A Comparison of High Technology Centers

Regional Connections
Working Paper 4

Joseph Cortright
Heike Mayer

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Regional Connections Project
Institute for Portland Metropolitan Studies
Portland State University

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REGIONAL CONNECTIONS

A Comparison of High Technology Centers

By Joseph Cortright and Heike Mayer

A number of mid-sized metropolitan areas throughout the United States have frequently been identified as current or emerging centers for high technology business. This paper presents a comparison of many of the important features of these economies, including their overall size and recent growth rates, an analysis of employment in certain high technology industries, an identification of large high technology firms in each region, and an examination of patent data. While the term "high technology" is broadly used to describe the distinctive nature of these metropolitan areas, this analysis shows that each area tends to have its own areas of distinctive technological specialization. Specialization and differentiation are inherent qualities of high technology. There appear to be durable and persistent tendencies for metropolitan high tech development that are unique to each region.

Comparing—and ranking—the nation's high technology hotspots is a popular pastime for academics, journalists and economic developers. Seeing how your region stacks up against Silicon Valley, and a growing list of silicon wannabes, is taken as a prime indicator of economic success. This report presents a comparison of a baker's dozen metropolitan areas that are frequently counted among the nation's leading high tech centers. Looking carefully at each of these areas, in particular, examining not just overall employment data, but looking at the characteristics of leading firms, the kinds of innovation and the historical roots of their development, we conclude that metropolitan specialization is a key attribute of high technology industries.

Regional Connections is an ongoing effort to analyze and explain the structure and performance of the Portland Metropolitan Economy, sponsored by Portland State University's Institute for Metropolitan Studies. Funding for this project has been provided in part by lottery funds from the Regional Strategies program for Multnomah and Washington Counties, administered by the Portland Development Commission and the Oregon Economic and Community Development Department., and from the American Electronics Association and Portland State University.

Regional Connections work products include a technical report—Progress of a Region: The Metropolitan Portland Economy in the 1990's—briefings on the regional economy and a series of working papers summarizing the project's studies of the region's industry clusters, including high technology, metals, creative services and nursery products.

For more information about Regional Connections, contact Ethan Seltzer at 503-725-5170 or visit our website at www.upa.pdx.edu/ims/regcon/regecon.html.

Key highlights are:

- **Places specialize**: High technology specializations vary dramatically from place to place. Different areas tend to specialize in certain technologies and have major concentrations of firms and employment in relatively few specializations. A few places, like Silicon Valley, excel in many areas. Most metro areas, even those labeled high tech centers, usually concentrate in just a few products or technologies. An area that's strong in one area, say medical devices, does not necessarily have an edge in another area, like telecommunications, or semiconductors or software.

Typical Product Specializations for Selected Metropolitan Areas

Region	Product Specializations
Boston	Computers, Medical Devices, Software
Atlanta	Telecommunications, Databases
Phoenix	Semiconductors
Minneapolis	Computers, Peripherals, Medical Devices
San Diego	Communications Equipment, (Biotechnology)
Seattle	Software, (Biotechnology, Aerospace)
Denver	Telecommunications Equipment & Software, Data Storage
Portland	Semiconductors, Display Technology, SME/EDA, Wafers
San Jose	Semiconductors, Computers, Software, Communication Equipment, SME/EDA, Data Storage
Sacramento	Computers, Semiconductors
Salt Lake City	Software, Medical Devices
Austin	Semiconductors, Computers, SME
Raleigh-Durham	Pharmaceuticals, Computers, Databases

Note: EDA: Electronic Design Automation Software; SME: Semiconductor Manufacturing Equipment.

- **Silicon Valley plays a special leadership role in high technology**. The San Jose metropolitan area distinguishes itself from other high tech centers based on the scale, breadth and leadership qualities it plays. It has more high tech employees than any of the other region's studied, a broader array of production and technological competencies, and a larger volume of patents (in the aggregate and per employee) than any other region. It alone accounts for nearly 40 percent of the nation's reported venture capital investment. The largest Silicon Valley firms are all locally headquartered, and account for more headquarters locations of high tech enterprises in other metro areas than our other 12 regions combined.

- **Knowledge differs from place to place**. Specializations apparent in employment data are mirrored in patterns of knowledge creation, as evidenced by patent data. Similarly, venture capital investment patterns follow the same specializations. Inventors and investors in any given area are likely to focus their efforts in the same areas (or areas closely related to) the current economic strengths of the region.

- **History matters**. Industrial and knowledge specializations tend to persist over time. While some areas acquire or grow new technological specializations (Austin: semiconductors), other places demonstrate a remarkable continuity in specific technological prowess over many generations of firms and technologies (Minneapolis: medical devices, Denver/Boulder: computer storage, telecommunications).

- **Historical lock-in can be good or bad**. Technological specializations can produce powerful forces for growth in expanding industries, but can easily produce stagnation or decline when an industry or technology is displaced. In some cases, technological specializations can undermine economic growth. Both Minneapolis and Boston, which were major centers for computer design and production in the era of mainframes and minicomputers (respectively), suffered serious downturns when markets for these products were overwhelmed by the PC revolution.

- **Evolution is at work**. While areas do specialize, they tend not to remain constant over time. As industries and technologies change, the mix of firms and knowledge in specific metropolitan areas evolves. In practice, development processes appear to be cumulative and path dependent: a region's opportunities for development today are determined, in part, by the kinds of development that have occurred in the past. In retrospect, the importance of pivotal events—like the initial commercialization of key research breakthroughs, substantial and sustained government research and procurement spending, and some industrial relocation decisions—is clear.

- **High technology is not a monolith**. High technology is neither a monolithic industry grouping nor a fungible set of products or production methods or technologies. Almost by definition, high technology goods are highly differentiated, and neither end products, nor production processes, are interchangeable among firms. Though some skills are applicable to a wide range of situations, much technical knowledge is specific to particular firms or narrow industry segments. Statistical analyses that group inherently disparate firms such as medical devices, semiconductors, telecommunications, and software together into a single category of 'high technology' and attempt to explain their behavior as if they were homogenous units driven by a common set of factors are likely to be substantially misleading and incomplete.

Contents

Introduction

A common theme in both academic and popular literature in the past decade has been the attempt to identify those cities and metropolitan regions that are the new or emerging centers of high technology activity. The purpose of this paper is to compare the Portland metropolitan area's high technology cluster to those of other mid-sized American metropolitan areas that are frequently mentioned as its competitors.

This analysis is part of the Regional Connections project, an effort to develop a better understanding of the Portland metropolitan area. Other working papers in this series examine in detail the key characteristics of Portland's high tech cluster; this report compares Portland's high technology industry to those found in other metro areas, in hopes of illuminating the common and uncommon features of our high tech agglomeration.

As every researcher knows, acquiring data can be the most difficult and tedious part of any research project, particularly when one is looking for detailed information about a dozen different metropolitan areas. We are particularly grateful to those who helped us acquire data, including Mike Consol, publisher of the Portland Business Journal, who graciously provided us access to his collection of Top 25 lists for other metropolitan areas. We also wish to thank the Bureau of Labor Statistics, and the labor market information agencies of each of the studied states for providing custom tabulations of employment data for the industries and metropolitan areas we identified. Matthew Zook graciously shared his tabulation of venture capital investment data, and Clare Knight of PricewaterhouseCoopers gave us access to the MoneyTree database. Mark Falconer helped us understand Hewlett-Packard's far-flung operations. We also benefited from the first hand insights and advice of colleagues from most of the metropolitan areas we examined: Lee Munnich in Minneapolis, Bill Bishop in Austin, Dan Pilcher and Chris Gibbons in Denver, Trent Williams in Raleigh Durham, Phil Shapira in Atlanta, Mary Jo Waits in Phoenix, and Paul Sommers in Seattle.

In spite of all the assistance we received, we are painfully aware that our descriptions attempt to condense volumes of data and decades of important economic events into a few paragraphs. Any resulting violence to the truth is solely the responsibility of the authors.

I. Methodology

This study is a cross sectional comparison of the demographics, industrial structure and knowledge base of a series of selected metropolitan areas. Our methodology has been to choose a series of mid-sized regions, assemble basic demographic data about each, measure the overall size of the electronics, instruments and software industry in each, identify the largest local employers and their specializations and to examine the major sources of patent activity in each metropolitan area.

A. Selection of Metropolitan Areas

We have selected metropolitan areas for comparison based on those most frequently mentioned in the popular literature. In addition to Portland, we have included the two most frequently studied centers of high technology (Silicon Valley and Route 128; the San Jose and Boston NECMA, respectively), two smaller, but fast growing high tech centers (Austin and Research Triangle Park), and several of the other mid-sized Metropolitan areas in the West (Denver, Phoenix, Sacramento, Salt Lake City, San Diego, Seattle). We also included the Minneapolis and Atlanta metropolitan areas. Our sample omits many of the nation's largest areas (New York, Los Angeles, etc), as we assume that different processes may be at work in these areas than in the more rapidly growing mid-sized metro areas. Eight of our thirteen cities were on Fortune magazine's list of Ten Best Cities for Business in 1998 (Austin, Salt Lake City, Phoenix, San Jose, Raleigh, Portland, Atlanta, and Denver) (Fortune, 1998). As much as possible we have attempted to obtain and display data for the entire metropolitan area, using federally defined metropolitan statistical areas (MSAs) as our unit of measurement for each case study.

B. High Technology Definition

We define high technology as the computer, electronics, instruments and software industries, a definition drawn from our study of the high technology industry in the Portland metropolitan area. We used Standard Industrial Classification codes to determine analyze employment data and to classify firm level information. We restricted our analysis to two-digit and three-digit codes to maximize the availability of data. Included codes were as follows:

SIC 357: Electronic Computers
SIC 36: Electrical Machinery
SIC 38: Instruments
SIC 737: Software and Data Processing Services

Our definition of the high technology industry differs from that used in some other studies. Other definitions of high technology focus on the research and development intensity or occupational composition of certain industries, assigning groups of SIC codes to 'high technology' if they have relatively large research and development expenditures or relatively large fractions of workers who are scientists or engineers. Our definition is more closely aligned with an industry cluster, looking at groups of firms that share similar labor force demands, technologies, and markets, and for which there are likely to be significant buyer-supplier relationships. This definition is similar to that developed by the American Electronics Association for its analysis of CyberStates; it differs from the AEA definition in that it excludes telecommunications services (SIC 48) (American Electronics Association, 1999).

Table 1: High Technology Definitions Used by Various Studies

SIC Code	Industry Description	Markusen	Saxenian	DeVol	Oregon
28	Chemicals & Pharmaceuticals	All		Part	
30	Rubber & Plastics	Part			
34	Fabricated Metals	Part			
35	Industrial Machinery	Part			
357	Computers	All	All	All	All
36	Electrical Equipment	Part	Part	Part	All
37	Transportation Equipment	Part	Part	Part	
38	Instruments	Part	Part	Part	All
481	Telephone Communication Services		All	All	
737	Software & Data Processing		All	All	All
87	Engineering & Management Services			Part	

Sources: Methodology reported by (Markusen, Hall, & Glasmeier, 1986), (Saxenian, 1994), (DeVol, 1999). Oregon is the Oregon Employment Department.
Note: 'All' means all subsidiary SIC codes in the two or three digit category are included in the definition of high technology; 'Part' means only some of the subsidiary SIC codes are considered high technology.

Academic studies that have analyzed the geographic location patterns of high technology industry frequently classify firms as high technology based on the average intensity of industry-wide research and development spending or on an industry's relative concentration of certain broad occupational groups (scientists, engineers and technicians) (Markusen et al., 1986). Arguably, these approaches identify groups of industries that use higher levels of technology than the average firm in their production processes.

The implication of these studies is that high tech industries as a group are similar to one another and different from all other industries in not only their identifying characteristics, but also in their locational processes and preferences. But as Porter's detailed analyses of geographic clusters around the world makes clear, firms (and regions) tend to specialize in product niches that are much narrower than the broad amalgams of three-digit SIC codes that are almost always used to define high technology. As a result, clusters rarely conform to standard industrial classification systems (Porter, 1998). As Porter argues:

> The view that there are different explanations for international success that apply to different industries has led some authors to divide industries into groups such as traditional, knowledge intensive, resource intensive, scale or mass production sensitive, and high technology (or science-based). The aim of such categories is to reflect the varying determinants of competitive success in different industries. The problem with such generalizations is that technological change and the globalization of strategy have blurred

> the categories. No simple division of industries can capture the diversity of sources of competitive advantage and how they are achieved. (Porter, 1990)

Any definition that relies on groups of standard industrial classification codes is likely to only roughly capture the product and market specializations of the firms and areas being analyzed. At the two and three digit level, there is still considerable variety in the outputs, technologies and scale of individual firms. Where possible, we have attempted to more precisely characterize the specializations of each metropolitan area by looking at firm level information. In some cases we have included firms that are not primarily classified as part of one of the four two and three digit industry groups listed above. For example, in our analysis of the Denver metropolitan area, we identified a high concentration of telecommunications firms, which in addition to providing services to customers also had substantial research and development activities in Denver. Because these telecommunications, satellite and cable firms are headquartered in this area and develop new technologies there (incorporating electronics and software) we included them in our discussion of the high technology industry in Denver.

C. Aggregate Data

To benchmark the overall size and recent economic performance of each of these metropolitan areas, we have assembled data on overall population growth, employment, numbers of manufacturing jobs, and other key characteristics of these areas. This data is drawn from estimates prepared by the Bureau of Economic Analysis and the Census Bureau, and selected commercial data sources (Bureau of Economic Analysis, 1999).

A key measure for assessing the relative size and concentration of high technology firms in particular metropolitan areas is the number of employees working in specific SIC codes. The Census Bureau and the Bureau of Labor Statistics publish estimates of the number of establishments, employment and payrolls by metropolitan area. Census data is published in County Business Patterns (Bureau of the Census, 1998). The Bureau of Labor Statistics publishes Covered Employment and Payroll from data collected by state employment security agencies. The utility of both of these data sources is limited by the agency's suppression of certain data for SIC categories in metropolitan areas where one or a few firms account for nearly all employment.

County Business Patterns reports the number of establishments, total employment and payrolls for each county in the United States at varying levels of detail. More populous counties typically show greater levels of detail. Data cells with non-disclosable information (typically too few firms) are often coded with a range of employment levels.

Employment data reported by industrial classification has another flaw one that is frequently ignored in data analysis. While firms may undertake activities and produce products and services that span a variety of SIC codes, as a rule, employment at the establishment level (and frequently at the firm level) is classified according to a single SIC code. Firms, particularly large firms, often combine a variety of functions and activities in a single location. In many cases the characteristics of these activities vary greatly in their pay levels, technical complexity, and substance. For example, a telecommunications company might include the development of software or services at a location that also provides communication services. Similarly, a semiconductor manufacturer, may also be a software firm. Many computer firms operate large customer support call centers, whose personnel are aggregated with manufacturing employees if they are housed in the same establishment.

D. Firm Level Data

We attempted to identify, by name, the largest high technology firms in each of the metropolitan areas we studied. While the statistical data published by public agencies seldom identifies individual firms (to protect confidentiality), private data sources regularly attempt to name names. The American City Business Journals, a national chain of weekly business newspapers, regularly publishes lists of firms in specific industry categories in each of its markets, typically coinciding with metropolitan statistical agencies. Typical lists include largest local employers, largest public and private firms, and largest high technology or electronics employers in a region. These lists are compiled by researchers for the newspapers, typically by calling individual firms to verify pertinent information. While coverage is seldom complete, and definitions for particular data fields are not as rigorous as those produced by statistical agencies, these lists represent good pictures of the larger firms in any given metro area.

We supplemented in the information contained in the American City Business Journal lists with other data. For example, we utilized the Corp Tech database and the Thomas Register, to obtain additional information about the products and industrial classification of certain firms. In addition, we consulted other sources, including trade associations, universities and public development agencies in the subject metropolitan areas to obtain additional information and, to provide a top employer list for Salt Lake City, where the American City Business Journals did not have a local affiliate.

A key characteristic of the high technology industry is the continuous and rapid creation of new products and new production processes. We attempted to analyze the relative importance of knowledge creation in high tech industries by examining patent data. The U.S. Patent and Trademark Office produces several statistical series summarizing patenting activity, including tabulations of the number of patents issued by metropolitan area and by firm. For our analysis, we examined both the overall number of patents issued in each subject metropolitan area, and the number of patents issued to private high technology firms in each metro area. Our analysis generally excluded patents issued to higher education institutions. Collectively, universities account for fewer than ten percent of the patents issued in given metropolitan areas, and we wanted to focus primarily on private sector commercial research activities.

The availability of equity capital to finance the start-up costs of new firms is an important ingredient in the growth of high technology industries. A number of private financial firms track venture capital investing throughout the nation. We present some limited data tabulated by PricewaterhouseCoopers and by Matthew Zook detailing the regional distribution of venture capital investments in the United States in recent years.

II. Overview of Metropolitan Areas

A. General Economic Characteristics

Our thirteen selected areas range in size from slightly more than one million residents to slightly fewer than six million, with most in the range of 1.5 million to 3 million population. Population growth in these 13 areas as a group has been about half again as fast as in the nation's metropolitan areas as a whole (1.7% annually for the thirteen compared to 1.1% annual for all metropolitan population), though there is considerable variation. Per capita incomes in these areas are somewhat higher than in other areas, and incomes in these areas have been growing more rapidly than elsewhere. Again, there is a large range: per capita incomes in San Jose are 40 percent higher than in the rest of the metropolitan US, and about 20 percent higher in Seattle and Boston.

Table 2: Population and Income Characteristics of Selected Metropolitan Areas, 1997.

Metropolitan Area	Population 1997	Growth 1990-97	Per Capita Income	Growth 1990-97	Percent of US Average
Boston	5,826,816	0.3%	31,808	4.3%	119%
Atlanta	3,634,245	2.8%	28,253	4.4%	105%
Phoenix	2,842,030	3.4%	24,137	4.0%	90%
Minneapolis	2,794,939	1.3%	30,123	4.4%	112%
San Diego	2,723,711	1.1%	24,965	3.0%	93%
Seattle	2,279,236	1.5%	33,373	5.0%	124%
Denver	1,901,927	2.2%	30,743	5.0%	115%
Portland	1,789,790	2.3%	27,388	4.8%	102%
San Jose	1,620,453	1.1%	37,856	5.6%	141%
Sacramento	1,503,900	1.5%	25,335	3.4%	94%
Salt Lake City	1,250,854	2.1%	22,264	5.3%	83%
Austin	1,069,755	3.3%	25,420	5.3%	95%
Raleigh-Durham	1,050,358	2.8%	27,711	4.8%	103%
These 13 Metros	30,288,014	1.7%	28,921	4.4%	108%
All US Metropolitan Areas	214,137,630	1.1%	26,840	4.0%	100%

Source: Bureau of Economic Analysis, Regional Economic Information System.
Note: Dollars are current dollars, US per capita average income is the average for all metropolitan areas.

Table 3 shows the overall employment level in each of our metropolitan areas, as well as the number of manufacturing employees. Employment in these metro areas (like population) is collectively growing about half again as fast as in the rest of the metropolitan US (2.5% annually versus 1.6% annually). The disparity in manufacturing growth is even more striking: these 13 metro areas grew by about 0.5 percent per year, while all metro areas manufacturing declined by about the same amount.

Table 3: Total Full- and Part-time Employment and Manufacturing Employment in Selected Metropolitan Areas, 1997.

Metropolitan Area	Total Employment	Growth, 1990-97	Manufacturing Employment	Growth, 1990-97
Boston	3,794,933	1.2%	476,980	-1.6%
Atlanta	2,418,795	3.5%	227,327	1.9%
Minneapolis	1,995,778	2.3%	287,625	0.8%
Phoenix	1,705,381	4.2%	168,393	2.0%
Seattle	1,640,113	2.1%	229,236	0.0%
San Diego	1,543,307	1.0%	133,312	-0.7%
Denver	1,359,022	3.3%	98,965	0.0%
San Jose	1,179,100	1.7%	267,546	-0.2%
Portland	1,165,642	3.4%	155,263	2.5%
Sacramento	862,315	1.7%	50,624	2.6%
Salt Lake City	842,823	4.2%	86,026	2.7%
Raleigh-Durham	756,420	3.7%	88,305	1.4%
Austin	726,712	4.9%	80,067	6.2%
These 13 Metropolitan Areas	19,990,341	2.5%	2,349,669	0.5%
All US Metropolitan Areas	128,723,093	1.6%	14,982,986	-0.4%

Source: Bureau of Economic Analysis, Regional Economic Information System

B. High Technology Employment

We compiled three separate measures of high technology employment in metropolitan areas. Our attempt to triangulate the approximate size and employment composition of each metro area was necessitated by the limitations of the various data sources.

Table 4: Estimated High Technology Employment in Selected Metropolitan Areas, 1996. (County Business Patterns)

REGION	Employment	Payroll	Establishments	Average Pay
San Jose	189,601	13,322,050	3,330	$ 70,264
Boston	170,348	8,579,542	4,105	$ 50,365
Minneapolis	82,064	2,858,571	2,638	$ 34,833
Atlanta	67,114	2,944,946	3,087	$ 43,880
San Diego	56,315	2,590,749	1,632	$ 46,005
Phoenix	54,694	2,647,429	1,443	$ 48,404
Seattle	54,556	3,090,220	1,990	$ 56,643
Austin	48,142	2,309,524	912	$ 47,973
Raleigh-Durham	47,672	1,141,008	866	$ 23,935
Portland	43,230	1,539,344	1,233	$ 35,608
Denver	31,927	1,435,743	1,748	$ 44,970
Salt Lake City	25,403	746,170	672	$ 29,373
Sacramento	14,550	607,078	444	$ 41,724

Source: Authors Calculations from County Business Pattern Data

County Business Patterns data, produced by the Census Bureau are presented in Table 4. San Jose and Boston are far and away the largest centers for high technology activities, with approximately 190,000 and 170,000 workers, respectively, in the two areas. Minneapolis and Atlanta are the next largest employment centers, with less than half the employment level of the two leaders. The next six metropolitan areas have between 43,000 and 56,000 high tech workers.

A similar overall picture, but decidedly different numbers emerge when we examine the covered employment data produced by state employment agencies and the U.S. Department of Labor. San Jose and Boston still emerge as the leading centers for high technology, but with total employment of 245,000 and 220,000 respectively. They are followed by Minneapolis and Atlanta, and then six metropolitan areas with between 54,000 and 65,000 high tech workers. The covered employment data differ from County Business Pattern data for a number of reasons: they are a year later (1997 instead of 1996), and the Department of Labor and Census Bureau use different underlying databases and classification schemes for aggregating the data (Reamer & Cortright, 1998).

Table 5: Estimated High Technology Employment in Selected Metropolitan Areas, 1997 (Covered Employment, ES-202).

Metro Area	Computers SIC 357	Electrical Equipment SIC 36	Instruments SIC 38	Software SIC 737	Total
San Jose	53,463	91,021	44,623	55,896	245,003
Boston	31,152	76,476	40,100	72,323	220,051
Minneapolis	12,353	22,291	36,148	33,381	104,173
Atlanta	2,257	18,567	7,457	46,466	74,747
Denver/Boulder	8,214	9,442	12,649	35,031	65,336
Portland	8,200	29,700	9,400	13,800	61,100
Austin	17,029	25,146	4,419	12,263	58,856
Seattle	2,235	9,237	11,276	34,518	57,266
San Diego	6,290	22,202	12,266	13,906	54,664
Phoenix-Mesa	(D)	44,893	8,876	(D)	53,769
Salt Lake City	5,406	(D)	9,114	10,716	25,236
Sacramento	7,700	8,400	(D)	7,510	23,610
Raleigh-Durham	(D)	19,810	3,524	(D)	23,334

Source: Bureau of Labor Statistics, Covered Employment and Payroll, 1997. Except Current Employment Statistics (CES) where data shown in italics. (D) - Data unavailable due to disclosure restrictions.

A third perspective on the relative size of high technology complexes is provided by tabulations of Top 25 lists published in local business journals. The approximate rankings of metropolitan areas remain the same, but because we are counting only the 25 largest firms in each metropolitan area, the number of employees is much smaller. These data, however, are the least reliable, gathered by different organizations from information self-reported by firms.

Table 6: Estimated High Technology Employment at 25 Largest Hi-Tech Firms, Selected Metropolitan Areas, 1997-98.

Ranking	Metropolitan Area	Employment at Top 25
1	San Jose	95,221
2	Boston	61,037
3	Austin	47,389
4	Phoenix	45,313
5	Atlanta	40,549
6	Minneapolis	38,724
7	Portland	37,610
8	San Diego	32,676
9	Raleigh-Durham	24,568
10	Seattle	24,169
11	Salt Lake City	23,700
12	Sacramento	23,076
NR	Denver	Not available

Source: Authors' Calculations. See Text.
Comparable data not available for the Denver Metropolitan Area.

Beyond comparing the overall size of high technology production complexes, it is useful to examine their relative concentrations in particular industry segments. To assess the relative specializations of each metro area, we computed location quotients for each of the high technology industry sectors included in the study. The results, for 1996, based on County Business Patterns data, are shown in **Table 7**.

Table 7: Location Quotients for Selected Industry Sectors, 1996 Employment

Sector	Computers	Electronics	Instruments	Software	All
SIC Code	**357**	**36**	**38**	**737**	
San Jose	**10.67**	**5.29**	**3.14**	**2.68**	**4.30**
Austin	**4.08**	**4.27**	0.96	1.62	**2.69**
Raleigh-Durham	**16.58**	**2.34**	0.57	1.58	**2.56**
Boston	**1.53**	**1.42**	**2.09**	**2.20**	**1.82**
Minneapolis	**2.74**	1.06	2.63	**1.60**	**1.67**
Portland	**4.87**	**1.43**	**1.45**	1.03	**1.51**
San Diego	**2.44**	1.18	2.11	1.27	**1.48**
Seattle	1.16	0.58	**2.68**	**1.47**	1.35
Phoenix	0.37	**1.76**	**1.51**	0.78	1.30
Salt Lake	**2.05**	0.53	**2.56**	1.07	1.22
Atlanta	0.71	0.62	0.69	**2.10**	1.13
Denver	0.21	0.29	0.94	**1.90**	0.95
Sacramento	**4.26**	0.29	0.13	0.89	0.69

Source: Authors calculations from County Business Patterns data.
Highest location quotients (greater than 1.4) shown in **bold.**

While all of the region's shown have a significant location quotient (2.0 or greater) for at least one of the industry sectors, only the San Jose area shows this high level of specialization in all of the subject industry sectors. The typical metro area in our sample is unusually strong in one or two aspects of high technology, and is relatively under-represented (i.e. location quotient of less than one) in several others.

Leading sectors vary substantially from area to area: computers are the most prominent specialization in San Jose, Raleigh, Portland and Sacramento; electronics are most prominent in Phoenix, and Austin, instruments are the leading sector in Salt Lake, and Seattle, Seattle, and software is the leader in Atlanta Denver and Boston.

Data on the average overall high technology location quotient for the metropolitan areas confirms the common perceptions about the nation's high tech centers. San Jose shows up with the highest location quotient, followed by two relatively small (fewer than 1 million workers) metropolitan areas Austin and Raleigh Durham. Boston, Minneapolis and Portland have the next highest overall high tech location quotients.

We have some reason to question the precision of estimates based on the County Business Pattern data. Because they are reported at the county level, data are often subject to significant suppression for smaller counties and those with a single large employer. Data for the Portland metropolitan area estimate about 40,000 high technology employees for 1996, comparable state covered employment data suggest a total of approximately 60,000 employees.

C. Patent Intensity

One rough measure of the innovative activity in a metropolitan area is the number of patents awarded to firms, individuals and research institutions. Table 8 shows the total number of patents issued in each of our subject metropolitan areas in 1990 and 1997. We have also computed the growth rate in the total number of patents between 1990 and 1997 and the number of patents per ten thousand manufacturing employees in 1997 (the year 1997 was selected because it was the latest year for which manufacturing employment data were available from the Bureau of Economic Analysis for each of these areas).

Collectively, patent activity in the subject metro areas is dramatically greater than elsewhere, and is increasing much more rapidly. Overall, the average rate of patenting in our selected metropolitan areas is about twice as high (per manufacturing employee) than it is for the entire metropolitan population of the United States. Manufacturing employment seems like a plausible factor for adjusting gross patent counts because a large fraction of patents are issued for technologies used to manufacture goods, and the largest patentees in almost every metropolitan area are manufacturing firms. Metro areas as a whole average about 38 patents per ten thousand manufacturing workers annually and our subject metro areas averaged more than 70 patents per ten thousand workers. Patent activity is also growing faster in these 13 areas than in all of the metro U.S.: 11 percent annually versus about 7 percent annually.

Among the thirteen metro areas we studied, patent rates varied by a factor of four, from about 120 patents per ten thousand manufacturing workers in San Jose to about 30 patents per ten thousand manufacturing workers in Atlanta. Patent rates in all of our studied areas were appreciably higher than the average for all metropolitan areas, and the rate of increase between 1990 and 1997 was faster than for the nation's metro areas in all areas except Denver.

Table 8: Total Patents Issued and Patent Intensity, Selected Metropolitan Areas, 1997.

Metropolitan Area	1990	1997	Growth, 1990-97	Patent Rate
San Jose	1,295	4,931	16.7%	121.7
Austin	354	1,440	17.5%	110.9
San Diego	761	1,673	9.8%	92.6
Raleigh-Durham	233	828	15.8%	59.7
Boston	2,051	3,687	7.3%	57.6
Minneapolis	1,154	2,051	7.2%	54.9
Salt Lake City	236	472	8.7%	50.1
Phoenix	493	1,182	10.9%	47.4
Sacramento	121	289	10.9%	45.4
Denver	346	581	6.5%	44.0
Seattle	573	1,275	10.0%	42.0
Portland	384	948	11.3%	41.3
Atlanta	461	1,034	10.1%	32.7
These 13 Metropolitan Areas	8,462	20,391	11.0%	70.1
Totals for All US Metro Areas	43,637	74,714	6.7%	38.2

Source: U.S. Patent & Trademark Office, 1999
Note: Patent rate is 1997 utility patents issued per 10,000 manufacturing employees.

To assess the relative knowledge creation strengths of each of the metropolitan areas examined, we computed location quotients for the most common high technology and biotechnology patent classifications. Location quotients are an indication of the relative specialization in a particular technology in a given metropolitan area.

The six selected patent classes shown in **Table 9** represent a total of 34,500 patents, or more than ten percent of all of the patents issued in the United States between 1994 and 1998. These more common patent classifications were chosen to minimize the variation in location quotients due solely to the detailed nature of the patent classification system (unlike the SIC code system for classifying industries, the patent classification system does not have a rigid, nested hierarchy for aggregating classifications into larger groupings). Presenting location quotients for each of the 408 patent classifications is roughly the equivalent of computing location quotients at the four-digit SIC code level.

Table 9: Location Quotients for Selected Technologies, 1994-98 Patents

Technology	Electronics and Software Technologies				Biomedical Technologies	
Class	Class 345	Class 364	Class 395	Class 438	Class 435	Class 514
Class Description	Computer Graphics Processing *	Electrical Computers and Data Processing	Information Processing System Organization	Semiconductor Device Manufacturing: Process	Chemistry: Molecular Biology and Microbiology	Drug, Bio-Affecting and Body Treating Compositions
Atlanta	0.49	0.43	0.35	0.12	0.76	0.54
Austin	**4.12**	**4.49**	**7.61**	**6.30**	0.26	0.16
Boston	1.17	0.91	**1.79**	0.50	**2.30**	1.25
Denver	0.38	0.65	0.57	0.69	0.95	0.58
Minneapolis	0.30	0.88	0.54	0.26	0.44	0.23
Phoenix	1.49	**1.84**	1.44	4.52	0.06	0.20
Portland	**3.89**	**2.20**	**4.91**	1.20	0.53	0.21
Raleigh Durham	**1.70**	1.44	**2.01**	0.74	**3.17**	**2.09**
Sacramento	0.46	1.00	**3.42**	0.40	0.24	0.23
Salt Lake	1.28	0.48	0.30	0.00	1.15	0.67
San Diego	1.10	0.81	0.56	0.47	**3.45**	**1.91**
San Jose	**3.40**	**3.22**	**3.58**	**3.78**	0.79	0.39
Seattle	**4.45**	0.94	**2.33**	0.06	**2.21**	1.01

Source: Authors calculations, U.S. Patent and Trademark Office, 1999
Location Quotients greater than 1.5 shown in **bold**.
* - Complete Class description is Computer Graphics Processing Operator Interface Processing, and Selective Visual Display Systems.

The data show considerable variation in the technological specializations of each of the metropolitan areas. Except for San Jose, none of the metro areas show strong specializations (location quotients in excess of 1.5) in all four of the electronics and software related technologies. The areas that are strongest in these technologies (San Jose, Phoenix, Portland and Austin) tend to be relatively least specialized in biomedical technologies. Conversely, the areas with the most emphasis on biotechnology (Raleigh Durham, San Diego, Boston and Seattle) have fewer strong specializations in electronics. Atlanta, Denver and Minneapolis have no significant specializations in these particular technologies, even though they have significant high technology employment.

D. Headquarters Locations

One important indicator of the nature of business activities in particular metropolitan areas is the concentration of locally headquartered firms. In many cases important strategic, resource allocation, research and development, and other decisions are made in primarily corporate headquarters.

To get an idea of the corporate structure of the metropolitan areas in our study, we identified the headquarters location of the ten largest high technology firms in each region. Table 10 summarizes our analysis. The largest high tech employers in the metropolitan area we examined had a mix of locally-headquartered firms, firms with headquarters in other states (particularly in Silicon Valley), and a few foreign-headquartered firms. Among the metropolitan areas considered in our analysis, San Jose has the largest concentration of headquarters firms—all of the ten largest high tech firms in Silicon Valley were headquartered there. A majority of the ten largest high tech firms in Seattle, Boston and San Diego were also locally headquartered there. Half or fewer of the largest high tech firms in the remaining metro areas were locally headquartered.

Table 10: Headquarters Location of Ten Largest High Tech Firms, Selected Metropolitan Areas, 1997.

Metropolitan Area	Headquarters Location			
	Local	San Jose	Other US	Outside US
San Jose	10	10	0	0
Minneapolis	8	1	1	0
Seattle	8	1	1	0
Boston	7	1	1	1
San Diego	6	1	1	2
Salt Lake City	5	2	2	1
Portland	4	2	1	3
Austin	3	3	4	0
Phoenix	3	3	4	0
Atlanta	3	2	4	1
Raleigh-Durham	2	1	7	0
Sacramento	2	5	1	2
Denver	Not available			

Source: Authors calculations, see text. Data sorted by number of locally headquartered firms among the top ten high tech employers.

A handful of large firms, among the world's most important producers of computers, semiconductors, instruments and communications equipment appear again and again among the lists of the ten largest high tech firms in the metropolitan areas we studied.

Table 11: Largest High Tech Firms and Those Most Frequently Appearing Among the Ten Largest High Tech Employers, Selected Metropolitan Areas, 1997.

Metro Area	Largest Firm	Hewlett-Packard	IBM	Intel	Motorola	Lucent
Atlanta	Lucent	4	2			1
Austin	Dell		3		2	3
Boston	Raytheon	6	4*			
Denver			Not available			
Minneapolis	Honeywell					
Phoenix	Motorola			2	1	6
Portland	Intel	4	3*	1		
RTP	IBM		1		7	
Sacramento	Hewlett Packard	1		2		
Salt Lake	Novell					
San Diego	Qualcomm	4				
San Jose	Hewlett Packard	1		2		
Seattle	Microsoft	6				

Note: Numbers in each column correspond to each company's rank among the ten largest high tech employers in each metropolitan area. For example, Hewlett Packard is the fourth largest high tech employer in Atlanta, 6^{th} largest in Boston, and so on. * - Lotus Development Corporation (Boston) and Sequent Computer (Portland), both acquired by IBM, are counted as IBM subsidiaries in this table.
Source: Authors' calculations, see text.

Table 11 shows how the local operations of each of these firms ranked among the ten largest high tech areas in each of our metropolitan areas. Hewlett Packard is one of the ten largest high tech firms in seven of the thirteen areas we examined. IBM's far-flung operations appear in five metro areas, Intel in four and Motorola and Lucent in three each. This picture will undoubtedly change in the years ahead, as high tech firms reorganize their operations. In 1999, Hewlett-Packard began splitting its operations into two companies, one retaining the historic name, the second called Agilent Technologies; our data reflect the historic combination of its activities under the single corporate entity.

E. Venture Capital Investments

A key factor fueling the growth of high technology industries in the United States has been the availability of venture capital for new start-up firms. While the standard economic assumption is that financial capital is extremely mobile, following easily from one place to another, especially within a national economy, the practical experience with venture capital indicates that capital flows are often highly localized, with venture capital funds focusing most of their investments in nearby firms and in a relatively narrow range of technologies. Venture capital tends to be localized, because in addition to financial support, venture capital firms typically take an active role in advising and assisting the management of the firms in which they invest: recruiting key personnel, brokering relationships with vendors, technology partners, other sources of finance.

Venture capital investments are highly concentrated in a relatively few metropolitan areas. According to one study, more than 60 percent of all venture capital flowed to just five metropolitan areas—San Francisco, Boston, New York, Los Angeles and Washington D.C.(Zook, 1999). Data for the metropolitan areas in our analysis (where reported) is shown in Table 12. Data for five metropolitan areas was not shown separately in Zook's analysis of the venture capital investment data (their cumulative levels of investment over the time period in the study did not place them among the top 13 regions receiving venture capital in the nation).

Table 12: Venture Capital Investments, 1994 to 1999

REGION	Count of Investments	Percent of Total
San Jose	1,518	15.2%
Boston	1,048	10.5%
San Diego	326	3.3%
Seattle	283	2.8%
Atlanta	240	2.4%
Minneapolis	215	2.2%
Raleigh-Durham	179	1.8%
Denver	172	1.7%
Austin	168	1.7%
Phoenix	84	0.8%
Portland	78	0.8%
Salt Lake City	45	0.5%
Sacramento	17	0.2%

Source: (Zook, 1999).
Note: Data are total number of venture capital investments between 1994 and 1999 (First quarter).

Like productive activity, venture capital tends to have pronounced regional specializations. Studying the patterns of venture capital investment in the late 1990s, Zook computed location quotients, measures of specialization, for five of the metropolitan areas included in our sample. Venture capital investments are highly concentrated in a relatively few metropolitan areas. A location quotient of 1 implies a region's investments are no more or less concentrated in a particular industry than they are nationally; location quotients greater than 1 indicate higher than average concentration of a particular industry, and location quotients less than one indicate than an industry is less than proportionately found in a given area. According to one study, more than 60 percent of all venture capital flowed to just five metropolitan areas—San Francisco, Boston, New York, Los Angeles and Washington D.C.(Zook, 1999) Data for the metropolitan areas in our analysis (where reported) is shown in Table 12.

Table 13: Location Quotients for Venture Capital Investments in Selected Metropolitan Areas, by Industry Segment, 1996 to 1999.

Industry	San Francisco	Boston	Denver	Seattle	San Diego
Communications	.95	.87	2.04	1.23	.73
Computers & Peripherals	2.01	.40	1.50	.12	.38
Electronics & Instrumentation	1.29	.55	.92	-	1.39
Medical Instruments/Devices	1.08	1.23	.04	.04	5.31
Semiconductors & Equipment	2.61	.85	-	-	-
Software & Information	1.36	1.16	.63	1.33	.49
Biotechnology	.79	1.63	.89	1.25	4.80

Source: (Zook, 1999).
Note: Numbers shown in bold represent industries with a location quotient greater than 1.10, indicating greater relative concentration of in investments in a specific industry than for all venture capital investments nationally over this time period.

III. Profiles of Metropolitan Areas

This section presents our detailed analysis of the high technology industry in each of the 13 subject metropolitan areas. For each area, we examine a common set of statistics and descriptive information, including employment and income data, the list of the ten largest high technology manufacturers, and each region's most prolific non-governmental, non-educational patenting organizations. Where possible, we have supplemented this material with additional descriptions of the history and specializations of each metropolitan area drawn from narrative and journalistic accounts.

Atlanta, Georgia

Atlanta is one of the largest and fastest growing commercial centers in the Southern United States. It is a hub for airline transportation. The region's largest manufacturing employers include defense contractor Martin Marietta, which builds large aircraft in the Atlanta area. The region's aerospace industry is a legacy of government efforts to disperse production of strategic weapons (Combes, n.a.).

Table 14: Key Economic Indicators, Atlanta Metropolitan Area, 1997.

	Atlanta	13 High Tech Metropolitan Areas	All US Metropolitan Areas
Population	3,634,245		
Population Growth	2.8%	1.7%	1.1%
Employment	2,418,795		
Employment Growth	3.5%	2.5%	1.6%
Manufacturing Employment	227,327		
Manufacturing Growth	1.9%	0.5%	-0.4%
Per Capita Income	28,253	$ 28,921	$ 26,840
(Percent of Metro Average)	105.3%	108%	100%
Per Capita Income Growth	4.4%	4.4%	4.0%
Median Housing Price	126,100		

Sources: Bureau of Economic Analysis, Regional Economic Information System, except Median Housing Price, National Association of Home Builders

Atlanta's major high technology firms hare highly concentrated in telecommunications and computer services, including database operations. The region's largest high tech employer is telecommunications equipment maker Lucent Technologies. Metropolitan Atlanta is also headquarters for many of the nation's largest paper producers including Georgia Pacific. Two Atlanta-based companies, Mindspring and Earthlink, recently merged to form the nation's second-largest Internet Service Provider. Virginia-based America Online (AOL) is the largest. The region is also home to a number of important research institutions, including the federal Centers for Disease Control. Georgia Tech and Emory University together have a research budget approaching $500 million per year.

Table 15: Major High Technology Firms, Atlanta Metropolitan Area, 1997.

Rank	Firm	Employment	Products	Headquarters
1	Lucent Technologies	7,300	Telecommunication	Murray Hill, NJ
2	IBM Corp.	7,166	Computers and computer services	Armonk, NY
3	Scientific-Atlanta Inc.	3,200	Telecommunication	Norcross, GA
4	Hewlett-Packard Co.	3,000	Computers and computer services	Palo Alto, CA
5	Equifax Inc.	2,780	Information solutions	Atlanta, GA
6	First Data Corp.	2,090	Computer services	Paramus, NJ
7	Worldspan L.P.	1,800	Computer services	Atlanta, GA
8	Nortel Networks	1,700	Telecommunication	Canada
9	HBO & Co	1,650	Software companies	San Francisco, CA
10	Electronic Data Systems	1,600	Information technology	Plano, TX

Source: (Atlanta Business Chronicle, 1998)

Patent data shows two strong specializations in the region's commercial research: paper and electronics, especially communications. The region's most prolific patenter is paper maker Kimberly Clark. Half of the region's ten largest patenting firms produce electronics and communications equipment including Motorola, Lucent, and NCR.

Table 16: Patents Granted to High Technology Firms, Atlanta Metropolitan Area, 1994-98.

Rank	Firm	Industry	Patents Issued
1	Kimberly-Clark Corporation	Paper	293
2	Riverwood International Corporation	Other	122
3	Scientific-Atlanta, Inc.	Electronics/Software	112
4	Motorola, Inc.	Electronics/Software	81
5	Lucent Technologies Inc.	Electronics/Software	76
6	Bellsouth Corporation	Electronics/Software	61
7	NCR Corporation	Electronics/Software	60
8	Mead Corporation	Paper	55
9	Nordson Corporation	Other	54
10	Coca Cola	Food Processing	52

Source: US Patent and Trademark Office, 1999

Austin, Texas

Austin, Texas is one of the fastest growing centers for high technology manufacturing in the United States. Although it is a relatively small area, with a metropolitan population of less than one million until the 1990s, the region has seen an extraordinary economic transformation in the past two decades. Traditionally a government center (the capital of Texas) and a university town, the region is now home to a significant concentration of computer, semiconductor and software producers (Miller, 1999).

High technology firms in Austin trace their roots to Tracor, an engineering services firm started by a professor teaching at the University of Texas (Oden, 1997). In the 1970s and 1980s, the region attracted a number of important branch plants, including both IBM and Motorola. IBM initially started assembling electric typewriters, but in the 1980s, it became a major center for personal computer construction. Motorola designs and builds semiconductor devices, including microprocessors in Austin. Local leaders and university officials campaigned to make Austin the home of two major research institutions the Microelectronics and Computer Technology Corporation, and Sematech a government and industry funded joint research entity to restore US technological superiority in semiconductor production. Austin added to these firm's technical capabilities, with homegrown Dell Computer (now the region's largest employer), Advanced Micro Devices construction of a major design facility.

Austin's high tech boom of the 1990s has made the region one of the nation's fastest growing metropolitan areas, with employment growth averaging nearly 5 percent per year. Manufacturing employment has increased more than 6 percent per year, but per capita income remains below the average for all US metro areas.

Table 17: Key Economic Indicators, Austin Metropolitan Area, 1997.

	Austin	13 High Tech Metropolitan Areas	All US Metropolitan Areas
Population	1,069,755		
Population Growth	3.3%	1.7%	1.1%
Employment	726,712		
Employment Growth	4.9%	2.5%	1.6%
Manufacturing Employment	80,067		
Manufacturing Growth	6.2%	0.5%	-0.4%
Per Capita Income	25,420	$ 28,921	$ 26,840
(Percent of Metro Average)	94.7%	108%	100%
Per Capita Income Growth	5.3%	4.4%	4.0%
Median Housing Price	128,900		

Sources: Bureau of Economic Analysis, Regional Economic Information System, except Median Housing Price, National Association of Home Builders

Austin's strengths are in computers, semiconductors and semiconductor manufacturing equipment. Dell Computer and IBM have major facilities for manufacturing personal computers in the Austin area. Motorola and Advanced Micro Devices design and build sophisticated semiconductors, including microprocessors (such as AMD's K6 and Athlon processors). Two leading Silicon Valley semiconductor manufacturing equipment firms (Applied Materials and Solectron) have established facilities in Austin. In addition, the area is home to hundreds of small software firms, mostly small startups.

Table 18: Major High Technology Firms, Austin Metropolitan Area, 1997.

Rank	Firm	Employment	Products	Headquarters
1	Dell Computer Corp.	11,000	Personal Computers	Round Rock, TX
2	Motorola Semiconductor	10,500	Semiconductors	Schaumburg, IL
3	IBM Corp.	7,500	Computers	Armonk, NY
4	Advanced Micro Devices	3,500	Semiconductors	Santa Clara, CA
5	Applied Materials	3,149	Semiconductor Process Equipment	Santa Clara, CA
6	3M	1,800	R&D for telecommunication and electronics applications	Saint Paul, MN
7	Solectron Texas	1,470	Semiconductor Process Equipment	Milpitas, CA
8	Tivoli Systems	1,150	Software developers	Austin, TX
9	National Instruments	1,007	Instruments	Austin, TX
10	EDS Inc.	830	Data Processing	Plano, TX

Source: (Austin Business Journal, 1999)

Austin ranks second after Silicon Valley in patent intensity, measured as the number of patents per ten thousand manufacturing workers. Nearly all of the region's largest patenting organizations are closely related to the production of computers and semiconductors as Table 19 illustrates.

Table 19: Patents Granted to High Technology Firms, Austin Metropolitan Area, 1994-98.

Rank	Firm	Industry	Patents Issued
1	International Business Machines Corporation	Electronics/Software	920
2	Motorola, Inc.	Electronics/Software	861
3	Advanced Micro Devices, Inc.	Electronics/Software	648
4	Dell USA, L.P.	Electronics/Software	360
5	Minnesota Mining And Manufacturing Company	Electronics/Software	145
6	National Instruments Corporation	Electronics/Software	55
7	Microelectronics And Computer Technology Corp.	Electronics/Software	54
8	Crystal Semiconductor Corporation	Electronics/Software	48
9	Staktek Corporation	Electronics/Software	39
10	Texas Instruments, Incorporated	Electronics/Software	32

Source: US Patent and Trademark Office,
Note: Rank is rank among all organizations receiving patents in the metropolitan area, including individuals, educational institutions, and non-high technology firms.

Boston, Massachusetts

High technology manufacturing has a longstanding tradition in the greater Boston area. Already in the nineteenth century, Massachusetts was a center for industrialization in areas such as textile, armaments and machine tools. This development was followed by advances in electronics activity in the first decades of the twentieth (Saxenian, 1994). The growth in high technology manufacturing was not only fueled by a number of industry-oriented research and education institutions such as MIT but also by a sustaining flow of private and federal funding of research in electronics (Saxenian, 1994). Although the region has gone through several phases of decline in manufacturing and hence employment in high technology, the area still maintains an important position as a high technology region widely known as 'Route 128'. The region specializes in computers, medical devices and in software.

Table 20: Key Economic Indicators, Boston Metropolitan Area, 1997.

	Boston, MA	13 High Tech Metropolitan Areas	All US Metropolitan Areas
Population	5,826,816		
Population Growth	0.3%	1.7%	1.1%
Employment	3,794,933		
Employment Growth	1.2%	2.5%	1.6%
Manufacturing Employment	476,980		
Manufacturing Growth	-1.6%	0.5%	-0.4%
Per Capita Income	$ 31,808	$ 28,921	$ 26,840
(Percent of Metro Average)	119%	108%	100%
Per Capita Income Growth	4.3%	4.4%	4.0%
Median Housing Price	$ 232,100		

Sources: Bureau of Economic Analysis, Regional Economic Information System, except Median Housing Price, National Association of Home Builders

Among the biggest firms in the region is Raytheon. Located in Lexington, Raytheon is tied to the longstanding tradition of high technology innovation in the Boston area. Founded by MIT electrical engineering professor Vannevar Bush, the company started out as 'American Appliance Company'. The name was changed in 1925 "after acquiring the rights to a new kind of vacuum tube that would permit radios to run on household current" (Saxenian, 1994). In the Second World War, and thereafter, Raytheon was a major defense contractor, which it continues to be today. As a growing company Raytheon was also the source for over a hundred start-up companies in the region (Saxenian, 1994). Today, Raytheon's core business segments are defense and commercial electronics, business aviation and special mission aircraft, and engineering and construction (Raytheon, 1999). Raytheon's founder Vannevar Bush played an important role in attracting military spending to the Boston region. He was head of the Office of Scientific Research and Development and he made MIT (and to a lesser extent, Harvard) the educational linchpin of high technology.

Boston was the principal center for the growth of the minicomputer industry, the initial set of competitors to large mainframe computers. Basic research in that field had already began in the 1950s at MIT' Lincoln Laboratory. MIT graduate Ken Olsen started the company Digital Equipment Corporation (DEC) in 1957 in the middle of a time where exciting research around the minicomputer took place in the nearby laboratories and firms. By 1977, DEC led the market with 41% of worldwide minicomputer sales (Saxenian, 1994). DEC continues to be the leading patentee in the region with over 660 patents in the period of 1994 until 1998. Several other minicomputer companies flourished in the region during the 1970s, including Wang and DataGeneral. But Boston

Area minicomputer makers fundamentally missed the shift to personal computers. In 1998, DEC, the region's historic leader, was sold to PC maker Compaq.

The historical technology trajectory of the Boston region is closely tight to the technological needs during the wars in the 20th century and thus, it can be concluded that federal defense spending was a key factor behind the region's high technology boom (Warsh, 1986). Warsh (1986) characterizes New England as the center for the development of military command and control technology. Significant developments in the "strands of radio, radar, sonar, engines, missiles, instrumentation, telemetry, and satellite photography" (Warsh, 1986, p. 315) took place in this area.

Table 21: Major High Technology Firms, Boston Metropolitan Area, 1997.

Rank	Firm	Employment	Products	Headquarters
1	Raytheon Co.	15,400	Defense, Electronics	Lexington, MA
2	Compaq Computer Corp.	8,000	Computers	Houston, TX
3	Lucent Technologies Inc.	5,600	Telecommunication Equipment	Concord, MA
4	Lotus Development Corp.	4,050	Software	Cambridge, MA
5	EMC Corp.	3,600	Software	Hopkinton, MA
6	Hewlett-Packard Medical Products Group	2,800	Medical Equipment	Santa Clara, CA
7	Analog Devices Inc.	2,600	Semiconductors	Norwood, MA
8	Siebe Intelligent Automation	2,500	Software	England
9	Teradyne Inc.	1,800	Largest high tech manufacturers	Boston, MA
10	Medical Information Technologies	1,800	Software	Westwood, MA

Source: (Boston Business Journal, 1999)

In recent years, the greater Boston area has become increasingly a place for healthcare technology, specifically medical devices. Hewlett-Packard is among the largest firms in that field employing around 2,800 people. Firms in this field are also active in patenting. General Hospital Corporation and Genetics Institute Inc. are among the top ten patenting firms. A number of research institutions that are in geographic proximity to the firms in this field might be important since they are the locations for scientific research (Collaborative Economics, 1999).

Although the region around Boston accounts for almost 3,700 patents in 1997, the region experienced decline in patent activity in the period from 1990 to 1997 (see table 7). Thus the patent rate for these years is not as high as for instance in the Silicon Valley or in the Austin region. Nevertheless, Boston is an important area for innovations especially in the electronics sector.

Table 22: Patents Granted to High Technology Firms, Boston Metropolitan Area, 1994-98.

Rank	Firm	Industry	Patents Issued
1	Digital Equipment Corporation	Electronics/Software	668
2	Polaroid Corporation	Electronics/Software	266
3	General Hospital Corporation	Biomedical	175
4	Analog Devices, Inc.	Electronics/Software	169
5	Raytheon Company	Electronics/Software	109
6	Hewlett-Packard Company	Electronics/Software	101
7	Genetics Institute, Inc.	Biomedical	96
8	Davidson Textron Inc.	Electronics/Software	96
9	Boston Scientific Corporation	Electronics/Software	92
10	Charles Stark Draper Laboratory, Inc.	Other	91

Source: US Patent and Trademark Office, 1999

Denver, Colorado

The Denver-Boulder Metropolitan Area has traditionally been a center for mining, oil, gas and agriculture, as well as a major transportation hub and financial as well as educational center for the Rocky Mountain West. During the decade of the 1990s, Denver has grown relatively rapidly, with population and job growth both outpacing the averages for our 13 metropolitan areas. The region's manufacturing job growth, however, has been virtually nil during the 1990s.

Denver's chief high technology strengths are in telecommunications, and computer storage. Colorado Springs, an area about 100 miles south of Denver, and not included in this study, is also recognized as having a concentration of electronics firms, chiefly branch plants of computer and semiconductor manufacturers, including Apple, Digital Equipment, Hewlett Packard and Atmel (Gray & Markusen, 1999).

Table 23: Key Economic Indicators, Denver Metropolitan Area, 1997.

	Denver	13 High Tech Metropolitan Areas	All US Metropolitan Areas
Population	1,901,927		
Population Growth	2.2%	1.7%	1.1%
Employment	1,359,022		
Employment Growth	3.3%	2.5%	1.6%
Manufacturing Employment	98,965		
Manufacturing Growth	0.0%	0.5%	-0.4%
Per Capita Income	30,743	$ 28,921	$ 26,840
(Percent of Metro Average)	114.5%	108%	100%
Per Capita Income Growth	5.0%	4.4%	4.0%
Median Housing Price	169,000		

Sources: Bureau of Economic Analysis, Regional Economic Information System, except Median Housing Price, National Association of Home Builders

Denver is home to strong concentrations of telecommunications companies (including equipment providers, cable companies and others). The region has served as the headquarters for Baby Bell US West (recently purchased by Qwest, another Denver-based telecommunications firm). Lucent, and AT&T Corporation have substantial operations in Colorado, as to a number of satellite builders and operators and cable television firms (the bulk of employment in these firms is classified in non-manufacturing SIC codes, and is not part of our high technology definition).

Table 24: Major Telecommunications Firms, Denver Metropolitan Area, 1997.

Rank	Firm	Employment	Segment	Headquarters
1	US West Inc.	13,264		Englewood, CO
2	TeleTech Holdings Inc.	7,600	Telecommunications	Denver, CO
3	Lucent Technologies	7,000	Telecommunications	Murray Hills, NJ
4	Tele-Communications Inc.	3,000	Cable Provider	Denver, CO
5	AT&T	3,000	Telecommunications	New York, NY
6	MCI Communications Corp	2,300	Telecommunications	Washington D.C.
7	Ball Aerospace & Technologies	2,200	Satellite Communication	Muncie, Ind.
8	Qwest Communications Inc.	1,500	Telecommunications	Denver, CO
9	ICG Communications Inc.	1,300	Telecommunications	Englewood, CO
10	Primestar Inc.	1,000	Satellite Television	Englewood, CO

Source: Denver Business Journal
Note: Data for Denver firms is not directly comparable to high tech firm listings for other metropolitan areas. These data are for telecommunications firms only.

To supplement the listing of Denver area telecommunications firms provided by the Denver Business Journal, we also examined the statewide employment totals for major Colorado firms produced by the Colorado Office of Business Development (Table 25). This data confirms the importance of high technology and illustrates some of the region's other specializations. Hewlett Packard has several facilities in Colorado (Dave Packard grew up in Colorado; and also purchased Colorado Memory Systems, a tape drive manufacturers in the early 1990s).

Table 25: Leading Colorado Technology and Telecommunications Firms, 1997

Rank	Firm	Sector	Employment
1	US West	Telecommunications	16,000
8	AT&T	Telecommunications	8,000
9	Hewlett Packard	Computer Systems	8,000
10	Lockheed Martin	Aerospace	7,924
11	TeleTech Holdings	Customer Service	7,600
12	MCI Communications	Telecommunications.	6,000
13	Lucent Tech., Inc.	Telecom Equipment.	5,650
19	Storage Technology	Computing Storage	3,317
22	TeleCommunications, Inc.	Telecommunications/cable	3,000
23	IBM	Data Processing	2,900
27	Ball Aerospace & Tech.	Aerospace	2,068
28	COBE Laboratories	Medical Equip	2,000

Source: Colorado Office of Business Development. Note: These data are not comparable to similar tables for other metropolitan areas. Statewide employment is shown. Rank is rank among largest private employers in the State of Colorado. Data for telecommunications firms include all employment, including local service provision.

Denver is a national center for the cable television industry. The industry started in Denver in the 1960s by entrepreneur Bill Daniels; most of the region's current cable firms can be linked back to the one he founded (Intermountain Partners, 1997). Denver is home to a cooperative industry funded research and development venture, CableLabs. In the past year, however, corporate takeovers — like AT&T's purchase of Telecommunications International (TCI) — have resulted in the headquarters of many formerly Denver-based firms being shifted to other locations (Olgeirson, 1999).

Denver has long been a major center for the production of magnetic-tape data storage devices, which began with an IBM facility established in Boulder in the 1960s. "The Denver region dominates the tape storage market and serves as a center for research and product development for many world leaders […] Denver region leaders in this group include StorageTek, Exabyte, Breece Hill, McData and other companies. The genealogy and start-up capital can be traced to the IBM magnetic tape storage facility in Denver. Though IBM's focus has broadened beyond storage, its impact is still being felt through a concentration in Denver of innovative global leaders in computer storage and peripherals." (Taratec Corporation, 1998)

Patent data underscore Denver's principal industries including telecommunications (US West, AT&T), computer storage (Storage Tek) and petrochemicals.

Table 26: Patents Granted to High Technology Firms, Denver Metropolitan Area, 1994-98.

Rank	Firm	Industry	Patents Issued
1	Cobe Laboratories, Inc.	Bio Medical	69
2	Storage Technology Corporation	Electronics/Software	46
3	AT&T Corp.	Electronics/Software	37
4	Marathon Oil Company	Petrochemical	37
5	Schuller International, Inc.	Other	30
6	Coors Brewing Company	Other	25
7	Lucent Technologies Inc.	Electronics/Software	25
8	Telectronics Pacing Systems, Inc.	Electronics/Software	23
9	U.S. West Inc.	Electronics/Software	20
10	Cortech, Inc.	Electronics/Software	17

Source: US Patent and Trademark Office, 1999

Minneapolis/St. Paul, Minnesota

Minneapolis/St. Paul is one of the larger metropolitan areas in our group of 13, with nearly 3 million residents. It is growing somewhat more slowly than the other high technology areas we examined (population growth of 1.3% per year during the 1990s, compared with 1.7% for our sample. Per capita income in this region is substantially (12 percent) above the average for all U.S. metro areas.

The Twin Cities are a major regional center for finance, education and government. Historically a center for the Midwest's agricultural industries, the region has a diverse array of manufacturing industries including Minnesota Mining & Manufacturing (3M) and a significant agglomeration of printing firms.

Table 27: Key Economic Indicators, Minneapolis- St. Paul Metropolitan Area, 1997.

	Minneapolis-St. Paul	13 High Tech Metropolitan Areas	All US Metropolitan Areas
Population	2,794,939		
Population Growth	1.3%	1.7%	1.1%
Employment	1,995,778		
Employment Growth	2.3%	2.5%	1.6%
Manufacturing Employment	287,625		
Manufacturing Growth	0.8%	0.5%	-0.4%
Per Capita Income	30,123	$ 28,921	$ 26,840
(Percent of Metro Average)	112.2%	108%	100%
Per Capita Income Growth	4.4%	4.4%	4.0%
Median Housing Price	136,700		

Sources: Bureau of Economic Analysis, Regional Economic Information System, except Median Housing Price, National Association of Home Builders

Minneapolis/St. Paul was one of the nation's early centers for computers and data processing. Several of the nation's largest computer manufacturers, including Sperry, and Burroughs, and Control Data Corporation as well as Cray Computer were all founded in the Twin Cities. The region's computer industry fell victim to the growth of personal computers that undercut the market for the mainframes, minicomputers and supercomputers. Between 1992 and 1997, computer employment in the metropolitan area declined 8,900 jobs—about 43 percent (Graham, 1998). Sperry and Burroughs merged into a downsizing Unisys, Control Data has downsized and divested many of its operations, and Cray has been purchased by Silicon Valley's Sun Microsystems (Munnich, 1995).

Another key element of high technology in Minnesota is the region's medical device cluster known as 'Medical Alley' consisting of more than 200 firms and 10,000 employees, highly specialized in cardiovascular, urological and imaging/diagnostic products. Leading firms in this region include Medtronics, and portions of 3M (Lawson & Lorenz, 1999).

The creation of new, locally based firms has played a key role in the both the computer and medical device industry clusters in the Twin Cities. Most of the region's computer firms trace their origins to an early computer builder called Engineering Research Associates, which was founded in St. Paul in 1946. Similarly, many medical device manufacturers are spin-offs from Medtronic, a firm built around Earl Bakken's invention of the first battery operated heart pacemaker in 1957, and still the region's largest medical device maker (Munnich, 1995).

Table 28: Major High Technology Firms, Minneapolis-St. Paul Metropolitan Area, 1997.

Rank	Firm	Employment	Segment	Headquarters
1	Honeywell	7,500	Instruments, Controls	Minneapolis
2	IBM	6,000	Computers	Armonk, NY
3	Hutchinson Technology	4,159	Suspension assemblies for rigid disk drives	Hutchinson, MN
4	Seagate Technology	4,000	Data storage	Santa Clara, CA
5	Ceridian Corporation	2,200	Information services and defense electronics	Minneapolis, MN
6	Imation Corporation	2,000	Data storage and imaging	Minneapolis, MN
7	Lawson Software	1,169	Management Software	St. Paul, MN
8	MTS Systems Corporation	950	Instruments	Minneapolis, MN
9	DataCard Corporation	900	Card personalization systems	Minnetonka, MN
10	National Computer Systems	800	Optical-mark readers	Eden Prairie, MN

Source: (Minnesota Department of Trade and Economic Development, 1999)

The 3M company (Minnesota Mining and Manufacturing) has long been recognized as one of the nation's leading innovators. It accounts for more patents than the next 10 most prolific Minneapolis area patentees combined over the past five years. The region's strengths in computers (Honeywell, Unisys, Seagate) and medical devices (Medtronic, Angeion) show up clearly in the data.

Table 29: Patents Granted to High Technology Firms, Minneapolis Metropolitan Area, 1994-98.

Rank	Firm	Industry	Patents Issued
1	Minnesota Mining And Manufacturing Company	Varied	2106
2	Medtronic Inc.	Medical Technology	362
3	Honeywell Inc.	Electronics/Software	301
4	Sci-Med Life Systems, Inc.	Medical Technology	169
5	Unisys Corporation	Electronics/Software	149
6	Seagate Technology	Electronics/Software	124
7	Angeion Corporation	Medical Technology	89
8	Ecolab Inc.	Other	85
9	Pillsbury Company	Other	74
10	Rosemount Inc.	Other	71

Source: US Patent and Trademark Office, 1999

Phoenix, Arizona

As one of the emerging Sunbelt cities, Phoenix experienced immense growth in employment in the last decades. Among the growth sectors in the Maricopa County is the high technology industry that employs over 54,000 workers.

Table 30: Key Economic Indicators, Phoenix Metropolitan Area, 1997.

	Phoenix	13 High Tech Metropolitan Areas	All US Metropolitan Areas
Population	2,842,030		
Population Growth	3.4%	1.7%	1.1%
Employment	1,705,381		
Employment Growth	4.2%	2.5%	1.6%
Manufacturing Employment	168,393		
Manufacturing Growth	2.0%	0.5%	-0.4%
Per Capita Income	24,137	$ 28,921	$ 26,840
(Percent of Metro Average)	89.9%	108%	100%
Per Capita Income Growth	4.0%	4.4%	4.0%
Median Housing Price	126,100		

Sources: Bureau of Economic Analysis, Regional Economic Information System, except Median Housing Price, National Association of Home Builders

Phoenix high technology industry is specialized in semiconductors. Motorola is the region's largest employer offering more than 20,000 jobs. Motorola's presence in Phoenix can be traced back to the early 1950s (Collaborative Economics, 1999). Today Motorola specializes in wireless infrastructure systems and high performance memory technologies (Business Wire, 2000). Motorola is a prolific innovator, and the largest patentee in Phoenix, garnering more 1,470 patents in the period 1994 to 1998.

The second most important company in the area is Intel. Intel's Phoenix operation employs over 9,000 people producing semiconductors. Overall employment in high technology in Phoenix is concentrated primarily in the five biggest firms each employing over 1,000 people.

Table 31: Major High Technology Firms, Phoenix Metropolitan Area, 1997.

Rank	Firm	Employment		Headquarters
1	Motorola Inc.	20,000	Semiconductors	Schaumburg, IL
2	Intel Corp.	9,275	Semiconductors	Santa Clara, CA
3	Honeywell Inc.	7,500	Electrical Equipment	Minneapolis, MN
4	Continental Circuits Corp.	1,300	Printed Circuit Boards	Phoenix
5	Microchip Technology Inc.	1,118	Semiconductors	Chandler, AZ
6	AG Communication Systems	1,100	Telecommunications	New Jersey (Lucent)
7	Medtronic Micro-Rel	1,000	Medical Instruments	Minneapolis, MN
8	ADFlex Solutions Inc.	753	Electrical Equipment	Chandler, AZ
9	Varian Tempe Electronics Center	650	Electrical Equipment	Palo Alto, CA
10	EF Data Corp.	638	Electrical Equipment	Sunnyvale, CA

Source: (The Phoenix Business Journal, 1999)

Table 32: Patents Granted to High Technology Firms, Phoenix Metropolitan Area, 1994-98.

Rank	Firm	Industry	Patents Issued
1	Motorola, Inc.	Electronics/Software	1471
2	Intel Corporation	Electronics/Software	191
3	VLSI Technology, Inc.	Electronics/Software	148
4	Honeywell Inc.	Electronics/Software	135
5	Allied-Signal Inc.	Electronics/Software	89
6	TRW Inc.	Electronics/Software	81
7	Microchip Technology Incorporated	Electronics/Software	52
8	Bull HN Information Systems Inc.	Electronics/Software	38
9	Litton Systems Inc.	Electronics/Software	32
10	McDonnell Douglas Helicopter Co.	Aerospace	30

Source: US Patent and Trademark Office, 1999

Portland, Oregon

Known as 'Silicon Forest', the Portland region has become a major high technology center in the Pacific Northwest. The Portland high technology agglomeration is composed of more than 2,000 firms that employ over 70,000 people. Over the past years, the area has emerged as a significant center for the production of silicon wafers, research, development and manufacturing of semiconductors as well as related semiconductor measurement equipment (SME) and electronic design automation (EDA). The 'Silicon Forest' also specializes in display technology and printers. Thus, the area is not a random assortment of electronics firms. Rather the region hosts a specific set of firms that follow certain historical technology trajectories.

Table 33: Key Economic Indicators, Portland Metropolitan Area, 1997.

	Portland	13 High Tech Metropolitan Areas	All US Metropolitan Areas
Population	1,789,790		
Population Growth	2.3%	1.7%	1.1%
Employment	1,165,642		
Employment Growth	3.4%	2.5%	1.6%
Manufacturing Employment	155,263		
Manufacturing Growth	2.5%	0.5%	-0.4%
Per Capita Income	27,388	$ 28,921	$ 26,840
(Percent of Metro Average)	102.0%	108%	100%
Per Capita Income Growth	4.8%	4.4%	4.0%
Median Housing Price	163,700		

Sources: Bureau of Economic Analysis, Regional Economic Information System, except Median Housing Price, National Association of Home Builders

A majority of high technology firms in Portland trace their roots back to Tektronix, a company that fundamentally advanced information displays in the form of oscilloscopes and later with graphic computer display terminals. Founded in 1946, the company went through tremendous growth periods that allowed it to recruit and hire an enormous amount of talented engineering specialists and carry through research and development in a variety of areas. The growth period also allowed the company to venture into new technology areas and develop strong research and development skills from which the organization as well as the employees could benefit in their advancement. A dramatic decrease in employment (1980: 23,890; 1999: 7,495) set off rationalization processes that triggered the development of several spin-off companies from Tektronix.

Among the direct or indirect spin-off companies from Tektronix are display technology firms such In Focus that subsequently spun off other companies (Pixelworks, Lightware). Recent technological developments in the display sector include electroluminescent flat panel displays (Planar Systems) liquid crystal display projectors (In Focus, Lightware), customized display circuitry (Pixelworks), and 'heads up' displays for aerospace (Flight Dynamics). Thus, the regional competence in display technology can clearly be traced back to Tektronix and the company's evolution during the past few decades. Today, Tektronix is still among the top ten high technology firms in the region employing more than 5,000 people at several locations. Tektronix is also a major patentee in the area with more than 230 patents in the period of 1994 to 1998.

The Portland area is also a major center for the production of silicon wafers and semiconductors. Silicon wafers are the platform for manufacturing integrated circuits. Firms like Wacker Siltronic, SEH America and Komatsu are located in the area. Due to immense capital intensity in this sector, all these firms are subsidiaries of multinational corporations. Closely related to silicon wafers, is the production of semiconductor chips. Semiconductor manufacturing is another important sector in the region and semiconductor manufacturing firms in the Portland area accounted for more than ten percent of all the semiconductors produced in the United States (Bureau of the Census, 1999). Intel is the region's largest semiconductor producer employing more than 11,000 people in six locations. Oregon is Intel's premier site for inventing and testing new manufacturing technologies. Thus, a nearly half of all Intel's patents (1994-1998: 879 out of 1,816) are issued for research in Oregon.

Table 34: : Major High Technology Firms, Portland Metropolitan Area, 1998.

Rank	Firm	Products	Employment	Headquarters
1	Intel	Semiconductors	11,000	Santa Clara, CA
2	Tektronix	Electronics	5,100	Wilsonville, OR
3	Sequent Computer Systems	Computers	2,500	Beaverton, OR
4	Hewlett-Packard Co	Printers	2,000	Santa Clara, CA
5	Epson Portland Inc	Printers	1,800	Japan
6	SEH America Inc	Wafer Maker	1,800	Japan
7	Wacker Siltronic Corp	Wafer Maker	1,700	Germany
8	Merix Corp	PCB Supplies	1,100	Forest Grove, OR
9	Precision Interconnect	Cable	1,000	New Jersey
10	Planar Systems	Displays	900	Beaverton, OR

Source: Authors calculations from (The Portland Business Journal, 1999) and Quanix Data Services.

Closely related to the production of semiconductors is the segment of electronic design automation (EDA) and semiconductor equipment manufacturing (SME). Firms like Mentor Graphics (a spin-off of Tektronix), Synopsys, ORCAD, and others make software tools to design, refine and virtually test microcircuits and other electronic devices. Additionally, Electro-Scientific Industries (ESI), FEI, Integrated Measurement Systems (IMS), ETEC and Cascade Microtech, all make equipment to produce and/or test semiconductors (EDA). Tektronix also makes a wide range of electrical test and measurement equipment.
The Portland metropolitan area is home to production facilities for three firms that are among the world's leading producers of printers for personal computers: Tektronix produces color laser printers in Wilsonville (an operation recently purchased by Xerox), Epson produces inkjet printers in Hillsboro, and Hewlett Packard produces inkjet printers in Vancouver, WA (though this facility has been scaled back in recent years). The technological trajectory of the printer business – at least in the case of Tektronix – is closely tied to the past technological developments in the display sector; early printers were devices to record information displayed on an oscilloscope that were then captured in a printed version.

Patent data shown in table 35 mirrors the regions high tech specialization. The fact that Intel is the most prolific patentee in the area reflects Intel's emphasis on research and development in its Portland's facilities.

Table 35: Patents Granted to High Technology Firms, Portland Metropolitan Area, 1994-98.

rank	Company	Industry	Patents
1	Intel Corporation	Semiconductors	879
3	Tektronix Inc.	Electronics	233
4	Hewlett-Packard Company	Printers	182
5	Sharp Microelectronic Technology, Inc.	Semiconductors	49
8	In Focus Systems, Inc.	Displays	27
10	A-Dec, Inc.	Instruments	21
11	Seiko Communications Holding NV	Communications	18
13	SEH America, Inc.	Wafer Maker	17
14	Analog Devices, Inc.	Semiconductor	17
15	NEC America, Inc.	Electronics	16

Source: US Patent and Trademark Office, 1999

Raleigh-Durham, North Carolina (Research Triangle Park)

Research Triangle Park in North Carolina is widely mentioned as one of the nation's leading high technology centers. Three nearby cities (Raleigh, Durham, and Chapel Hill) and three higher education institutions constitute this publicly initiated technology park. 'Research Triangle' has become the synonym for a high technology region that was formerly heavily dependent on traditional industries such as tobacco, textile, and furniture. The synonym describes a geographic area in North Carolina that is surrounded by several research universities such as University of North Carolina in Chapel Hill, Duke University in Durham, and North Carolina State University in Raleigh. The area was founded as a research park by North Carolina's Governor Luther Hodges in the mid 1950s to stimulate the state's and region's economy (Herbig & Golden, 1993). As the largest planned research park in the country, the park and its institutions such as the Research Triangle Institute (established in 1959) emphasize pure and applied research. Moreover, "Research Triangle Park has been designed to act as an incubator for high-technology companies, especially in microelectronics and biomedicine/genetic engineering." (Herbig & Golden, 1993, p. 84)

Table 36: Key Economic Indicators, Raleigh-Durham Metropolitan Area, 1997.

	Raleigh-Durham	13 High Tech Metropolitan Areas	All US Metropolitan Areas
Population	1,050,358		
Population Growth	2.8%	1.7%	1.1%
Employment	756,420		
Employment Growth	3.7%	2.5%	1.6%
Manufacturing Employment	88,305		
Manufacturing Growth	1.4%	0.5%	-0.4%
Per Capita Income	27,711	$ 28,921	$ 26,840
(Percent of Metro Average)	103.2%	108%	100%
Per Capita Income Growth	4.8%	4.4%	4.0%
Median Housing Price	162,600		

Sources: Bureau of Economic Analysis, Regional Economic Information System, except Median Housing Price, National Association of Home Builders

In 1965, IBM bought 425 acres of land and opened a plant in 1966. Today the company employs over 13,000 people. IBM assembles personal computers as well as advanced high-end computers. Today, firms in the Triangle specialize in pharmaceuticals and electronics industries and about 33,000 people work in the park (Herbig & Golden, 1993). There are 20 organizations in the area of biotechnology/biopharmaceuticals that employ around 2,000 employees. In the field of microelectronics/software, around 21 organizations employ more than 15,000 employees. Additionally, telecommunications and internetworking as a field contains about 8 organizations with almost 12,000 employees (Research Triangle Park Organization, 1999).

However, some analysts claim that the park has not been as successful in creating new start-up firms. "Its success has been mainly in attracting large established firms" (Herbig

& Golden, 1993, p. 85) as well as R&D branch plants of large corporations (Luger & Goldstein, 1991).

Table 37: Major High Technology Firms, Raleigh-Durham Metropolitan Area, 1997.

Rank	Firm	Products	Employment	Headquarters
1	IBM	Information technology	13,000	Armonk, NY
2	SAS Institute Inc.	Decision software and support	3,100	Cary, NC
3	Commscope Inc.	Electronics	2,700	Hickory, NC
4	EDS Corp.	Data processing and software	1,375	Plano, TX
5	Cisco Systems Inc.	Networking Equipment & Software	600	San Jose, CA
6	Keane Inc.	Software	420	Boston, MA
7	Motorola	Semiconductor manufacturer	400	Schaumburg, IL
8	Data General Corp.	Software	300	Westborough, MA
9	Decision Consultants Inc.	Software	285	Southfield, MI
10	DuPont Electronic Technology Center	Microelectronic components	270	N.R.

Source: (Triangle Business Journal (Raleigh/Durham), 1998)

Organizations in the Research Triangle are very active in patenting and the area ranks fourth behind Silicon Valley, Austin and San Diego in terms of the patent rate.

Table 38: Patents Granted to High Technology Firms, Raleigh-Durham Metropolitan Area, 1994-98.

rank	Company	Industry	Patents
1	International Business Machines Corporation	Information technology	366
2	Ericsson, Inc.	Telecommunications	148
3	Becton, Dickinson And Company	Biotechnology testing and research and development services	135
4	Alcatel Network Systems, Inc.	Telecommunications	50
5	Glaxo Wellcome Inc.	Pharmaceutics ??	49
6	Mitsubishi Semiconductor America, Inc.	Semiconductors	37
7	Square D Company	???	37
8	Lord Corporation	Manufactures coating material	33
9	ABB Power T&D Company Inc.	???	31
10	Kennametal Inc.	Supplies metalworking industry	31

Source: US Patent and Trademark Office, 1999

Sacramento, California

The Sacramento region was long thought to be the eastern extension of San Jose's Silicon Valley, but today it is clear that Sacramento carved out its own niche in high technology manufacturing and is therefore more than just a mere annex to the well-known neighbor. Evidence for this tendency can be found in basic data about employment growth in the manufacturing sector. Manufacturing employment grew 2.6 percent annually between 1990 and 1997 accounted 2.6% indicating a healthy increase. In contrast to Boston or the Silicon Valley,

Table 39: Key Economic Indicators, Sacramento Metropolitan Area, 1997.

	Sacramento, CA	13 High Tech Metropolitan Areas	All US Metropolitan Areas
Population	1,503,900		
Population Growth	1.5%	1.7%	1.1%
Employment	862,315		
Employment Growth	1.7%	2.5%	1.6%
Manufacturing Employment	50,624		
Manufacturing Growth	2.6%	0.5%	-0.4%
Per Capita Income	25,335	$ 28,921	$ 26,840
(Percent of Metro Average)	94.4%	108%	100%
Per Capita Income Growth	3.4%	4.4%	4.0%
Median Housing Price	131,100		

Sources: Bureau of Economic Analysis, Regional Economic Information System, except Median Housing Price, National Association of Home Builders

Sacramento is a fairly young high technology agglomeration that has managed to attract major corporations such as Intel, Apple, and NEC. Drawing from this base, Sacramento specializes in computer and semiconductor manufacturing. In contrast to Silicon Valley, Sacramento has still some advantages such as lower housing costs and less traffic congestion.

Sacramento's biggest high technology corporations are Hewlett-Packard, Intel, NEC, and Apple. These companies are all specialized in computer and semiconductor manufacturing. Hewlett-Packard set up its plant in the area in 1979, followed by NEC in 1983, Intel in 1984. In 1992, Apple established a plant in the southern Sacramento County (Larson, 1994). All of these companies do not exceed the mark of 6,000 employees indicating that Sacramento is not the main site of their operations. But clearly all of the companies specialize in manufacturing processes: Intel and NEC with semiconductors and Apple with the production of the Macintosh computer. These companies have had a magnet effect and attracted smaller support companies but also spun out new firms in software and other related high technology sectors. Intel's Folsom facility is a major center for the design of the company's core microprocessor products. NEC announced in 1998 a $1.4 billion investment in new manufacturing facilities for paper-thin chips (County of Sacramento Department of Economic Development, 1998).

Table 40: Major High Technology Firms, Sacramento Metropolitan Area, 1997.

Rank	Firm	Employ ment	Products	City
1	Hewlett-Packard Co.	5,500	Computing, Internet and Intranet Solutions, Communication Products and Measurement Solutions	Palo Alto
2	Intel Corp.	5,200	Computer Chips, Personal Computer Networking and Communication Products	Santa Clara
3	Packard Bell NEC Inc.	3,100	PC-Compatible Desktop Computers and Notebook Computers and Network Servers	Japan
4	NEC Electronics Inc.	1,825	Semiconductor Components	Japan
5	Apple Computer Inc.	1,500	Computer Manufacturing, Distribution and Services	Cupertino, CA
6	Artesyn Solutions Inc.	1,165	Contract assembly of electronic components	Boca Raton, FL
7	Level One Communications Inc.	550	Integrated Circuits for High Speed Digital Broadband Transmission	Sacramento, CA
8	Coherent Auburn Group	450	Laser and Optic Components and Instruments	Santa Clara
9	Objective Systems Integrators Inc.	300	Software	Folsom, CA
10	Oracle Corp.	300	Software	Redwood Shores, CA

Source: (Sacramento Business Journal, 1999); Additional information on product specializations from (Sacramento Economic Development Council, 1999)

Table 41: Patents Granted to High Technology Firms, Sacramento Metropolitan Area, 1994-98.

rank	Company	Industry	Patents
1	Intel Corporation	Semiconductors	364
2	Aerojet-General Corporation	Aerospace	51
3	Hewlett-Packard Company	Electronics	46
4	C & K Systems Inc.	Other	16
5	Op-D-Op, Inc.	Other	12
6	NEC Electronics Inc.	Semiconductor devices	9
7	Level One Communications, Inc.	Telecommunications	8
8	Tri Tool, Inc.	Manufacturing Equipment	8
9	VLSI Technology, Inc.	Semiconductor	7
10	Energy Absorption Systems, Inc.	Manufacturing Equipment	6

Source: U.S. Patent & Trademark Office, 1999

Salt Lake City, Utah

Salt Lake City is a relatively small, but rapidly growing center for computer software, electronics and biomedical products. The metropolitan area has approximately 1.25 million residents, and has been growing more rapidly than the average of 13 metropolitan areas in our study. Salt Lake City has among the lowest per capita incomes of the areas we studied, about 17 percent below the average for all U.S. metro areas, in part a reflection of the region's high birth rate and relatively young population.

The region's two most recognized high tech firms are Novell—an early leader in computer networking, and Word Perfect Corporation—at one time the dominant provider of word processing software for personal computers, and now a subsidiary of Canada's Corel. The region is also home to the headquarters of Iomega, a leading manufacturer of computer storage devices.

There are a number of medical device manufacturers that are spin-offs from the University of Utah, which is a world leader in medical research, especially in artificial organs (Rogers & Larsen, 1984). The University of Utah has established a research park specifically aimed at encouraging biomedical firms. Catheter Technology, a biomedical firm originally established in Oregon, now operates out of a headquarters in Utah.

Table 42: Key Economic Indicators, Salt Lake City Metropolitan Area, 1997.

	Salt Lake City	13 High Tech Metropolitan Areas	All US Metropolitan Areas
Population	1,250,854		
Population Growth	2.1%	1.7%	1.1%
Employment	842,823		
Employment Growth	4.2%	2.5%	1.6%
Manufacturing Employment	86,026		
Manufacturing Growth	2.7%	0.5%	-0.4%
Per Capita Income	22,264	$ 28,921	$ 26,840
(Percent of Metro Average)	83.0%	108%	100%
Per Capita Income Growth	5.3%	4.4%	4.0%
Median Housing Price	138,000		

Sources: Bureau of Economic Analysis, Regional Economic Information System, except Median Housing Price, National Association of Home Builders

The Salt Lake City metropolitan area has a diverse array of high tech firms, including home-grown firms and subsidiaries of national and international firms. Among the region's largest home-grown high tech firms are Novell, Iomega, computer graphics designer Evans and Sutherland and several medical device manufacturers. Packard Bell (a subsidiary of NEC), Megahertz and Litton have electronics manufacturing operations in Utah.

Table 43: Major High Technology Firms, Salt Lake City, Utah Metropolitan Area, 1997.

Firm	Jobs	Principal Products	Headquarters
Novell	2,884	Networking	Orem, UT
Iomega Corp	1,454	Computer Storage	Park City, UT
Packard Bell Electronics Inc	1,300	Computers	Japan
Unibase Data Entry	1,285	Data Processing	Sandy, UT
Loral Defense Systems	1000-1999	Defense Electronics	New York
Sorenson Research Co	1000-1999	Medical Devices	Salt Lake City, UT
Evans & Sutherland	704	Computer Graphics	Salt Lake City, UT
America Online	700-999	Internet	Vienna, Virginia
Megahertz Corp (3 Com)	700-999	Communications	Santa Clara, CA
Litton Systems Inc	700-999	Defense Electronics	Santa Clara, CA

Source: (Utah Information Technology Association, 1999), (Utah Department of Community & Economic Development, 1999)

Patent data for Utah, shown in Table 44 show the diversity of the region's technological strengths, including electronics and software, biomedical devices and instruments, chemicals and aerospace.

Table 44: Patents Granted to High Technology Firms, Salt Lake City Metropolitan Area, 1994-98.

Rank	Firm	Industry	Patents Issued
1	Morton International, Inc.	Chemicals	249
2	Becton, Dickinson And Company	Biomedical	67
3	Baker Hughes Incorporated	Oilfield Equipment	49
4	Morton Thiokol, Inc.	Aerospace	43
5	Iomega Corporation	Electronics/Software	42
6	Ultradent Products, Inc.	Biomedical	36
7	Unisys Corporation	Electronics/Software	34
8	Ceramatec, Inc.	Instruments	28
9	Merit Medical Systems, Inc.	Biomedical	23
10	Sarcos Group	Electronics	21

Source: US Patent and Trademark Office, 1999

San Diego, California

Located between the Los Angeles metropolitan area and the U.S. Mexico Border, San Diego has been a rapidly growing, and of late, rapidly changing economy. The San Diego economy has long been associated with the defense establishment. The area has always been home to major military bases, and most of the region's large manufacturing firms have been major defense contractors. (The region is still home to more than 100,000 military personnel and civilian employees of the armed services, down about 15 percent since 1980). The downsizing of the defense budget in the 1990s, though in contributed to a substantial economic slowdown, has helped lead to substantial changes in the region's economic base. Employment in defense related manufacturing has declined by more than half in the 1990s (San Diego Association of Governments, 1998).

The fastest growing segments of the San Diego economy during the 1990s have been biotechnology, communications, software and computer services and recreational goods manufacturing (San Diego Association of Governments, 1998).

As with the rest of the California economy, the first half of the 1990s was marked by recession. San Diego experienced a net loss in employment between 1990 and 1992, and overall growth through 1997 was slower than for the average of the metropolitan areas studied.

Table 45: Key Economic Indicators, San Diego Metropolitan Area, 1997.

	San Diego, CA	13 High Tech Metropolitan Areas	All US Metropolitan Areas
Population	2,723,711		
Population Growth	1.1%	1.7%	1.1%
Employment	1,543,307		
Employment Growth	1.0%	2.5%	1.6%
Manufacturing Employment	133,312		
Manufacturing Growth	-0.7%	0.5%	-0.4%
Per Capita Income	24,965	$ 28,921	$ 26,840
(Percent of Metro Average)	93.0%	108%	100%
Per Capita Income Growth	3.0%	4.4%	4.0%
Median Housing Price	227,500		

Sources: Bureau of Economic Analysis, Regional Economic Information System, except Median Housing Price, National Association of Home Builders

San Diego's largest high tech employer is Qualcomm, a leading manufacturer of wireless communication technologies. Qualcomm was established in San Diego in 1978, and grew from about 400 employees in 1990 to approximately 10,000 (Wells, 1995). The region has long had a concentration of defense electronics firms, several specializing in military communications and avionics. Sony has long assembled television sets in San Diego and also manufactures communications equipment.

Table 46: Major High Technology Firms, San Diego Metropolitan Area, 1997.

Rank	Firm	Jobs	Principal Products	Headquarters
1	Qualcomm Inc.	10,000	Wireless Communication	San Diego
2	Science Applications International	4,189	Mobile Communications	San Diego
3	Sony Technology Center	4,000	Television, Communications	Japan
4	Hewlett-Packard Co.	2,438	Printers, Copiers	Palo Alto, CA
5	Cubic Corp.	1,800	Defense electronics, Fare Collection Systems	San Diego
6	GDE Systems Inc.	1,354	Defense electronics	Wayne, NJ
7	REMEC Inc.	1,130	Communications, Defense	San Diego
8	Kyocera America Inc.	949	Ceramics	Japan
9	Cohu Inc.	751	Semiconductor Equipment	San Diego
10	The Titan Corp.	650	Communications, Defense	San Diego

Source: (San Diego Business Journal, 1998)

Patent data show that electronics and biomedical companies are the region's most prolific innovators. Half of the region's top ten patentees research or manufacture biotechnology or pharmaceuticals. The region's venture capital investments also flow disproportionately to biotechnology and communications firms.

Table 47: Patents Granted to High Technology Firms, San Diego Metropolitan Area, 1994-98.

Rank	Firm	Industry	Patents Issued
1	Hewlett-Packard Company	Electronics/Software	272
2	Qualcomm, Inc.	Electronics/Software	175
3	Isis Pharmaceuticals, Inc.	Biomedical	110
4	Eastman Kodak Company	Electronics/Software	92
5	Salk Institute For Biological Studies	Biomedical	89
6	Gen-Probe Incorporated	Biomedical	82
7	La Jolla Cancer Research Foundation	Biomedical	75
8	Solar Turbines Incorporated	Other	63
9	Hughes Aircraft Company	Aerospace	56
10	Mycogen Corporation	Biomedical	58

Source: US Patent and Trademark Office, 1999

San Jose, California (Silicon Valley)

Silicon Valley is the world's premiere high technology metropolis. Largely responsible for the development and commercialization of the microprocessor and the personal computer, firms in the Silicon Valley are still recognized as world leaders in computing, networking and electronic commerce.

The history of Silicon Valley has been frequently told and exhaustively analyzed. The pivotal actors included radio pioneer Lee de Forest, who demonstrated the audio amplifier in 1912, Fred Terman, Dean of Stanford's engineering school and mentor to David Hewlett and Bill Packard in the 1930s, and William Shockley, inventor of the transistor, who founded the valley's first semiconductor firm in the 1950s (Rogers & Larsen, 1984). Although Shockley's firm failed, the core of engineers he assembled and brought to Silicon Valley formed the nucleus of Fairchild Semiconductor, which in turn produced dozens of spin-off firms, including Intel, Advanced Micro Devices, National Semiconductor and LSI Logic. By the mid-1980s, about half of the seventy semiconductor firms in Silicon Valley were direct or indirect descendants of Fairchild.

The founding and funding of these startup firms was enabled by (and in turn stimulated) the nation's premiere accumulation of venture capital funding. Starting with a handful of venture capitalists in the 1960s, Silicon Valley is now home to dozens of venture capitalists and alone accounts for more than a third of all venture capital investments in the United States (PricewaterhouseCoopers, 1999).

Silicon Valley is a large and dense agglomeration of electronics and software firms and their suppliers. Close interactions among firms, the free flow of labor and ideas between firms, the ease of establishing new start-ups, and the strong base of educational institutions, venture capital, and suppliers of components and services has produced a unique dynamic that seems to drive this region (Saxenian, 1994).

Silicon Valley is generally recognized to be composed of the San Jose Metropolitan Area, itself consisting of the entirety of Santa Clara County. San Jose abuts two other larger metropolitan areas San Francisco and Oakland, but is classified separately for statistical reporting. The metropolitan area has one of the highest levels of per capita income of any region in the United States (nearly $38,000 per capita in 1997, 40 percent higher than the average of all metropolitan areas).

Even though it is among the smaller metropolitan areas in our sample, with about 1.6 million residents (about the same as Portland or Sacramento), it has more than a quarter-million manufacturing jobs, more than all but two of the other metro areas in our sample do have.

Table 48: Key Economic Indicators, San Jose Metropolitan Area, 1997.

Indicator	San Jose, CA	13 High Tech Metropolitan Areas	All US Metropolitan Areas
Population, 1997	1,620,453		
Population Growth Rate 1990-97	1.1%	1.7%	1.1%
Employment, 1997	1,179,100		
Employment Growth Rate 1990-97	1.7%	2.5%	1.6%
Manufacturing Employment	267,546		
Manufacturing Growth Rate 1990-97	-0.2%	0.5%	-0.4%
Per Capita Income, 1997	$ 37,856	$ 28,921	$ 26,840
Percent of All US Metropolitan Areas	141.0%	108%	100%
Per Capita Income Growth	5.6%	4.4%	4.0%
Median Housing Price	$ 391,600		

Sources: Bureau of Economic Analysis, Regional Economic Information System, except Median Housing Price, National Association of Home Builders

The region's economic performance has been mixed in the 1990s. Due in part to California's lengthy slowdown in the early 90s, population and employment growth were just about the same as for all US metro areas, and noticeably slower than for all the metro areas in our sample. The region's per capita income, however, dramatically outpaced other metropolitan areas, rising 5.6% annually during the 1990s.

Published employment data confirm the important role of computer, electronic, instrument and software firms in Silicon Valley's industrial structure. With nearly 190,000 employees in these industry segments in 1996, the San Jose metropolitan area is the largest such concentration of these firms among the 13 regions we examined.

Silicon Valley's leading firms include some of the best-recognized technology leaders in the world, including Hewlett Packard, Intel, Silicon Graphics, Apple, Oracle and others. The region's ten leading firms, shown in Table 49, reflect the region's key competencies: semiconductors and the equipment used to produce them, computers and peripherals, networking equipment, and software.

Table 49: Major High Technology Firms, San Jose Metropolitan Area, 1997.

	Firm	Employ-ment	Products	Headquarters
1	Hewlett-Packard Co.	14,700	Computers and Instruments	Palo Alto, CA
2	Intel Corp.	7,283	Semiconductors	Santa Clara, CA
3	Cisco Systems, Inc.	7,000	Networking Systems	San Jose, CA
4	Applied Materials Inc.	6,100	Semiconductor Equipment	Santa Clara, CA
5	Silicon Graphics Inc.	6,000	Computers	Mountain View, CA
6	Oracle Corp.	5,000	Database Software	Redwood Shores, CA
7	Apple Computer Inc.	4,775	Computers	Cupertino, CA
8	National Semiconductor	4,300	Semiconductors	Santa Clara, CA
9	Seagate Technology Inc.	3,400	Disk Drives	Scotts Valley, CA
10	Lam Research Corp.	3,200	Semiconductor Equipment	Milpitas, CA

Source: (San Jose Business Journal, 1998)

Looking only at the ten largest firms greatly understates both the breadth and depth of the region's base. The region has 30 high tech firms (the ten shown in Table 49 and twenty more) with 1,000 or more employees in Silicon Valley. In addition, there are hundreds of smaller firms. Unique among all of the areas studied in this report is that all of the ten largest firms in San Jose are headquartered locally. Silicon Valley's dominance of leadership of the high tech industry is underscored by the fact that Silicon Valley firms have more branch plants among the ten largest employers than all of the other region's we studied. In all, Silicon Valley firms had 22 branch locations that were among the ten largest high tech employers in the other 12 metro areas studied. The next largest headquarters location among the region's studied—Minneapolis, had just three.

The Silicon Valley is the most prolific patentee of new ideas of any metropolitan area in the United States, by itself accounting for nearly 5,000 of the roughly 80,000 patents issued to U.S. based inventors in 1998. As Table 50 shows, all ten of the leading recipients of patents in Silicon Valley were high tech producers of electronics and related products.

Table 50: Patents Granted to High Technology Firms, San Jose Metropolitan Area, 1994-98.

rank	Firm	Industry	Patents Issued
1	International Business Machines Corporation	Computers	884
2	National Semiconductor Corporation	Semiconductor	587
3	Apple Computer, Inc.	Computers	543
4	Hewlett-Packard Company	Computers and Instruments	479
5	Sun Microsystems, Inc.	Computers	471
6	Advanced Micro Devices, Inc.	Semiconductors	456
7	LSI Logic Corporation	Semiconductors	416
8	Xerox Corporation	Computers/Hardware	394
9	Applied Materials, Inc.	Semiconductor Equipment	353
10	Intel Corporation	Semiconductors	280

Source: US Patent and Trademark Office, 1999

San Jose has been by far the largest recipient of venture capital funding of any metropolitan area in the nation. In the second quarter of 1999, the latest period for which data are available, Silicon Valley firms received more than $2.7 billion in venture capital, more than a third of all the venture capital invested in the nation (PricewaterhouseCoopers, 1999). The San Francisco Bay area has strong specializations in computers and peripherals, electronics and instrumentation, semiconductors and equipment and software and instrumentation (Zook 1999).

Seattle, Washington

Seattle is another vibrant high technology region in the Pacific Northwest. While the region has grown somewhat more slowly than other high tech metropolitan areas, it has a substantially above average income level, and per capita income growth continues to outpace the nation and competitor regions.

Table 51: Key Economic Indicators, Seattle Metropolitan Area, 1997.

	Seattle	13 High Tech Metropolitan Areas	All US Metropolitan Areas
Population, 1997	2,279,236		
Population Growth	1.5%	1.7%	1.1%
Employment	1,640,113		
Employment Growth	2.1%	2.5%	1.6%
Manufacturing Employment	229,236		
Manufacturing Growth	0.0%	0.5%	-0.4%
Per Capita Income	33,373	$ 28,921	$ 26,840
(Percent of Metro Average)	124.3%	108%	100%
Per Capita Income Growth	5.0%	4.4%	4.0%
Median Housing Price	215,100		

Sources: Bureau of Economic Analysis, Regional Economic Information System, except Median Housing Price, National Association of Home Builders

Technology-based industries in this region are represented by industry sectors such as aerospace, electronics, software and other computer services, telecommunication and biomedical/biotechnology. This diversity has led to "cross-fertilization" as well as to the development of a certain technological trajectory which emphasizes the software sector as one of the most important high technology segments in the region. The software industry is one of the major exporters of the region and generated an estimated $15 billion in 1997, and is projected to generate more than $20 billion by the year 2000. "From 1990 to 1996, annual employment growth in the state's software industry increased an average of 17.8 percent, and in 1996, employment increased by 20 percent to an estimated 27,000 jobs and wages increased by 50 percent" (Moll, 1999). Additionally, Seattle is home to a significant concentration of biotechnology firms. Biotech firms in the region have annual revenues of over $1 billion and employ more than 12,500 workers according to their local trade association (Moll, 1999).

The origins of the software industry in Seattle can be traced back to a company that at the first glance does not fit into the category of high technology. Seattle is home to the Boeing Corporation; the world's most successful aircraft maker. The Puget Sound region can be characterized as an important aerospace hub in the United States. The aerospace corporation was instrumental in the development of the software industry in the region because for a long time Boeing Computer Services (BCS) was the largest software developer in the region. The company not only served the internal needs of the mother business, but also ventured into the commercial market with prepackaged software (Gray, Golob, & Markusen, 1996). It can be assumed that BCS helped to lay the seeds for an emerging software industry by attracting skilled labor into the region and thus, helped to establish a regional pool of computer specialists that later went on to work for other companies or started their own business in the software industry long before Microsoft Corporation incorporated in 1981. Additionally, some electronics firms such as Eldec, Avtech, Integrated Circuits, Korry Electronics are now suppliers to Boeing (Economic Development Council of Seattle & King County, 1995). Most of the firm relationships to firms or customers are outside the region, nationally or even internationally. This is reflected in the fact that half of Microsoft sales going to foreign customers (Economic Development Council of Seattle & King County, 1995).

Of course nowadays, one cannot talk about high technology in the Seattle area without mentioning Microsoft; perhaps the world's most influential software firm. Located in Redmond, the company is the largest high technology employer in the city with more than 14,200 employees. While the Seattle area has a number of other software firms like Real Networks, Aldus (purchased by Adobe Systems), Visio (a spin off of Aldus, now purchased by Microsoft), and a strong concentration of e-commerce pioneers (Amazon.Com, and HomeGrocer.com), the region is not a major center for computer hardware or semiconductors. The Seattle area has a single sizable stand-alone fab, operated by Matsushita in Puyallup. The region's chief hardware producers mainly manufacture instruments and a variety of aviation-related electronics. Thus, we can infer that the historical trajectory of high technology development in the Seattle area follows the seeds that Boeing Computer Services (BCS) laid in the 80s. Interestingly Microsoft's corporate strategy gives an additional clue to the regional technology trajectory in so far as "Microsoft unabashed desire to corner the software market and eliminate clones has resulted in more software employees working in the Seattle region than if the firm had adopted a more modest approach." (Gray et al., 1996) Microsoft's market success attributes to the recent regional economic growth in software also in a more subtle way: the company's growth resulted in stupendous stock option values for many of its employees which in turn has lead many of them leave and start their own companies. Also other successful software companies began to spin-off new companies that contributed to the regional growth in software employment in the last years.

The software sector in the Seattle region focuses mainly on the sales of prepackaged software. Sales of prepackaged software account for the majority of the industry's revenues (approximately 80%) (Economic Development Council of Seattle & King County, 1995). With regards to the influence of higher education on the development of the software industry in Seattle, some researchers have concluded that the University of Washington has played a minor role in the development of the software industry (Gray et al., 1996).

Another industrial sector in the Seattle region can be found in biotechnology and medical devices. This industry mainly centers on two non-profit institutions, namely the University of Washington (i.e. Department of Molecular Biotechnology) and the Fred Hutchinson Cancer Research Center. Companies in this sector are among the top ten patentees in the region (i.e. Zymogenetics Inc., Immunex Corporation). Immunex Corporation is Seattle's largest biotechnology firm, which currently employs about 1,200 people. However, Immunex never expanded into manufacturing. This development is typical for the biotechnology industry in which the companies are focused on R&D and later turn their products to existing pharmaceutical companies for large-scale productions.

Table 52: Major High Technology Firms, Seattle Metropolitan Area, 1997.

Rank	Firm	Employment	Products	Headquarters
1	Microsoft Corp	14,259	Software	Redmond, WA
2	Fluke Corp.	1,493	Instruments	Washington, DC
3	Intermec Technologies Corp.	1,105	Computers and Instruments	Everett, WA
4	Eldec Corp.	1,000	Aerospace and defense electronics	Lynnwood, WA
5	Attachmate Corp.	800	Software	Bellevue, WA
6	Hewlett Packard	745	Instruments, medical devices	Palo Alto, CA
7	WRQ Inc.	657	Software	Seattle, WA
8	Pacific Circuits Inc.	638	Printed circuit boards	Redmond, WA
9	Alpha Technologies	620	Power Supplies	Bellingham, WA
10	Korry Electronics Co.	590	Aerospace electronics	Seattle, WA

Source: (Puget Sound Business Journal (Seattle/Tacoma), 1999)

Judged by on patent rates, Microsoft is the most innovative company in the Seattle region followed by Boeing. Patent data for Seattle, displayed in table 53, show an obvious emphasis on software and biomedical industry as highly innovative segments of Seattle's high technology industry.

Table 53: Patents Granted to High Technology Firms, Seattle Metropolitan Area, 1994-98.

Rank	Firm	Industry	Patents Issued
1	Microsoft Corporation	Electronics/Software	646
2	Boeing Company	Aerospace	435
3	Intermec Corporation	Electronics/Software	94
4	Zymogenetics, Inc.	Biomedical	86
5	Immunex Corporation	Biomedical	65
6	Siemens Medical Systems, Inc.	Electronics/Software	64
7	Allied-Signal Inc.	Electronics/Software	55
8	Incontrol, Inc.	Other	50
9	John Fluke Mfg. Co., Inc.	Electronics/Software	47
10	Weyerhaeuser Company	Wood Products	47

Source: US Patent and Trademark Office, 1999

IV. Analysis: High Technology Specializations

Looking in detail at the identities and technologies of the leading high technology firms in 13 metropolitan areas provides a much more variegated picture of high tech than the usual statistical aggregations of high technology employment. We conclude that metropolitan high tech centers are usually much more specialized than is usually recognized, and that this specialization is evidence of the particular and varied processes that have resulted in the emergence of high tech production in each metropolitan area.

A. Metropolitan areas have different "high technology" specializations

The term high technology is widely and loosely applied, both in academic circles and in everyday conversation. But while many industries and activities fit into agreed-upon definitions of high technology, there is considerable variation in the nature of high tech industries. Each of the 13 metropolitan areas we examined can be classified as being a center for high technology industry, yet no two areas have identical mixes of industrial specializations, technological competencies or growth trajectories. The principal large firms that account for the bulk of high technology employment in different areas tend to specialize in particular technologies.

With the exception of Silicon Valley (which seems to have an unusually broad range of technological competencies) the bulk of high technology employment in most areas is in firms that specialize in just a few technologies. Denver has a particular strength in cable and telecommunications and a strong cluster of computer storage firms. San Diego is a center for wireless communication and biotechnology. Salt Lake City specializes in medical devices and some kinds of software. Besides aerospace and avionics, Seattle is a center for software and biotechnology. The mix of high technology industries in none of these metro areas resembles that found in Portland (semiconductors, wafers, SME/EDA, displays and computers). Portland's mix of industries more closely resembles Austin (semiconductors and computers) and to some extent Phoenix (semiconductors).

Specialization in production is mirrored in knowledge creation. Patent data confirm the heterogeneity of high technology in the metropolitan areas we examined. Frequently, a majority of the patents issued in any given metropolitan area are to a handful of firms specializing in one or more related technologies. Our analysis has only scratched the surface of the patent data; a more detailed analysis could construct location quotients or other indexes of localization by patent classification.

Finally, metropolitan specialization appears to be reflected (and perhaps amplified by) geographical concentrations of venture capital. Capital, often pictured as the most mobile factor of production, shows a strong tendency toward localization. Venture capitalists in a particular region tend to specialize in investing in the set of technologies that are most concentrated in their home region, even when they make investments in other metropolitan areas (Zook, 1999).

B. History Plays a Critical Role in High Tech Development

Narrative accounts of the development of high technology in particular metropolitan areas consistently underscores the importance of history in shaping the kinds of companies and technical specializations located in different areas. The archetypal story of a single successful firm that establishes itself as a national leader in a particular field, and that over time becomes parent to successive generations of firms that extend and refine its technological specialization, are repeated time and again. The creation myths of Silicon Valley (Shockley Semiconductor, Fairchild, Intel, National Semiconductor, LSI) are well known. Less know, but similar are the analogous firms in other metropolitan areas (Denver's Bill Daniels (cable) and IBM Boulder (tape storage), Portland's Tektronix (instruments, displays, semiconductors), Minneapolis' Engineering Research Associates (computers) and Medtronics (medical devices), Boston's Raytheon (computers). Rarely are technological competencies transplanted de novo; far more often they build on pre-existing technical strengths. In almost every metropolitan area, today's high tech successes can (in retrospect) trace their roots to firms started decades ago.

Historical-lock in to a particular technology can be either good or bad. Surging demand for a hitherto modestly exploited technology (like wireless communication) can trigger phenomenal growth in those metropolitan areas with substantial competence in that area (Qualcomm and Sony in San Diego, for example). Likewise, being locked into a declining technology, or one jeopardized by other competitors, can be a regional disaster. The rise of micro-computers in the 1980s, which clearly triggered aggressive growth for the technologically well positioned firms of Silicon Valley (including Apple, Intel and others), undermined the fortunes of Boston's Route 128 (the nation's center for manufacturers of mini-computers, including DEC, Wang and Data General), and Minneapolis (home of mainframe manufacturers including Control Data, Honeywell and Unisys).

As Paul Krugman has pointed out the causes of industrial location often boil down to idiosyncratic stories of how a particular small event, occurring at a critical time, triggered a series of developments that over time produces an enduring industrial agglomeration (Krugman, 1991). Krugman offers one such typical story of how a tufted rug given as a gift in 1895 led to a local craft tradition that in turn served as the nucleus of most of the nation's carpet producers, even today located within a few miles of the small town of Dalton, Georgia.

Our analysis of metropolitan areas confirms the importance of historicity in explaining the characteristic distinctiveness of each of the metropolitan areas we examined. With great regularity, the current industrial structure and technological specializations of each metropolitan area is an outgrowth of events that occurred decades ago.

To be sure, many of the factors the conventional wisdom associates with the growth of high technology (strong higher educational institutions specialized in relevant fields, concentrations of venture capital and supplier industries, and well-trained workforce) are associated with these high tech centers. But in many, if not most cases, these are at least partially the products of positive feedback effects associated with the growth of the cluster in a particular location.

The role of history in shaping the different technological specializations of metropolitan areas suggests that high technology development is an evolutionary process. While areas do specialize, they tend not to remain constant over time. As industries and technologies change, the mix of firms and knowledge in specific metropolitan areas evolves. In practice, development processes appear to be cumulative and path dependent: a region's opportunities for development today are determined, in part, by the kinds of development that have occurred in the past. In retrospect, the importance of pivotal events is clear. Three kinds of events are frequently cited: the commercialization of research breakthroughs, government policy and spending decisions, and industrial relocations. Research breakthroughs include Earl Bakken's invention of the heart pacemaker in Minneapolis, Shockley's semiconductor firm in Santa Clara, and Howard Vollum's oscilloscope in Portland. Government policies—like the massive defense spending on electronics that supported Route 128 firms and early computer and semiconductor makers, were also pivotal at certain times. Finally, industrial relocations, like IBM's decision to build tape drives in Boulder or electric typewriters (and later PCs in Austin) triggered the initial assembly of a technical competent people in an area. Entrepreneurship and venture capital build-on and extend the existing technical competence of an area in the form of new firms. Startup firms are typically staffed by people with prior work experience in a metro area, and build on a technology developed or refined in that area.

C. Silicon Valley plays a distinctive leading role

The development mantra of the past two decades has been the grail-like quest to create the next Silicon Valley. Our data show that no one has come close. If anything, Silicon Valley plays an even more decisive role in leading the development of high technology that it did in the 1970s or 1980s. Silicon Valley is the single largest concentration of high technology employees of any of the 13 metropolitan areas we examined. It accounts for more patents than any of the other examined areas. Additionally, Silicon Valley has a higher level of patenting per employee than any other region. The Silicon Valley region alone accounts for nearly 40 percent of all of the reported venture capital investment made in the United States in 1999.

These data are underscored by the corporate leadership role played by Silicon Valley firms. All of the ten largest high tech firms in Silicon Valley are headquartered locally. Firms headquartered in Silicon Valley play key roles in the rest of the nation as well. At least one of the ten largest high tech firms in every region we investigated reported to a corporate headquarters in San Jose.

D. High technology cannot be treated as a monolith

The style of analysis presented in this working paper differs sharply from most of the academic and journalistic analyses of the location patterns of high technology industry. The general trend in such work is to establish a broad SIC code-based definition of what constitutes high technology, and then to simply aggregate data (employment, sales, value-added, investment) for all of the industries that meet the definition.

While useful conceptually, it is not clear this kind of definition is useful analytically. By implication, this binary classification of industries (an industry is either high tech or it is not, rather like the zero/one nature of binary computer data), implies that there is a great deal of homogeneity among the firms that are high technology. High technology is neither a monolithic industry grouping nor a fungible set of products, production methods or technologies. Almost by definition, high technology goods are highly differentiated, and neither end products, nor production processes are widely interchangeable among firms. While broad categories of skill may be applicable in a wide range of firms and situations (the ability to design circuits), much of the technical knowledge workers have is specific to a small industry segment or even a particular firm (for example, designing analog to digital circuits for cellular phones). Statistical analyses that group inherently disparate firms such as medical devices, semiconductors, telecommunications, and software together into a single category of 'high technology' and attempt to explain their behavior as if they were homogenous units driven by a common set of factors are likely to be substantially misleading and incomplete.

An essential characteristic of high technology is novelty and differentiation. The proxies studies typically use to identify high tech firms (research and development expenditures and proportions of scientists and engineers) are important precisely because they are the critical ingredients in ongoing innovation in process technologies and end products. High tech industries are high tech largely because their products are constantly being refined, improved and differentiated.

Given the enormous and inherent heterogeneity in high tech products and processes, there should be little surprise that there isn't any single cause that triggers the development of high tech clusters. Despite similarities in industrial classification, occupational composition and research intensity, the sheer variety of specializations among metro areas, and their persistence over time suggests that researchers should pay close attention to the diversity of high technology.

References

American Electronics Association. (1999). *Cyberstates Update: A State-by-State Overview of the High Technology Industry,* .

Atlanta Business Chronicle. (1998). Book of Lists. Atlanta: American City Business Journals.

Austin Business Journal. (1999). Book of Lists. Austin: American City Business Journals.

Boston Business Journal. (1999). Book of Lists. Boston: American City Business Journal.

Bureau of Economic Analysis. (1999). Regional Economic Information System. Bureau of Economic Analysis. Available: http://www.bea.doc.gov/ [1999, 9/19/1999].

Bureau of the Census. (1998). County Business Patterns, [Database]. Census Bureau. Available: http://www.census.gov/epcd/cbp/view/cbpview.html [1999, 9/19/99].

Business Wire. (2000). Motorola, Inc. Business Wire.com. Available: www.businesswire.com/emk/motocp.htm [2000, January 12].

Collaborative Economics. (1999). The changing face of the software cluster in Arizona .

Combes, R. S. (n.a.). Aircraft Manufacturing in Georgia: A Case Study of Federal Industrial Investment . Atlanta: Georgia Tech Research Institute.

County of Sacramento Department of Economic Development. (1998, Spring/Summer, 1998). . ED Times, County of Sacramento Business News.

DeVol, R. C. (1999). America's High Tech Economy: Growth, Development and Risks for Metropolitan Areas . Santa Monica, CA: Milken Institute.

Economic Development Council of Seattle & King County. (1995). Foundations for the Future: An Economic Strategy for the Central Puget Sound Region (Volume Two: Strategic Opportunities and Institutional Capabilities). Seattle, WA: Economic Development Council of Seattle & King County.

Fortune. (1998, November 23, 1998). The Best Cities For Business. Fortune, 138, 142.

Graham, T. (1998, August, 1998). Regional Spotlight: Twin Cities Area. Minnesota Employment Review.

Gray, M., Golob, E., & Markusen, A. (1996). Big firms, long arms, wide shoulders: the 'hub-and-spoke' industrial district in the Seattle region. (Seattle, Washington). Regional Studies, 30(7), 651(16).

Gray, M., & Markusen, A. R. (1999). Colorado Springs: A Military Anchored City in Transition. In A. R. Markusen (Ed.), Second Tier Cities: Rapid Growth Beyond the Metropolis (pp. 311-332). Minneapolis: University of Minnesota.

Herbig, P., & Golden, J. E. (1993). How to keep that innovative spirit alive: An examination of evolving hot spots. Technological Forecasting and Social Change, 43, 75-90.

Intermountain Partners, I. (1997). The Information Technology Industry in Colorado's Front Range: A New Engine for the Regional Economy . Denver: Metro Denver Network.

Krugman, P. (1991). Geography and Trade. Cambridge: The MIT Press.

Larson, M. (1994, May 30). Electronics firms lead area's economic recovery. (high technology industry in Sacramento, California) (All about Business in Sacramento) (Industry Overview). The Business Journal Serving Greater Sacramento, 11, S41(1).

Lawson, C., & Lorenz, E. (1999). Collective Learning, Tacit Knowledge and Regional Innovative Capacity. Regional Studies, 33(4), 305-317.

Luger, M. I., & Goldstein, H. A. (1991). Technology in the garden: research parks and regional economic development. Chapel Hill: The University of North Carolina Press.

Markusen, A., Hall, P., & Glasmeier, A. (1986). High Tech America: The what, how, where, and why of the sunrise industries. Boston: Allen & Unwin.

Miller, J. (1999). Regional Case Study: Austin Texas: Or How to Create a Knowledge Economy, [html]. European Commission Delegation. Available: http://www.eurunion.org/partner/regional.htm [1999, 8/16/99].

Minnesota Department of Trade and Economic Development. (1999). Compare Minnesota: An Economic and Statistical Factbook . St. Paul, MN: Minnesota Department of Trade and Economic Development.

Moll, R. (1999). Case Study: The Greater Seattle Area. European Union. Available: http://www.eurunion.org/partner/seattle.htm [1999, November 22, 1999].

Munnich, L. (1995). Twin Cities Industry Cluster Study . Minneapolis: Metropolitan Council.

Oden, M. (1997). From Assembly to Innovation: The Evolution and Current Structure of Austin's High Tech Economy. Planning Forum, 3, 14-30.

Olgeirson, I. (1999,). Big deals erase Denver's cable capital nickname,. Denver Business Journal.

Porter, M. E. (1990). The Competitive Advantage of Nations. Harvard Business Review, 90(2), 73.

Porter, M. E. (1998). Clusters and the New Economics of Competition. Harvard Business Review, 77-90.

PricewaterhouseCoopers. (1999). Money Tree Survey Pacific Northwest Results (Q2 1999). n.a.: PricewaterhouseCoopers.

Puget Sound Business Journal (Seattle/Tacoma). (1999). Book of Lists. Seattle: American City Business Journals.

Raytheon. (1999, August 1999). Historical Backgrounder, [Webpage]. Raytheon Company. Available: http://www.raytheon.com/ [1999, November 11, 1999].

Reamer, A., & Cortright, J. (1998). Socioeconomic Data for Economic Development: An Assessment . Washington, D.C.: Economic Development Administration, U.S. Department of Commerce.

Research Triangle Park Organization. (1999). R&D Organizations by Industrial Classification, [Webpage]. Research Triangle Park. Available: http://www.rtp.org/RTP_Co%27s_speciality.htm [1999, November 11, 1999].

Rogers, E. M., & Larsen, J. K. (1984). Silicon Valley Fever: Growth of High Technology Culture. New York: Basic Books.

Sacramento Business Journal. (1999). Book of Lists. Sacramento: American City Business Journals.

Sacramento Economic Development Council. (1999). Economic Profile. Available: http://www.sactoedc.org/economic_profile/employment.html [1999, December 4, 1999].

San Diego Association of Governments. (1998). San Diego Regional Economic Prosperity Strategy . San Diego: San Diego Association of Governments.

San Diego Business Journal. (1998). Book of Lists. San Diego: American City Business Journals.

San Jose Business Journal. (1998). Book of Lists. San Jose: American City Business Journals.

Saxenian, A. (1994). Regional Advantage: Culture and Competition in Silicon Valley and Route 128. Cambridge: Harvard University Press.

Taratec Corporation, (1998). MDN Tech Vision: A Blueprint for the 21st Century Economy of Metro Denver . Denver: Metro Denver Network.

The Phoenix Business Journal. (1999). Book of Lists. Phoenix: American City Business Journals.

The Portland Business Journal. (1999). Book of Lists. Portland: American City Business Journals.

Triangle Business Journal (Raleigh/Durham). (1998). Book of Lists. Raleigh/Durham: American City Business Journals.

Utah Department of Community & Economic Development. (1999). Utah Manufacturer's Directory,. Available: http://www.dced.state.ut.us/busdev/ [1999, 11/15/1999].

Utah Information Technology Association. (1999). Utah IT Companies. Available: http://www.proindex.com/uita_cgi/ [1999, November 1, 1999].

Warsh, D. (1986). War Stories: Defense Spending and the Growth of the Massachusetts Economy. New England Journal of Public Policy, 2(1).

Wells, K. R. (1995, October 30, 1995). They're manufacturing . . . manufacturing jobs. San Diego Business Journal, pp. 17.

Zook, M. (1999, October 21-24, 1999). The Impact of Venture Capital on the Emerging Internet Content and Commerce Industry in the United States. Paper presented at the Association of Collegiate Schools of Planning 1999 Conference, Chicago, IL.

List of Tables