed "Wireless Valley" or "Telecom Valley". For a long time, this cluster passed unnoticed outside the telecommunications industry: for example, it was omitted from Porter's (1998) list of 32 U.S. regional clusters.

While "Wireless Valley" promoted itself as another Silicon Valley, the reality is that outside Silicon Valley agglomeration effects have played a comparatively small role in ICT-based industries in the U.S. In particular, the development of cellular mobile telecommunications equipment was broadly dispersed throughout North America, with independent design centers for AT&T, Motorola, Northern Telecom and smaller firms (West 2000).

However, with the shift from analog to digital technology, in the late 1990s a new cluster of cellular equipment manufacturers and suppliers emerged in San Diego. By the end of the decade, some estimated that the region hosted more than 150 companies or research offices focusing on wireless communications (San Diego Regional Technology Alliance, 2001).

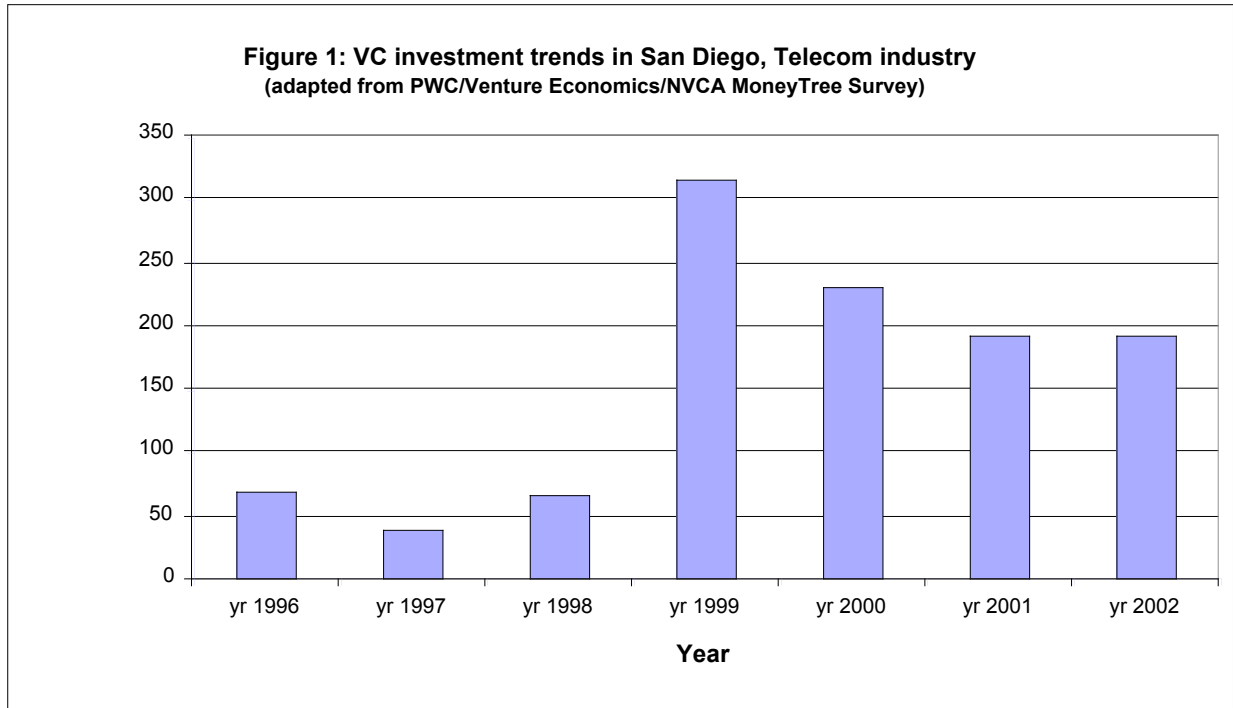
Many credit Qualcomm with creating this cluster. Certainly Qualcomm brought it global visibility, when in 1999 it had the fastest growing stock on the *Wall Street Journal's* list of small- or mid-cap issues (McGee 2000). Some considered the area an improbable location for Qualcomm or any other global technology leader; certainly there was nothing about its factor endowments or local demand that would suggest a telecommunications cluster (cf. Porter, 1990). As a *Fortune* cover article on Qualcomm co-founder Irwin Jacobs noted:

San Diego is one of the last places in America you'd expect to find a company like Qualcomm or a man like Jacobs. I know. I grew up there. For years San Diego was dominated by the Navy, defense contractors, retirees, and twentysomethings looking for a good time. It was said that you could never build a successful technology company in San Diego; the beach is just too enticing (Nee 2000).

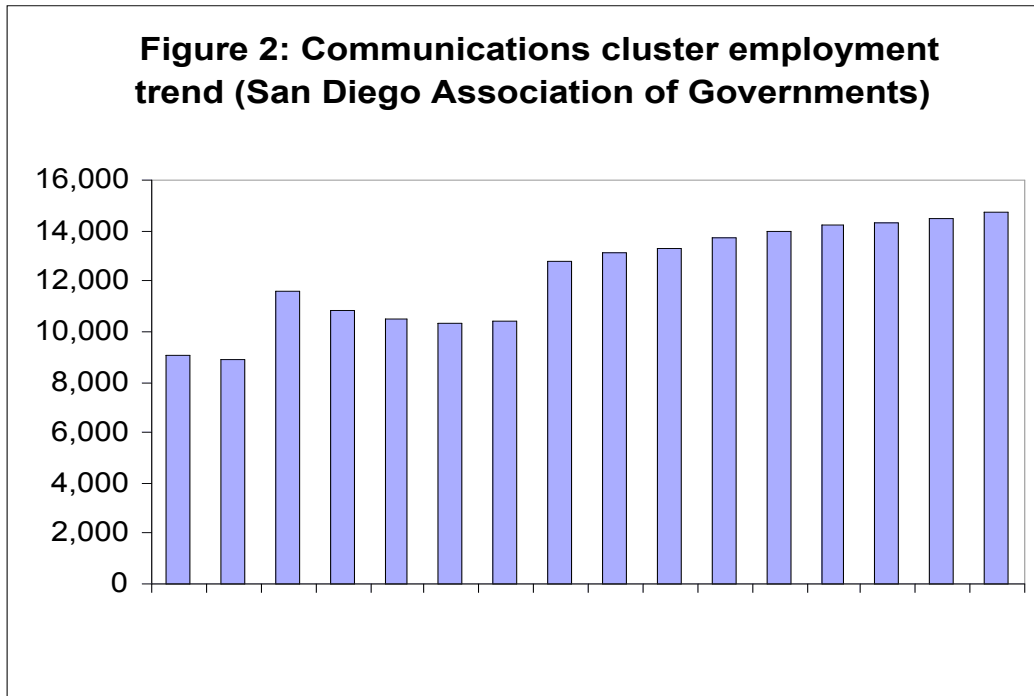
But the roots of the San Diego wireless cluster long predated Qualcomm. Much like Los Angeles to the north, aerospace (particularly military aircraft and missiles) had been San Diego's major manufacturing industry from the 1930s through the 1980s; local firms were responsible for key World War II and the Korean War aircraft. The end of the Cold War meant procurement cutbacks in military aircraft and a recession for Southern California. However, the same aerospace industry had also created a demand for San Diego firms that produced military electronics.

One such military electronics firm was Linkabit, founded in 1968 by two university professors, Jacobs and Andrew Viterbi. The small firm initially did general military consulting, but soon developed expertise in secure military communications; in 1980 it was acquired by a larger defense contractor for an estimated \$40 million. Linkabit was credited with spawning more than two dozen other local telecommunications companies, the most famous being Qualcomm, founded in 1985 by Jacobs, Viterbi and other Linkabit alumni. Qualcomm saw an opportunity to adapt sophisticated military communications technologies for civilian use, most notably the CDMA technology that helped spawn other San Diego-area firms in the late 1990s.

Of course, San Diego's wireless economy has suffered from the recent downturns in technology spending, particularly that related to wireless infrastructure. In 2002, San Diego's telecommunications industry received a total of \$194 million in Venture Capital investment, down from an all-time high of \$316 million in 1999 (Coopers, Economics, & Association, 2003). The trend of venture investment for the industry is shown in Figure 1.



Some industry observers suggest that San Diego’s wireless economy has suffered less than other regions in the United States (Thompson, 2002) and is showing continued growth despite of the recession, as suggested by employment data in Figure 2, which shows that while employment numbers in San Diego’s communications industry are growing at a much slower pace since the downturn (300 new jobs between 2000 and 2001, and 200 new jobs between 2001 and 2002) , they are not shrinking. Future forecasts for 2003 and beyond project a similar pattern of slow growth in employment.



4. Research Design

This paper is based on a new database developed as part of the first author’s dissertation on the San Diego wireless cluster. For the purposes of this study, the concept of wireless communications is broadly defined to include cellular telephones, satellite transmissions, microwave, other mobile communications, and their associated devices, components, services, operators, software and standards. This definition is consistent with that used by the wireless cluster’s leading trade association, the San Diego Telecom Council (www.sdtelecom.org).

The database of more than 300 organizations includes all organizations from 1980 to 2000 in the San Diego region that have some wireless telecommunication technology as part of their product(s) or mission. It was compiled from local high-tech company directories published by three different organizations. It was augmented by companies mentioned in by articles published in various general and business publications, including publications cataloged by Lexis-Nexis as well as strictly local publications not covered by that database. Discrepancies were resolved by contacting the company by telephone or e-mail. A subset of the information compiled for each of the firms is given by Table 1.

- Company name (including previous incarnations)
- Year of establishment, of location in San Diego
- Headquarter location
- Ownership status (public or private) and — where appropriate — date of IPO and exit (acquisition or bankruptcy)
- Primary business, and wireless focus
- Names of founders and prior links to other institutions (corporate, government or non-profit)

Table 1: Information gathered for San Diego wireless organizations (N=339)

Descriptive Statistics

The database included both wireless firms founded in San Diego, and firms founded outside San Diego that later established operations in San Diego to participate in the wireless cluster. The latter firms included those that relocated to San Diego, purchased as San Diego-based firm, or established a new branch office. Such foreign-headquartered firms are among those most active in the regional economy's development even though their headquarters are located elsewhere, including Nokia, Ericsson, and Sony.

Thus for each firm, we coded the founding date, year entering San Diego, and the headquarters location. This information was usually available in the business press literature. When in doubt, we checked SEC filings or made telephone calls to the organizations themselves.

The database contains 326 organizations that have some, if not a primary, focus on wireless technology and are located in San Diego County, either as a branch or a headquarters. About two-thirds of the organizations are currently headquartered in San Diego, implying that the region is indeed a center of wireless technology decision-making and development (see Table 2).

Location	#	Percentage
San Diego County	218	66.7%
Outside San Diego	106	32.5%
Missing	2	00.6%
Total	326	100%

Table 2: Location of Headquarters for Cluster Firms

Firm Characteristics

Even though wireless technology companies are numerous in San Diego, the data collected so far suggest that most are small organizations. Indeed, 45% of the organizations count 50 employees or fewer (in San Diego), while 61% have 100 employees or less. A handful of organizations have a large number of employees in San Diego (36 organizations have more than 500 employees in San Diego, with 16 having over 1,000 employees).

Therefore, the San Diego wireless landscape suggests a handful of very big employers alongside a multitude of small firms.

The analysis of founding date (overall founding date) reveals that 50% of 294 organizations¹ were founded between 1991 and 2002. The other half spreads from 1851 to 1990, with a concentration in the 1980s (See Figure 3). This suggests waves of organizational foundings with a wireless technology focus, once in the mid 1980s, and again in the 1990s and beyond.

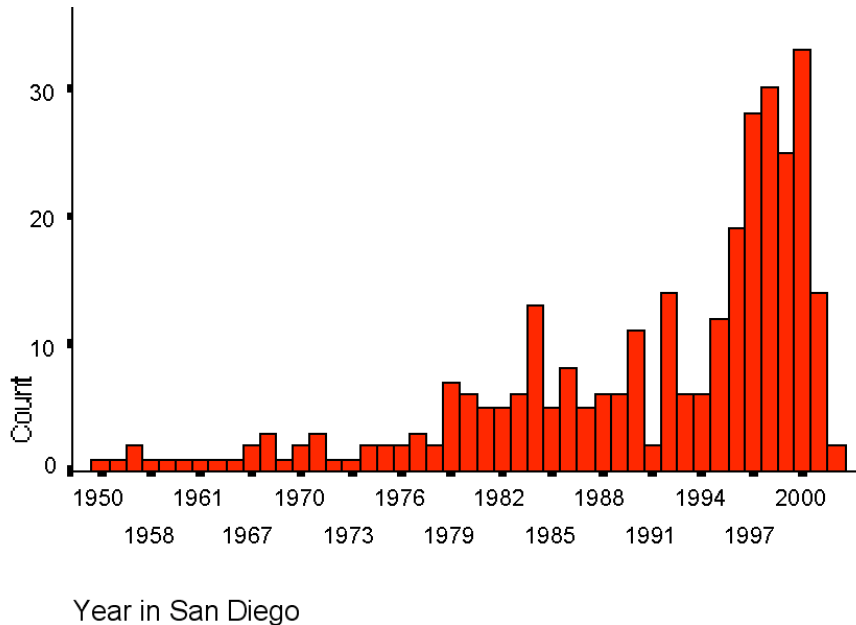


Figure 3: Date of San Diego founding or establishment (N=294)

Coding of Founder Career Affiliations

For companies founded in San Diego, the name of each founder was entered and their past career trajectories were coded as a list of institutions (e.g., US Navy, Qualcomm, MIT, etc.). Founder information was gathered from multiple public sources: business press articles, company websites, online vitas, SEC filings, and Hoover’s online database of companies and their key officials. When no information was found, we contacted the public relations department of the companies and asked for the information.

Of 202 organizations founded and headquartered in San Diego, we obtained founder information for 180. The remaining 22 organizations had no publicly available information on their founders and did not return requests for information. All career trajectory stops of a founder prior to founding a wireless organization were entered. For example, Jim Dunn founded AirFiber. Before founding this company, he worked at Linkabit, Primary Access, and studied at UCSD. Hence, Jim Dunn represents a possible knowledge spillover tie between all those organizations. The founders’ network yields some 580 nodes and was analyzed using Pajek, a network visualization tool² which is increasingly used for network analysis in the social sciences in other fields (de Nooy, Mrvar, & Batagelj, 2003; Powell et al., 2003). Pajek is a freeware program providing network visualization representing nodes and their linkages in space based on

¹ 33 are currently missing founding information, necessitating further data collection

² This software was developed by Vladimir Batagelj and Andrej Mrvar and is available online at <http://vlado.fmf.uni-lj.si/pub/networks/pajek/>

space position and number of linkages to other nodes (appendix by Owen-Smith, in Powell et al., 2003).

5. Analysis of Founder Ties

Networks of Ties

The analysis of this data is currently in progress. The project uses network methods to analyze patterns of firm formation in the San Diego wireless cluster, including:

- commonality within intense periods ('waves') of firm creation
- identification of key institutions and individuals responsible for directly or indirectly founding many of the firms
- linkages between firms within and across industry specializations

Figure 2 shows the overall structure of the founders' career ties. The network consists of a highly interconnected core with some peripheral organizations.

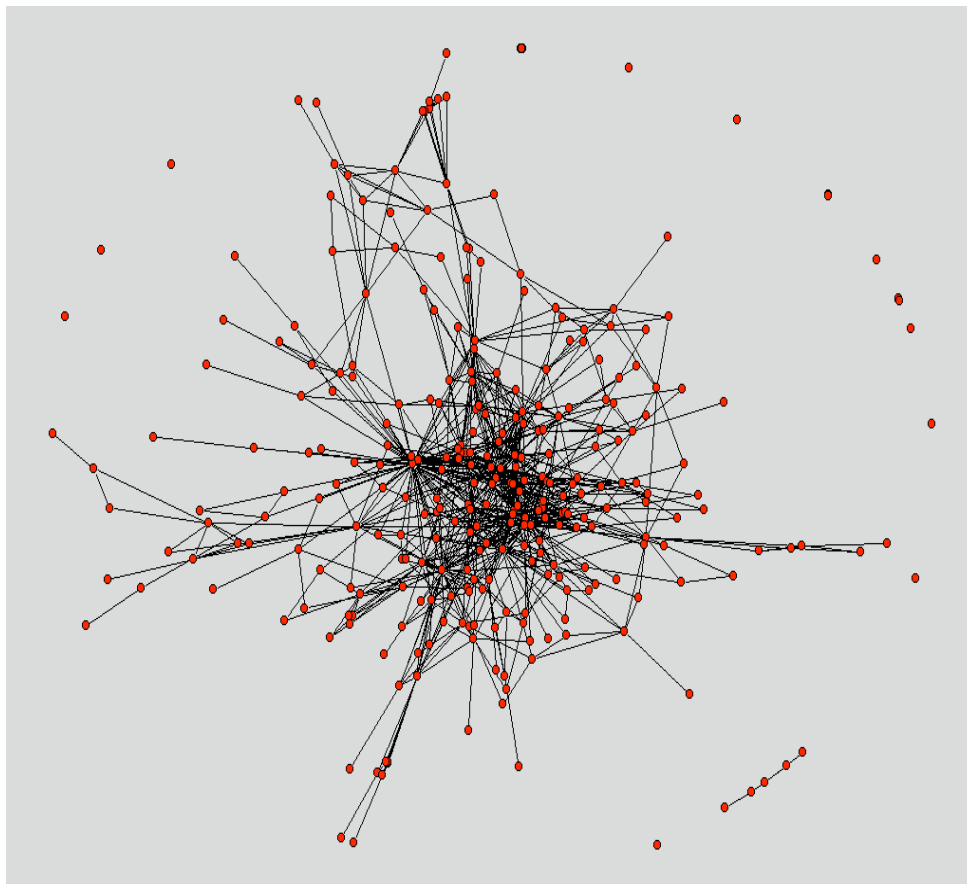


Figure 4: Linkage of founder ties, all organizations (N=580)

This paper is interested in the key organizations acting as a breeding ground for the creation of future startup firms in the cluster. Hence, who are those core actors? Figure 5 was drawn including only those organizations with a degree centrality of 20 ties and over, revealing 26

highly-central organizations that were part of the greatest number of founder careers.³ This core network shows the dominance of a few organizations which played some role in creating knowledge through development of human capital (i.e., the skills of the founders). The thickness of the lines represent a greater number of ties between the organizations.

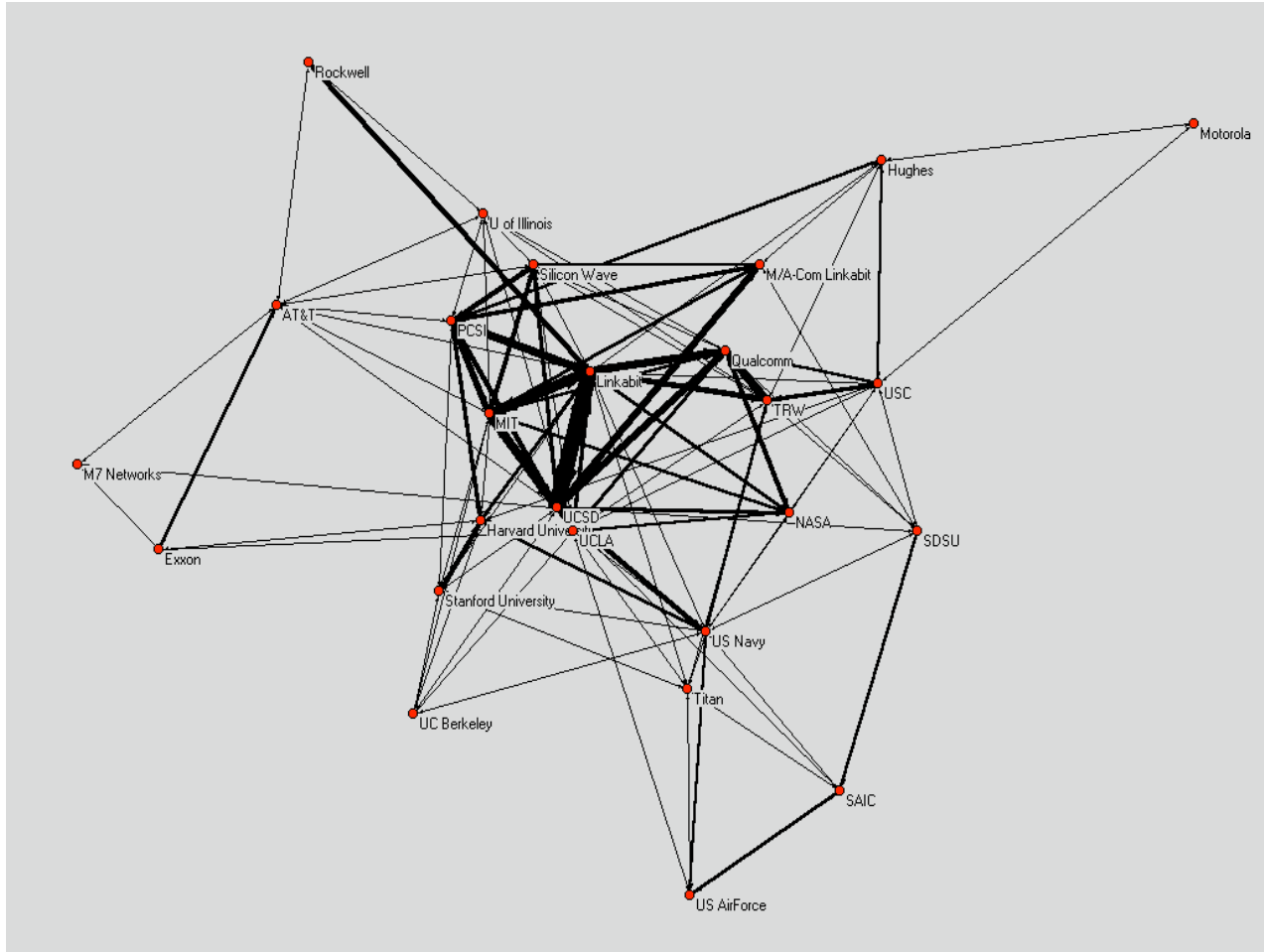


Figure 5: Core Network (Degree Centrality ≥ 20)

UCSD (University of California-San Diego), the major local research university, clearly stands out as an institution where many founders spent time before starting a company. This confirms the current regional economic literature suggesting that a local research university is paramount in creating knowledge spillovers.

But the impact is not limited to a single university. Indeed, many California universities are in the core of the network: SDSU (San Diego State University), USC (University of Southern California), UCLA (University of California-Los Angeles) and Stanford University, have all acted as breeding grounds for San Diego founders. Therefore, beyond a single local university, this study reveals that several universities can be instrumental in the emergence of a cluster. Top-

³ For most organizations (e.g. Linkabit, U.S. Navy), the career tie reflects work as an employee of the organization. For universities, the ties included both student and faculty roles.

tier universities from outside California also make the list: MIT, with significant centrality, Harvard, and University of Illinois. MIT holds an interesting position in the network. MIT's centrality is also emphasized in Figure 3 by the thickness of its link to other key organizations, namely UCSD and successful local wireless organizations PCSI (Pacific Communication Sciences Inc.), Linkabit, and SiliconWave. MIT, therefore, complements UCSD as a key knowledge-creating institution in San Diego, even though located outside the region.

Figure 6 shows that UCSD appears in founders' biographies 41 times, while MIT shows 14 such mentions, while UCLA has 12. Other universities have less than 10 founder ties to regionally founded organizations. We intend to further study the role of university-industry linkages in regional economic emergence and evolution.

Another highly central firm is Linkabit, a wireless communication organization catering to the defense industry. A look at Figure 6 reveals several other ties to the defense industry, suggesting that military knowledge spillovers are central in the founding of organizations based on wireless technology in San Diego. Other defense organizations with significant ties to founded companies are major defense contractors TRW, Rockwell, Hughes, and General Dynamics. These defense organizations cater to the defense and commercial industries, suggesting dual-use technology and hence knowledge spillovers between military and commercial applications. All have a presence in San Diego (although General Dynamics closed its San Diego facilities at the end of the Cold War in 1992), even though their headquarters is often located outside the region. SAIC (Scientific Applications International Corporation) and Titan are defense and commercial organizations headquartered in San Diego and major local employers.

Another interesting observation is that the US military and other governmental agencies were also a "breeding ground" for wireless founders in San Diego. The US Navy, the US Air Force and NASA are in the founder network core. Again, military and aerospace knowledge spillovers are at work through founders.

Finally, Figure 6 shows that the impact of multinational telecom organizations is not negligible in San Diego's evolution. Both AT&T and Motorola frequently appear in founders' biographies, suggesting instances of telecom-focused knowledge transfer to the region. We expect that multinational telecom ties will be apparent in the longitudinal network. The presence of those two telecom giants makes sense in the wireless industry: cellular telephony was invented at AT&T's Bell Labs and the cellular handset was designed at Motorola (King & West, 2002).

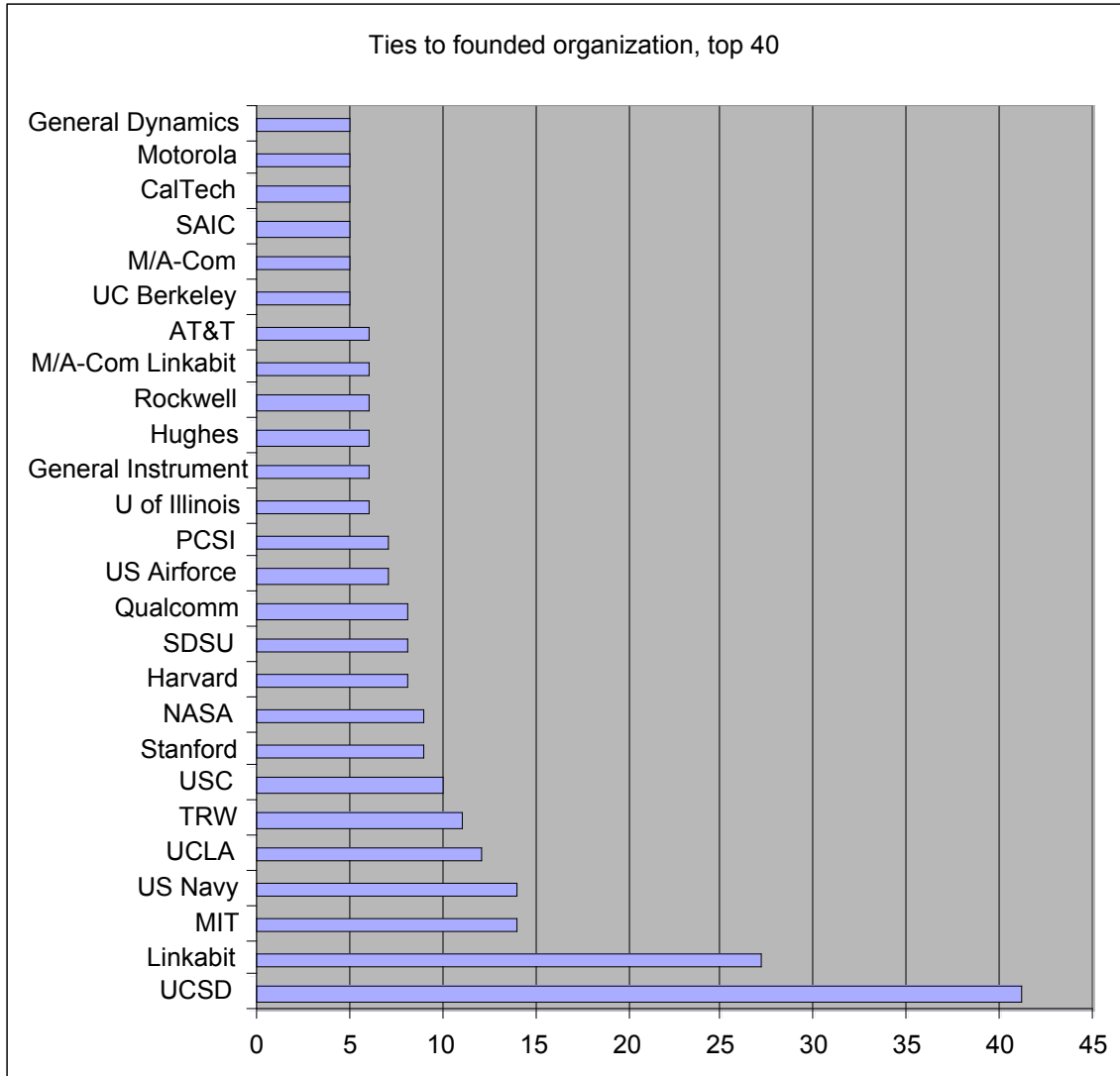


Figure 6: Wireless founders' most frequent affiliations

Firm Genealogy

In addition to the career linkages, we also looked at the chronological ordering of organizational founding, and the associated founder ties.

Beyond the aforementioned universities, the network of highly-central organizations also show that a few of the wireless companies are themselves at the core at the network. Many of these centrally located firms provided experience for founders of subsequent organizations, as illustrated by Figure 7.

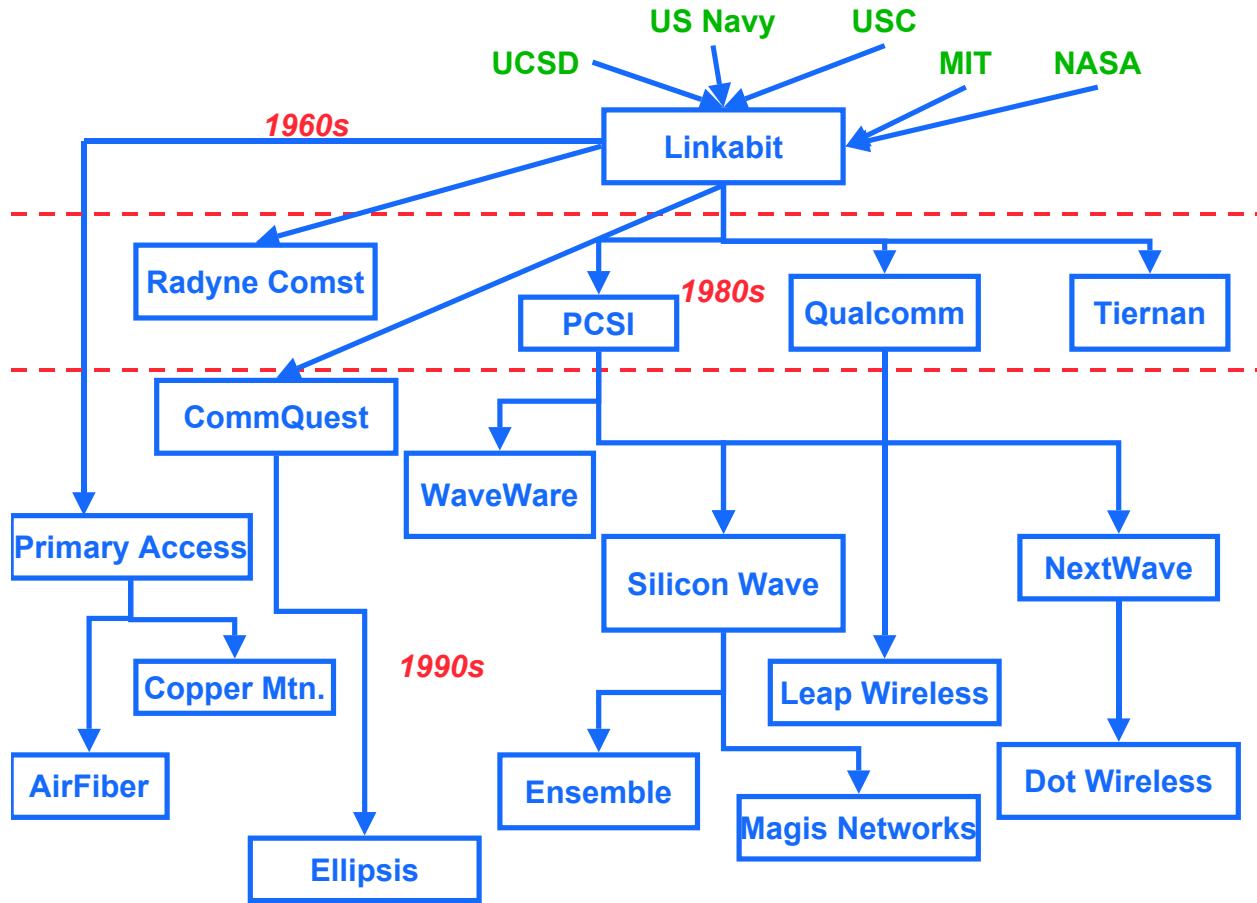


Figure 7: Genealogy of Key San Diego Wireless Firms

Role of Specific Organizations

From the core network (Figure 5) and genealogy (Figure 7), four central institutions stand out.

UCSD (Founded 1958).⁴ With 41 ties, UCSD is the most central organization — with linkages to around 44% of the 180 companies for which founder information is known (although some ties are linked to the same organization through multiple founders). UCSD is best known as the university that in 1966 attracted a Massachusetts-born electrical engineering professor, Irwin Jacobs, who left MIT after seven years on the faculty. Many years later, Jacobs attributed the unconventional move to personal ties with an undergraduate physics professor, a fondness for California, and the challenge of teaching at a new university (Jacobs 1999).

As one of two large universities in the region (the other being SDSU), it is not surprising that UCSD has played a major role in the education of many local entrepreneurs. But UCSD also had three administrative units that played a key role in the growth of Wireless Valley:

⁴ A marine biology research station was established in San Diego in 1903, was transferred to the University of California in 1912, and in 1925 was renamed Scripps Institute of Oceanography. UCSD's first college was established in 1958, but the university did not enroll undergraduates until 1964.

- the Jacobs School of Engineering (1960), ranked among the top 20 graduate engineering programs in the U.S, and in 1998 endowed by (and renamed for) Irwin Jacobs and his wife;
- UCSD Connect (1985), a non-degree entrepreneurship education and incubator founded by Bill Otterson, a retired entrepreneur, that assisted a wide range of technology startups in the region; and
- the Center for Wireless Communications (1995), an engineering research center in which UCSD faculty research was sponsored by U.S., Japanese and European electronics firms.

Linkabit (Founded 1968). With 27 ties to founded wireless companies, it is the most highly connected organization after UCSD. If we also consider M/A-Com Linkabit (the entity formed after M/A-Com bought Linkabit in 1980), the frequency of ties to founded organizations climbs to 33. Linkabit was founded as a communications consulting business for the defense industry by Irwin Jacobs of UCSD and two UCLA faculty, Andrew Viterbi and Leonard Kleinrock. The company's first consulting contract was with the Naval Electronics Lab, a major Navy civilian research facility located in San Diego (Viterbi 1999).

Because of its early founding date and its high number of ties to subsequently founded organization, it fits the characteristics of the "original successful incubator" which the literature on regional economies suggests plays a role in fueling future entrepreneurship. In talking about Linkabit, the business press has often labeled it as San Diego's equivalent of "HP for Silicon Valley" (Markoff, 1997). By one estimate, Linkabit either directly or indirectly spawned at least 27 other local companies in its first 25 years (Bigelow 1997).

Qualcomm (Founded 1985). After Linkabit was purchased, Jacobs and Viterbi remained with the company for five years. The two left in 1985 and, along with six others, founded Qualcomm Incorporated; most of the founders had worked together at Linkabit on military communications. The new company had a decidedly civilian orientation, marking an important continuation of the partnership of the two Massachusetts-born Ph.Ds, one that would eventually span three decades. At Qualcomm, Jacobs became the public businessman while Viterbi served as chief technical officer, providing credibility with academic scientists and industry engineers.

Although Qualcomm's initial product was a satellite truck tracking system, it became internationally known for Code Division Multiple Access (CDMA), a high-capacity but technologically complex encoding scheme for digital cellular telephone calls. In 1990, CDMA was approved as one of three digital standards for the United States, and was later adopted in Korea (1993) and Japan (1997). Qualcomm's patents also proved central for various competing "third generation" cellular technologies, including W-CDMA and cdma2000.

The complexity and early immaturity of the CDMA technology created a premium for the tacit knowledge necessary to commercialize it. Some of this knowledge spilled over into new firms founded by Qualcomm alumni and funded by local biotechnology venture capitalists or ICT-focused Silicon Valley VCs; these startups included both hardware companies (e.g. Neopoint) and wireless service providers (Leap Wireless, NextWave). But the cluster was not limited to startups: by 2000, leading telecommunications multinationals such as Nokia, Motorola, Ericsson, Siemens, Samsung, Sony and Kyocera had opened CDMA research & development offices in San Diego.

PCSI (Founded 1986). David Lyon was among the founders of Pacific Communications Sciences, Inc. An MIT Ph.D., Lyon had worked at Bell Labs and M/A-Com Linkabit; after PCSI was sold to chipmaker Cirrus Logic in 1993, Lyons went on to co-found two other local wireless startups, Silicon Wave and Ensemble Communications.

5. Conclusions

Limitations

There are obvious limitations to the data in its current form. The first one is that we have no measure of which organizations in a founder's past were more important than others. However, by looking at only the organizations which appear the most frequently in founder biographies, we believe that we get an accurate picture of which organizations were more important to subsequent foundings for the region. The other limitation, closely tied to the first, is that we currently have no measures of human and social capital. That is, we do not look at the specific occupations held by founders in those organizations. Surely, having been a student at UCSD differs from having been faculty. And having a degree in history differs from a degree in electrical engineering. However, the goal of this paper was not to measure individuals' specific positions and stock of knowledge in subsequent foundings, but to get a general view of the organizations which have shaped the careers of founders.

Implications

Preliminary analysis of the data suggests that position in career history linkages identifies a few crucial institutions that enabled San Diego's economic transformation. We believe data on organizational founding waves in the region, combined with data on organizational founders, will inform theory on the role of various institutional actors in regional transformation: the university, the military, regional organizations of high-technology, and technology.

We believe that this analysis of "Wireless Valley" is relevant to our understanding not only of the telecommunications industry, but also to the more general policy issues related to high-technology regional clusters.

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