America's High-Tech Economy

Growth, Development, and Risks for Metropolitan Areas

July 13, 1999

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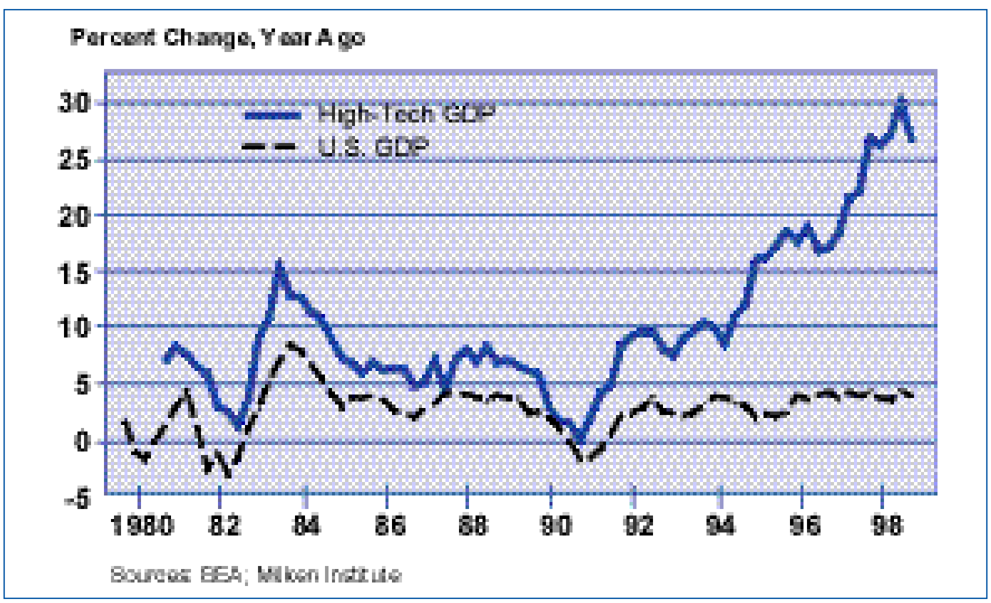
Section 1: Technology and U.S. Growth Potential

Technology is ubiquitous, directly or indirectly invading nearly all sectors of the U.S. economy. Moreover, a compelling case can be made that the high-tech sector is boosting the long-term potential growth path of the U.S. economy and determining the relative economic success of metropolitan areas around the country. "Information technology" (IT) describes the infrastructure and knowledge that is necessary to make information available rapidly. IT is increasingly the software and communication services that patch equipment together. Advances in technology in recent years have created entirely new growth industries including e-commerce, online information services, mobile communications, and greater advances in medical research. IT has spurred rapid, seemingly continuous innovation by creating networks that generate value through productive interactive relationships or collaboration.

Advances in technology in recent years have created entirely new growth industries, including e-commerce, online information services, mobile communications, and greater advances in medical research.

Firms have been investing in IT in an effort to boost production efficiencies, improve communication flows, and enhance overall business operations. Firms believe that these investments yield rewards such as

Figure 1
High Tech Surges in the 1990s
High-Tech vs. Total Real GDP



higher profitability by increasing productivity and hence reducing the growth of unit labor costs. Our standard of living is directly tied to productivity growth. The Milken Institute has constructed an end-use demand measure of high-technology products and services in an attempt to calibrate their rising contribution to economic growth. Its result is displayed in Figure 1. Since the 1990-91 recession, growth in the high-technology (high-tech) sector has been four times as large as in the aggregate economy. During the 1980s, the high-tech sector grew approximately twice as fast as the economy. Over the past three years, growth in high-tech products and services averaged over 20 percent, directly elevating real GDP growth by 1.5 percentage point.

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Growth in the high-tech sector has averaged four times that of the overall economy during the 1990s.

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Information technology and it application has spawned much debate among economists in recent years. IT pessimists point out that despite a massive investment in these technologies, productivity growth has fallen over the past 20 years. Furthermore, they assert that IT investments could not have improved productivity growth because they comprise too small a share of the capital stock and have merely been substituted for more expensive inputs, such as labor and other forms of capital. IT optimists, however, make a compelling case that output growth in services is being understated, and that the reported productivity growth is biased downward. IT optimists also claim that new technological innovations require a substantial time period before being absorbed throughout the economy. As evidence that something is indeed happening, they argue that productivity growth in the durable goods industries has risen in the 1990s, and that over the past three years, productivity growth in the entire economy has accelerated.

Technological innovation has improved productivity growth and boosted U.S. long-term economic growth.

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What can we conclude concerning the role of technology in promoting long-term economic growth? Some New Economy proponents are overzealous in the advocacy of their position. Concluding, based on only three years of supporting data, that sustainable productivity growth has improved from 1 percent of the past 25 years to 2 percent would be premature. We consider ourselves to be cautious optimists. Modern technology is altering production processes throughout the economy and enabling truly globally integrated firms. With the exponential growth of the Internet, many efficiency gains and lower costs will be realized. Technological innovation has boosted productivity growth to the 1.5-2.0 percent range, with more growth possible. This will increase long-term economic growth to between 2.5 and 3.0 percent in our view.

Section 2: National High-Tech Industry Performance

One of the most omnipresent influences of high technology has been in business investment patterns. IT hardware has accounted for a growing share of total business investment across a broad array of industries. In

1970, information processing equipment and related sectors represented 7 percent of real business equipment investment; however, last year it was responsible for over 50 percent of all capital spending.

One of the most difficult tasks in analyzing high-technology industries is defining which set of industries to include in the definition. The definition will vary depending upon the research interests and data availability across a number of dimensions. Our primary research interests are in determining the individual contributions of high-tech industries to the relative economic performance of metropolitan areas. For these reasons, we are focusing on the value of output for industries that may be considered high technology. Manufacturing industries such as drugs, computers and equipment, communications equipment, and electronic components are included, as are service industries such as communications services, computer and data processing services, and research and testing services.

These industries are among the fastest growing in the United States. The three industries with the most rapid growth — electronic components and accessories, computer and office equipment, and computer and data processing services — are all vital information technology industries. Over the past 20 years, high-tech industries have almost doubled their share of industry output in the United States to nearly 11 percent. Technology services, at 5.8 percent of national output, are larger than technology manufacturing.

Section 3: Technology and Metropolitan Economic Performance

Technology is having a pervasive influence on the spatial distribution of economic activity and, more importantly, the relative rate of growth among metropolitan areas within the United States. Prowess in technological innovation and assimilation will likely determine the relative success of nations in the future; it already is having profound impacts on the regional economic landscape of the United States. Ironically, just when globalization seemed to be forcing convergence among national economies and cheap, versatile communications seemed to be undermining the inherent advantages of doing business in one place rather than another, localities are emerging as important factors to the economic success of individual nations. Perhaps the best indicator of the ascendance of regionalism is that policymakers from Kuala Lumpur to Jerusalem are busy trying to clone Silicon Valley. Geographic clustering is becoming central to the creation and understanding of what economists call "comparative advantage" in trade — even in an information-age economy.

It is plain that economic geography — a discipline that studies where production occurs — has been neglected by the mainstream. But since the

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Information processing equipment accounts for over 50 percent of all capital spending.

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High tech has doubled its share of the U.S. economy over the past 20 years.

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Policy makers from Kuala Lumpar to Jerusalem are busy trying to clone Silicon Valley.

late 1980s, there has been an intellectual boomlet in the subject. This resurgence has been dubbed "new economic geography" and provides the foundation for analyzing highly specialized economic activity within regions. In essence, new economic geography attempts to provide the theoretical underpinnings to explain the agglomeration processes that result in highly specialized economic activity within regions. The central component of this theory is based upon the Marshallian notion that increasing returns — as in, "the more that's made, the cheaper it is to make" — lead to competitive advantages.

Economic geography posits two main opposing forces: concentration and dispersion.

Economic geography posits two main opposing forces: concentration and dispersion. Agglomeration forces, because of increasing returns, cause economic activity to cluster, whereas centrifugal (or congestion) forces push economic activity outward. The opposing forces are in constant competition as they seek a spatial equilibrium. The relative dominance of one over the other creates a landscape of economic activity, but it ultimately leads the countervailing force to exert a stronger influence, causing the geographic landscape to change. Such "externalities" play a particularly important role in the case of high-technology industries.

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Much of standard location theory is applicable to studying where high-tech industries locate and whether sufficient critical mass is achieved to develop clustering. Many factors interact in a complex, dynamic environment that ultimately determine the geographic evolution of technology industries. The relative importance of the factors alters over the stages of development. The relative weights placed upon the array of location factors will differ according to the specific high-tech industry — the major divide being whether it is a manufacturing or service industry.

High-tech firms want access to a trained workforce, close proximity to research institutions, a network of suppliers, access to venture capital, and a good quality of life.

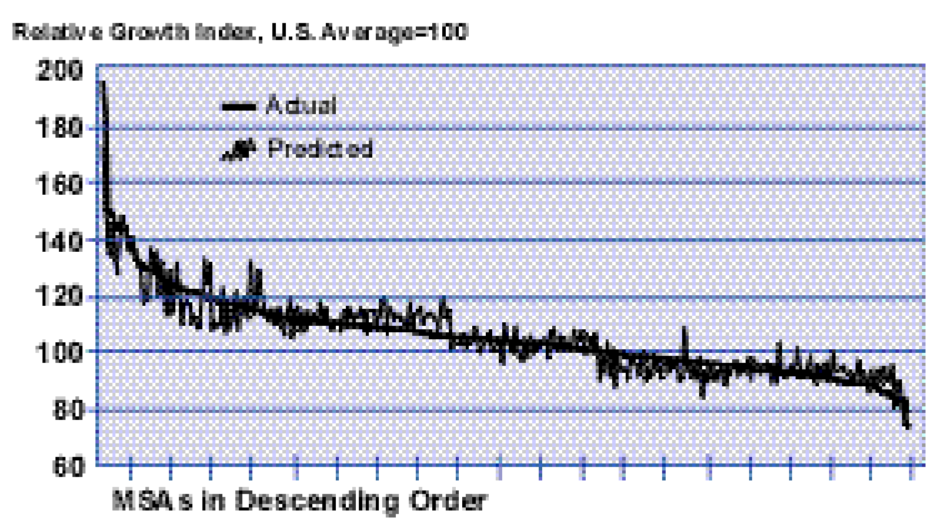
A historical accident or exogenous force can provide a critical advantage for one location. Many of the traditional location factors that have always attracted industries also are important to high-tech firms. These factors are generally referred to as "cost-of-doing-business measures": tax rates or incentives, compensation costs, land and office space costs, energy costs, capital costs, and firms' perception of the general business climate. However, other factors appear to contribute the most to high-tech firms' location decisions. They include: access to a trained / educated workforce, close proximity to excellent educational facilities and research institutions, an existing network of suppliers, availability of venture capital, climate and other quality-of-life factors, and the general cost of living.

We applied a series of econometric approaches to examine the importance of high-tech industries in explaining the relative economic growth of metros. The strength of the explanatory power of high-tech industries in determining the relative economic growth of metros is high, and the relationship is robust across most dimensions in these regressions. In one approach, we created a series of metro growth indices relative to the national growth pattern. In the case of high-tech output, the relative metro growth index is created by comparing growth in metros relative to the national average from 1990 to 1998. We chose the 1990s as the period of analysis because this is the period during which high-tech became vital in determining performance between metros.

The variable we were attempting to explain was the relative total real-output growth index for each of the 315 metros based upon two factors: movements in the relative metro real high-tech output growth index and an index of concentration (location quotient) in high-tech activity in 1990. Standardizing the relationship by the concentration of high-tech industries in a metro is important because if a metro had a low initial high-tech density, a given percentage gain in high-tech growth would not provide the same incremental stimulus as in a metro with a large initial high-tech density. Based upon this equation, we found that 65 percent of the total output growth differential between metros could be explained on the basis of their relative growth in high-tech and the initial high-tech density (see Figure 2).

High- tech activity can explain 65 percent of the growth differential between metros in the 1990s.

Figure 2
Metro Growth Explained by High Tech
Actual vs. Predicted (Cross-sectional)



Sources: Milken Institute; RFA

High-tech industries have a large direct economic impact on metro economies, but the indirect and induced effects are critical to understanding their role in promoting growth. Because of the high-value added production in high-tech industries, and the greater demand for high-skilled labor, these industries compensate their employees well. For example, extensive use of stock options in high-tech industries' total compensation mix is a powerful incentive — sometimes enabling even clerical personnel to become millionaires. The indirect effect (or the

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The high-tech sector stimulates the non-high-tech sectors of a metro economy ...the multiplier impact.

The relative technology gravitational pull of metros is measured in our Tech-Poles.

incremental stimulus to non—high-tech industries) from high-technology industries on metro economies is substantial. The induced effects stem from non—high-tech firms and their employees purchasing more local goods and services due to high sales by businesses and greater personal income increases.

We tried several approaches and weighting schemes to develop a composite measure of high-tech spatial concentration. A straightforward approach seemed to be the most appropriate. Combining the location quotient with the share of national high-tech output in a multiplicative fashion yields our composite measure of technology production centers, or as we term them, "Tech-Poles." They are Tech-Poles in the sense of the relative technology gravitational pull that they exert and are exhibited in Figure 3.

Figure 3
Milken Institute Tech-Poles

As a Tech-Pole, the gravitational pull of the San Jose metro is unparalleled.

The dominance of Silicon Valley (San Jose metro) as a high-tech industry center is well documented. But our composite index of 23.7 is more than three times the size of the second-ranked metro, which is barely larger than the third-place metro. As a Tech-Pole, the gravitational pull of the San Jose metro area, home to Hewlett-Packard, Applied Materials, Sun Microsystems, Intel, Cisco Systems, Oracle, and Silicon Graphics, is unparalleled. Silicon Valley created the personal-computer industry and is developing another industry — electronic networking — that has the potential to exceed the size of the PC.

Dallas's position, second on the index, might cause some surprise. But with a diversified high-tech base — seven industries out of a possible 14 are more concentrated than the national average — it deserves to be high on the list. The Dallas metro area includes six of the nation's 20 largest telecommunication services companies. GTE's global headquarters is based in Dallas, while Nortel, Ericsson, Fujitsu, and Alcatel have U.S. headquarters there. Austin is thought by many to be the center of Texas' electronic components industry, but Dallas produces over 20 percent more in terms of value of output and employs 4,200 more people.

Dallas, though it might surprise some, is the second most-powerful Tech-Pole.

Despite the loss of defense-related high-tech firms in the early 1990s, Los Angeles ranks third on the index. The ranking is somewhat inflated, perhaps, by the inclusion of non-high-tech portions of motion picture production and services. But even if the entire entertainment industry were excluded, Los Angeles would rank seventh.

Boston places fourth, with an above-average concentration in 11 high-tech industries. It is home to some of the leading universities and research centers in the nation. Although the joint impact of defense downsizing and heavy dependence on the lagging mainframe computer industry has been sizable, it is enjoying renewed vigor due to its Internet-related prowess. Internet portal giant Lycos is headquartered in Waltham, while many other startups are emerging on Route 128.

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Thanks to Boeing, aircraft is still a major industry in Seattle. But software's rapid growth has made computer and data processing services a vital part of the region's economy. Seattle ranks fifth on the index. Microsoft, of course, is at the nucleus of the Seattle software cluster.

From here on down, the rankings are full of surprises. On a composite ranking of high-tech services, Washington, DC, places first in the country, and sixth overall in high technology. Virtually unnoticed, Washington has become a communications hub. Its Virginia suburb of Fairfax County is home to America Online, UUNET, and PSINet. Over one-half of the nation's Internet traffic passes through local firms. Software and data processing are major sectors of the local economy as well.

L.A., Boston, Seattle, Washington D.C., Albuquerque, Chicago, New York, and Atlanta round out the top 10 Tech-Pole list.

Albuquerque's high ranking derives from its success in attracting electronic component manufacturers. Chicago is an important center of communications equipment, courtesy of Motorola. The windy city also has an above-average concentration in drugs and in research and testing services. New York's ninth-place rank is in part due to its major presence in telecommunications services. The city has very little high-tech manufacturing, which brings into question how much silicon is really in Silicon Alley.

Atlanta is the undisputed high-tech capital of the Southeast, with a foothold in telecommunication services, computer and data processing services. Oakland's 14th position places it just behind Orange County, California — a fact that may surprise those accustomed to thinking of it as

Smaller high-tech clusters are in the midst of rapid expansion.

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Albuquerque recorded the fastest high-tech growth in the 1990s...

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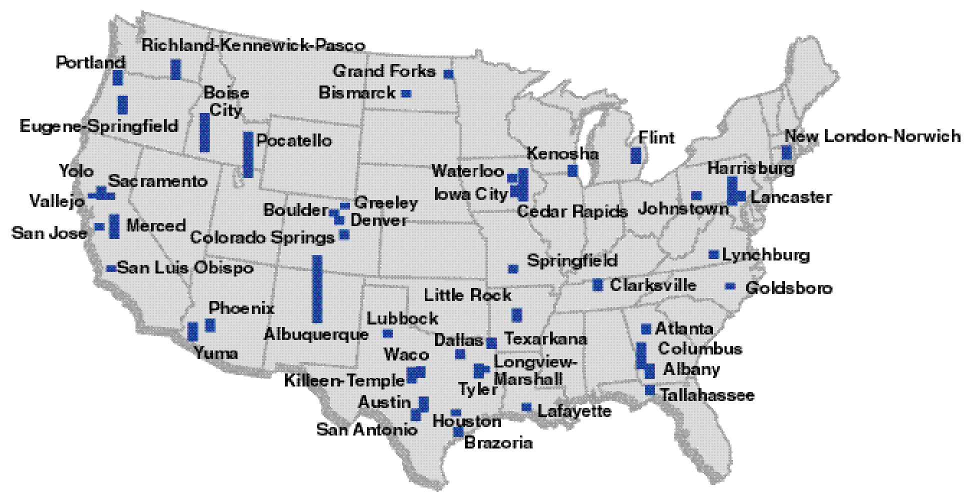
...followed by Pocatello, Boise, Cedar Rapids, Harrisburg, Columbus, GA, Merced, Richland, and Austin.

Figure 4

Relative High-Tech Real Output Growth, 1990–1998



an aging seaport and home to a struggling underclass. San Diego, with it highly diversified high-tech economy, ranks 17th. Raleigh-Durham-Chapel Hill, Denver, Austin, San Francisco, Houston, and Boise round out the top 25.

Spatial concentration is important, but it does not guarantee continuing high-tech growth. And here, with smaller clusters in the midst of rapid expansion, the rankings are quite different (see Figure 4). Albuquerque is at the top, recording a compound annual growth rate of 12.7 percent in high-tech output during the 1990s. This is almost entirely attributable to Intel's investments in electronic components and accessories production.

Pocatello and Boise are second and third, respectively. (Boise is home to Hewlett-Packard's laser-jet printer division as well as to Micron Technologies.) Cedar Rapids and Harrisburg, rapidly growing centers of electronic component manufacturing, are fourth and fifth. Columbus, GA, ranks sixth due to computer and data processing services. Merced, CA, recorded strong growth in pharmaceuticals, albeit on a very small high-tech base. The Richland, WA, metro area witnessed increases in engineering and architectural services. Austin, a center of computer and electronics production, ranked 10th on the index.

Eugene-Springfield, OR, has witnessed large percentage gains in computers and office equipment, communications equipment, and computer and data processing services. Albany, GA, experienced solid increases in pharmaceuticals as well as aircraft. Flint, MI, ranks high in the

1990s due to strong growth in computer and data processing services, while Portland, OR, is becoming a center of semiconductor chip and wafer production. Houston was built on energy, but its future will have a high-tech component. Indeed, the city has the distinction of being the largest metro in the top 50. Compaq, the largest supplier of PCs to the U.S. market, is based there.

High-tech manufacturing is becoming less spatially concentrated, but high-tech services may be becoming more concentrated.

Is high-tech production becoming more spatially concentrated or more dispersed? This is a complex issue and must be analyzed from several perspectives. There is evidence that high-tech manufacturing is becoming less spatially concentrated, but that high-tech services seem to exhibit strong agglomeration processes. Even though manufacturing seems to be dispersing to periphery regions, it remains highly geographically concentrated and clearly shows that agglomeration forces are exerting a continuing influence.

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Despite some evidence of rising spatial dispersion in high-tech manufacturing, it is remarkable how concentrated it remains. Agglomeration forces have an amazing ability to sustain themselves, only to be thwarted at some point by very high congestion-related costs. A combination of high costs and either obsolete technology or firms is almost required before high-tech activity begins to decline.

As we enter the age of human capital, firms' location decisions will increasingly be based on quality-of-life factors.

As we enter the age of human capital, where firms merely lease knowledge-assets, firms' location decisions will be increasingly based upon quality-of-life factors that are important to attracting and retaining this most vital economic asset. In high-tech services, strict business-cost measures will be less important to growing and sustaining technology clusters in metro economies. Locations that are attractive to knowledge-assets will play a vital role in determining the economic success of regions.

Section 4: High-Tech Industries and Economic Risk

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On balance, the benefits to the economy from technology far exceed the less-noticed negative aspects of technology-driven economic development. However, there are risks emanating from the technology industry's inherit volatility, its growing importance in the overall economy, and the closer relationship between it and the business cycle of the U.S. economy. Will these risks prove to be severe for metropolitan areas that have developed high-tech clusters that are prone either to technology cycles or to fluctuations emanating from the broader economy, or is high tech immune to the business cycle?

Is high-tech immune to the business cycle?

Because high-tech industries account for so large a share of national output today, the economy is more vulnerable to a high-tech contraction than ever before. A synchronous shock spread across a number of related technology industries, such as computers and semiconductors, in combination with some other inauspicious development could cause a recession in the entire economy.

Application of information technology likely will dampen business cycles in the future. IT is improving businesses' ability to manage inventories and reduce a key source of contractions in the broad economy. Changes in inventory investment are responsible for a very large proportion of the change in total business investment over the business cycle. Future business cycles will be less severe, but not extinct.

Future business cycles will be less severe - but not extinct.

We analyzed the behavior of high-tech industries over the business cycle, applying several quantitative approaches. We isolated the cyclical component from the trend and irregular (random) component of each high-tech industry output series, compared the standardized cyclical component of each industry to the economy overall, and ran regressions to determine their relative cyclicality. Lastly, we tested to see if the relationship with the business cycle is becoming stronger over time.

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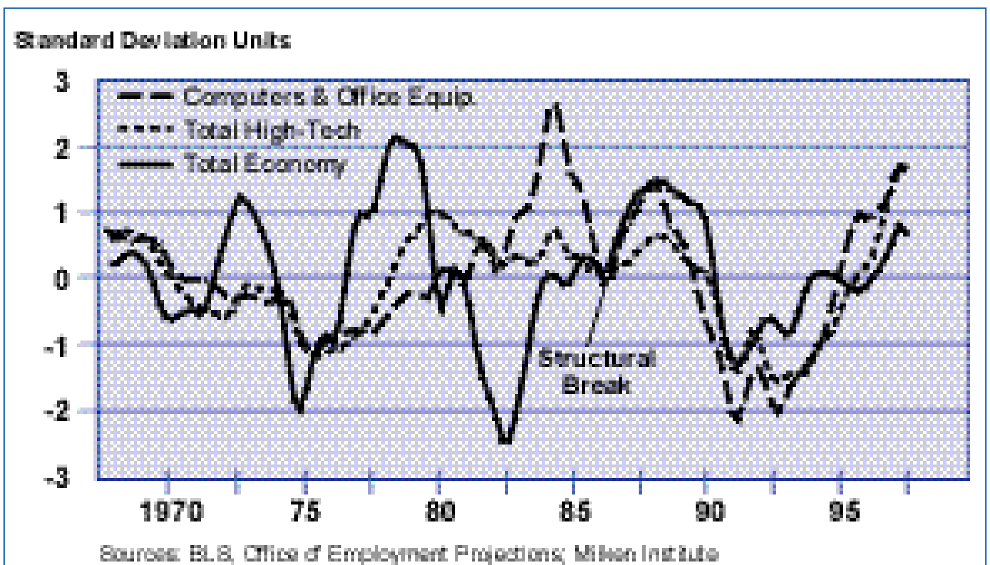
High-tech manufacturing industries are among the most volatile in the economy.

We determined that high-tech manufacturing industries are among the most volatile in the economy. A few high-tech industries lagged the cyclical movement in the overall economy, but many moved coincident with it. Several high-tech industries that were not highly correlated with the overall economy between 1965 and 1985 did show a relationship after 1985. Computers and office equipment has been cycling much more closely with the overall economy since 1985 (see Figure 5). The cyclical movement in computers approximately matched that of the overall

Figure 5
Computers Align with the Business Cycle
Cyclical Component Divided by its Standard Deviation



economy in the most recent business cycle. Industries such as communications equipment, electronic components and accessories, and computer and data processing services exhibit this pattern as well.

What does the closer co-movement between these industries and the business cycle mean for high-tech clusters around the country? In an attempt to address this question, we hypothesized that a simulation of a recession at some point in the future could show us how individual high-tech industries might behave. We chose to simulate a 1990-91 style recession, which was mild by historical standards with just a 1.0 percent-peak-to-trough decline.

Based upon our estimated relationships, high-tech manufacturing industries would experience a substantially more severe decline than the overall economy and could even exacerbate the overall decline in the economy. For example, the estimated peak-to-trough decline in computers and office equipment is 11.9 percent, closely followed by aerospace (Table 1). Output of electronic components also falls by more than the overall

Computers have been cycling much more closely with the overall economy since 1985, nearly matching it over the most recent business cycles.

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Communications equipment, electronic components, and computer and data processing services exhibit this pattern as well.

Table 1
High-Tech Sensitivity to Recession
Ranked by Peak to Trough

	SIC		Percent Decline, Peak to Trough	Percent Decline, Cycle Relative to Trend
1	357	Computer & Office Equipment	-11.9	-21.2
2	372	Aircraft & Parts	-10.7	-15.7
3	376	Guided Missiles, Space Vehicles, & Parts	-10.7	-15.7
4	871	Engineering and Architectural Services	-8.5	-4.7
5	381	Search & Navigation Equipment	-3.2	-8.2
6	367	Electronic Components & Accessories	-2.6	-14.5
7	382	Measuring & Controlling Devices	-2.4	-8.6
8	366	Communications Equipment	-1.9	-10.7
9		Total Economy	-1.0	-4.9
10	481	Telephone Comunications Services	0.8	-3.7
11	781	Motion Pictures	1.3	-3.7
12	737	Computer & Data Processing Services	1.9	-7.5
13	283	Drugs	3.9	-1.0
14	384	Medical Equipment, Instruments, & Supplies	3.9	-0.5
15	873	Research & Testing Services	8.4	-3.6

Source: Milken Institute

economy. Drugs and medical equipment are the only manufacturing industries that continue to grow during the recession. Engineering and architectural services experience a peak-to-trough decline of 8.5 percent in this simulation. Output continues to grow in the other four high-tech service industries, but growth slows substantially.

In future recessions, metros with dense concentrations of computers, aircraft, communications equipment, and electronic components will be the most impacted.

The most severely impacted metros have dense concentrations of computers and office equipment, aircraft, communications equipment, and electronic components. Metros with a heavy reliance on high-tech services are generally not affected, but because of high-tech services' growing susceptibility to the business cycle, they will be more exposed in the future.

This analysis suggests that metros that have experienced a high degree of success in developing clusters of computer, semiconductor, and other high-tech manufacturing industries should be more aware of the potential risks that a recession could pose to their local economies. Most economic development and government officials have encouraged these industries to locate within their borders, hoping that this might help insolate them from future business cycles. While high-tech industries will assist cities' long-term relative performance, they are unlikely to shield them from fluctuations in the aggregate economy.

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Section 5: Key Economic Development and Business Planning Implications

In light of the tremendous opportunity for employment creation and income gains, as well as the potential risks of national and regional economic downturns, a technology-based economic development strategy must be carefully formulated.

A technology-based economic development strategy must be carefully formulated.

Table 2 lists a set of variables that influence the development of regional high-tech industries. We divide those factors into three groups: public policy, comparative location benchmarking, and social infrastructure development. We rated each factor based upon its effectiveness in helping to establish a regional high-tech cluster in the different stages of regional economic development. All factors in the table are interrelated; their integral nature lends importance to the role of local government in the development process.

State and local governments, public policies, and the interaction between private and public sectors are crucial for the genesis, expansion, and fortification phases of high-tech development. Nonetheless, due to the unique characteristics of high-tech industries, government's role also is limited. Overly active government intervention and public policy may be counterproductive and even harmful to the long-term development of high-tech industries.

Table 2
High-Tech Development Factors

	Inception	Growth	Fortification
Public Policy			
Tax Incentives	• • •	•	
Public Investment	•	• •	
Commercialization of Ideas	•	• •	• •
Comparative Location Benchmarking			
Cost Factors	• • •		
Research Institutions	• • •	• • •	• • •
Skilled or Educated Labor Force	• •	• • •	• • •
Transportation Center	•		
Proximity to Supplies & Markets	• •	•	•
Social Infrastructure Developments			
Attending Changing Needs		• •	• • •
Re-education & Training Facilities		• • •	•
Establishing Trade Groups, & Affiliations		• • •	• • •
Housing, Zoning, & Quality of Life	• •	• •	• • •

• • • *Critical*
• • *Very Important*
• *Important*

State and local governments, public policies, and their interaction between the public and private sectors are crucial for all stages of high-tech development.

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Research centers and institutions are undisputedly the most important factor in incubating high-tech industries.

Research centers and institutions are undisputedly the most important factor in incubating high-tech industries. A side effect of the technical capability and scientific research activities of these institutions is the training and education of the skilled labor that will be critical to the expansion and reinforcement of regional high-tech industries. The federal government had an unintended impact on the formation of high-tech clusters around the country through its location of research centers and allocation of grants. Formation of public-private ventures that aim to establish and maintain leading-edge regional research centers and educational institutes is a critical long-term economic growth strategy. Raleigh-Durham-Chapel Hill, NC, represents one such success.

In the initial stages of high-tech manufacturing development, with other factors being equal, low-cost regions have a distinct advantage. The dispersion of high-tech manufacturing and processing from Tech-Pole regions such as Boston has intensified. As technology application is broadly adapted, more standardized forms of high-tech manufacturing can

Although initially important, low cost is not a sustainable comparative advantage in high-tech industries.

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Government's function should be to jump-start the development process.

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Growth-oriented firms should tap into the next rising tech-cluster regions.

be moved to low-cost locations. Proximity to suppliers and markets is becoming less relevant today as communication and shipping costs fall. If initial low-cost regions cannot establish agglomeration as their location costs rise, they can easily be superceded by other locations. So, while important initially, low cost is not a sustainable comparative advantage in high-tech industries. Since the new high-tech economy is globally based and hence has great mobility, a high-tech company can move from one region or country to another in a relatively short period of time.

The San Francisco Bay Area is the most expensive location in the country, yet the Bay Area remains the most concentrated Tech-Pole in the country. One cannot rule out the possibility that the success of high-profile metropolitan areas is based at least partially on the high cost of doing business in those regions. High costs can become the catalyst for the existing firms in the region to pursue higher revenues through inventing new concepts and products. High costs also force out marginal or older products, an evolutionary step that is both necessary and essential for the high tech cluster to remain at the leading edge of technology innovation.

Tax rebates and incentives can be a good tool in laying the foundation for corporate placement and particularly can help smaller entrepreneurs set up basic operations. Government entities should be cautious in distinguishing and recognizing the orientation of such policy, however. Government's function should be, at most, to jump-start the process. Providing a readily available labor pool is probably the best investment that state and local governments can make.

The process of establishing a high-tech economy is complex and multifaceted. Its evolution is totally dynamic and in many aspects self-guiding. Developing a regional culture that is amenable to change and growth and building a society that is open to new ideas are probably the best strategies and principles government can have to both attract and expand high-tech industry.

Just as we have changed our view about the contents of technology from a relatively pure form of products to a more complex combination of ideas, creativity, and entrepreneurial activities, economic development policy should adjust to being about the building of cultural and social environment as well as physical infrastructure. Establishing local public and private trade groups and affiliations is a sound policy in promoting the exchange of ideas, trade information, and public awareness of the development. Attending to the needs of local firms and newcomers alike will help the region in attracting the desired skilled labor.

The opportunity is tremendous for growth-oriented firms and business to tap into the next rising tech-cluster regions, where the customer base is widening and their needs are customized. More important, operating in the high-tech region and among firms that gain the first experience and knowledge of the next wave of change is a supreme competitive advantage.

There is nothing more dramatic than the impacts of the high-tech service boom upon the commercial and office construction markets. Mushrooming Internet Web-service firms and graphic design studios change the concept of space planning and building. A growing high-tech region rapidly transforms the local community. New tech clustering and rapid accumulation of wealth in a regional market creates business opportunity ranging from home building to retail. Professional service providers should be equally vigilant about the high-tech frontier development. These new and relatively smaller enterprises tend to utilize their limited and precious capital to create new ideas and products.

New tech clustering and rapid accumulation of wealth creates business opportunity ranging from home building to retail.

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Conclusions

The application of IT is improving productivity growth and boosting the long-term growth path of the U.S. economy. Advances in technology have created entirely new growth industries, such as e-commerce, and enabled truly globally integrated firms. Although remnants of the old economy remain, the New Economy is here. Core information technology industries — electronic components and accessories, computer and office equipment, and computer and data processing services — are the fastest-growing in the U.S economy.

High-tech industries are critical in gauging the health of the U.S. economy. They are determining which metropolitan areas are succeeding or failing. Without growth in high-tech sectors, metros will be left behind. In order to foster high-tech growth, metropolitan areas must understand what location factors are most important to high-tech firms. That high-tech clusters are perceived as important is clear from the worldwide attempts to repeat the success of Silicon Valley. Cloning Silicon Valley will be impossible, however, because the proper DNA sequence is locked away somewhere on Sand Hill Road. Those regions that come closest to duplicating Silicon Valley, however, will be the leading technology centers in the early stages of the 21st century.

Cloning Silicon Valley will be impossible because the proper DNA sequence is locked away somewhere on Sand Hill Road.

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The high-tech economy does pose risks for metropolitan areas. Technology-driven economic development is causing a widening of income disparity along educational attainment levels, reducing job security and job tenure, and resulting in greater risk of unemployment among workers in their 50s. Further, high-tech manufacturing industries are becoming more sensitive to the business cycle. Nevertheless, it is imperative for local government and economic development officials to promote high-tech expansion, or they risk substandard economic growth in the future. Although high tech is not the only development strategy to pursue, it will be the key distinguishing feature of metropolitan vitality as we enter the new century.

It is imperative for local government and economic development officials to promote high-tech expansion.

Introduction

For some years observers have assumed that it is technological innovation that is powering the Great American Prosperity Machine and sustaining America's preeminence in industries ranging from pharmaceuticals to entertainment to software. Only very recently have economists been able to piece together evidence to quantify that technology really is translating into higher productivity nationwide. And only now can we see how it is driving success (and failure) in local economies.

Now we can see how technology is driving success (and failure) in local economies.

Technology and high-technology (high-tech) industries are central to understanding the economic well-being of nations, regions, firms, and individuals as we enter the 21st century. Many terms are used to describe technology's impact on the economy and future. Some refer to the application of technology as the "New Economy"; others believe that we are entering the age of "knowledge-based capital," whether physical or human. The term "high-tech" is probably oversubscribed, but we believe that the U.S. economy is currently in the midst of the most dramatic technology-driven development in its history.

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This study's main focus is to examine technology's importance in determining the relative economic performance of metropolitan areas and what lessons can be applied to the future. To do so, we first establish technology's role in promoting economic growth in the aggregate U.S. economy. We also examine the sensitivity of high-tech industries to future business cycles and the likely impact on metropolitan economies. Lastly, we offer some implications and suggestions for economic development officials and business firms. The study is divided into five sections. An appendix describes each of the industries that are included in our definition of high technology and discusses developments in them.

This study's main focus is to examine technology's importance in determining the relative economic performance of metropolitan areas.

In Section 1, "Technology and U.S. Growth Potential," we establish what role the application of technology is playing in promoting long-term economic growth. Theory and evidence of how information technology aids micro and macro performance of the U.S. economy is examined. In what ways should investment in technology boost long-term economic growth? Are information technology and related knowledge-based services improving productivity growth in the U.S. economy? Is there evidence to support the proponents of a "New Economy?"

Section 2, "National High-Tech Industry Performance," catalogs many measures of technology's growing assimilation throughout the economy. Further, it defines and reviews the industries in our study. How dependent

Some of the questions we ask are: How important is the geographic clustering of high-tech industries to the relative economic growth of metropolitan areas?

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What type of economic environment helps create and foster superior development?

is the U.S. economy on information technology in its investment patterns? How have technology workers' wages performed relative to those of non-technology workers — is the gap growing larger? How large is high tech in the United States and how important is it in determining overall growth? Which high-tech industries are experiencing the most growth?

Section 3 is the focal point of our study, entitled, "Technology and Metropolitan Economic Performance." It examines many spatial dimensions of high-tech economic activity and highlights the theoretical underpinnings of economic geography and, more particularly, the agglomeration processes as they pertain to technology industries. How important is geographic clustering of high-tech industries in determining the relative economic growth of metropolitan areas (metros) in the 1990s and can this be measured quantitatively? Which metros lead in technology industry vertical density and horizontal depth, and are true technology-production centers? What factors determine where high tech is concentrated and where the greatest growth is occurring? How can high-tech industries promote growth in local non-high-tech sectors? Are agglomeration (centripetal) forces causing high tech to be more concentrated or are countervailing centrifugal forces causing a dispersion of high-tech industries?

Section 4, "High-Tech Industries and Economic Risks," analyzes risks emanating from high tech as they relate to the industry's inherit volatility, its growing importance in the overall economy, and the closer relationship between it and the business cycle of the U.S. economy. Will the assimilation of technology into virtually all economic sectors leave high-tech industries more exposed to fluctuations in the broad economy than ever before? Have high-tech industries become more sensitive to the business cycle over time? What might be the impact for metros with a large concentration of high-tech industries?

Lastly, in Section 5, "Key Economic Development and Business Planning Implications," we highlight economic development issues as they pertain to high-technology industries. Further, we translate the findings of the study into implications for established firms and new business formations in terms of expansion plans or location analysis. What type of economic environment helps create and foster superior development? Can economic policy induce high-tech industry formation and augment clustering in a region? If they can be duplicated, what kind of public policy and economic development strategies can expedite and fortify development in the future? What non-high-tech businesses can benefit most by monitoring newly emerging technology centers?

The Appendix, "High-Tech Industry Profiles, contains a review of the industry structure, changes in the industry, measures of industry size and performance, and issues relating to future developments of high-tech industries as classified in this study.

Section 1
Technology and U.S. Growth Potential

High-technology industries are critical in gauging the performance of the U.S. economy. They comprise an ever-increasing proportion of economic output and therefore are more important for monitoring business-cycle developments. A compelling case also can be made that the high-tech sector is boosting the long-term potential growth path of the U.S. economy. Technological advancement embodied in both new and more efficient traditional capital goods, and innovative implementation of them in the business sector, are prime determinants of economic growth (Jarboe and Atkinson 1998).

Due to acceleration in technological advances and innovation in computers, communications equipment, other high-tech products and the associated knowledge-based services, demand in these sectors during the 1990s has been rising at an increasing pace. As stated by Joel Mokyr, an economic historian at Northwestern University consulted by *BusinessWeek*, "We've never had a period in which innovation has so permeated our lives as in the 1990s."

Information technology is ubiquitous, directly or indirectly invading nearly all sectors of the U.S. economy. Information technology is transforming the mix of economic activity away from traditional sources, such as consumer durables and business investment in structures, while at the same time augmenting the level of aggregate output. "Information technology" (IT) is the term used to describe the infrastructure and knowledge that is necessary to make information available rapidly. IT increasingly comprises the software and communication services that patch equipment together. Advances in IT in recent years have created entirely new growth industries including e-commerce, online information services, mobile communications, and rapid advances in medical research. IT has spurred rapid, seemingly continuous innovation by creating networks that generate value through productive interactive relationships or collaboration. In the past, innovation transpired predominately by more discrete advances in research and development. We are still witnessing the early stages of the impact of IT and other newly emerging technologies on the potential growth of the U.S. economy.

Technological advancement embodied in both new and more efficient traditional capital goods, and innovative implementation of them in the business sector, are prime determinants of economic growth.

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IT has spurred rapid, seemingly continuous innovation by creating networks that generate value through productive interactive relationships.

Firms have been investing in IT in an effort to boost production efficiencies, improve communication flows, and enhance overall business operations.

A substantial portion of business costs involves the collection, exchange, and use of information (Williamson 1990). Information exchange is at the core of an efficient market-based economy. Markets function by interactions among producers, suppliers, vendors, financial intermediaries, brokers, trading partners, and, ultimately, consumers. In a globalized economy, information is the most valuable resource. Firms have been investing in information technology in an effort to boost production efficiencies, improve communication flows, and enhance overall business operations. Firms believe that these investments yield rewards, such as higher profitability, by reducing the growth of unit labor costs through greater advances in productivity. Even Federal Reserve Chairman Alan Greenspan, who is notorious for obfuscation, has noted the importance of IT in testimony before Congress, "Our nation has been experiencing a higher growth rate of productivity — output per hour worked — in recent years. The dramatic improvement in computing power and communications and information technology appear to have been major forces behind this trend." A fundamental question is: How much of the increase in productivity growth is sustainable?

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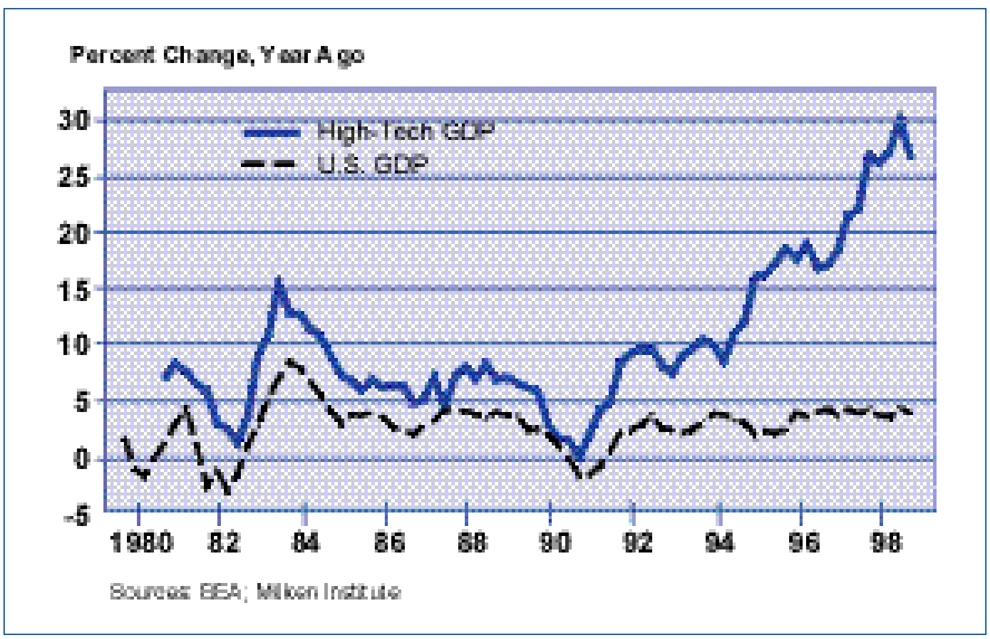
Since the 1990–91 recession, growth in the high-tech sector has been four times as large as growth in the aggregate economy.

While the recent positive economic evidence on the impact of investment in high technology may be inconclusive in a statistical sense, there can be no disagreement on how strong growth has been in recent years. The Milken Institute has constructed an end-use demand measure of high-technology products and services in an attempt to calibrate their rising contribution to economic growth. Figure 1.1 displays the surge in demand for the high-tech sector during the 1990s. This measure includes business

Figure 1.1
High Tech Surges in the 1990s
High Tech vs. Total Real GDP



and consumer purchases of computers and related equipment, communication equipment, scientific and engineering equipment, drugs, telecommunication services, pre-packaged software, cable TV, and other related sectors. Since the 1990-91 recession, growth in the high-tech sector has been four times as large as growth in the aggregate economy. During the 1980s, the high-tech sector grew approximately twice as fast as the economy. Over the past three years, growth in high-tech products and services averaged over 20 percent, directly elevating real GDP growth by 1.5 percentage points.

Technology and Growth Theory

Standard of living is directly tied to productivity growth.

The contribution of technology to economic growth has been debated since the time of the classical economists. Today, growth theorists generally agree that technological change is a major determinant of long-run economic growth. However, they disagree substantially on the contribution of technology relative to other factor inputs and the amount of technological change that is due to physical capital as opposed to human capital. Technological advances improve the degree to which inputs of physical and human capital are translated into output growth. To the degree that output grows more rapidly than the weighted-factor inputs, productivity growth is enhanced. Productivity growth (the rate of growth in output per unit of input, usually expressed in output per man-hour) is a key determinant of the long-run aggregate supply in the U.S. economy. Our standard of living is directly tied to productivity growth.

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The production function postulates that differing combinations of inputs can be used to produce a given level of output.

The theory of an aggregate or economywide production function has been used for several decades to evaluate the productivity of various factor inputs such as capital, labor, and R&D expenditures. Basically, the production function postulates that differing combinations of inputs can be utilized to produce a given level of output. Many have contributed to the literature in this area, but Robert Solow has long been a major figure in the advancement of growth theory, winning a Nobel Prize for his efforts. His pioneering work in the development of the neoclassical growth model was the foundation for modern growth theory (Solow 1957). Solow's theoretical framework, which decomposed contributions to output from capital and labor on the basis of a constant-returns-to-scale production function, helped establish a temporary consensus in the 1970s on growth theory. The neoclassical model allowed the substitution of capital for labor. Solow found that a small fraction of economic growth could be assigned to labor, and that capital formation accounted for approximately one-third of growth. This leaves a large residual that is assigned to technological progress. In Solow's model, technological progress was exogenously (outside the system) determined, dubbed the "Solow residual."

Assigning such a large portion of output growth to exogenously determined technological progress was a troubling concept for

New growth theorists hypothesize that knowledge has a separate and distinct impact on promoting technological advance.

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Solow quipped that "you can see the computer age everywhere but in the productivity statistics."

theoreticians, leading many others to attempt to develop alternatives to Solow's model. In the late 1980s, a diverse set of theoretical and empirical work began to emerge as endogenous, or new, growth theory. This body of work differentiates itself from neoclassical growth by emphasizing that economic growth is an endogenous outcome of a dynamic economic system, not the work of some mystical force emanating from outside. Endogenous growth theory postulates several channels through which technology, human capital, and the creation of new ideas enable a virtuous circle and feedback to economic growth (Romer 1990 and Barro 1991). This is critical in attempting to determine the contribution of information technology to the growth process and, specifically, how much it might improve productivity growth. New growth theorists postulate that knowledge has a separate and distinct impact on promoting technological advance. Technology innovation, stemming from improved knowledge, is the key to productivity improvements in their view.

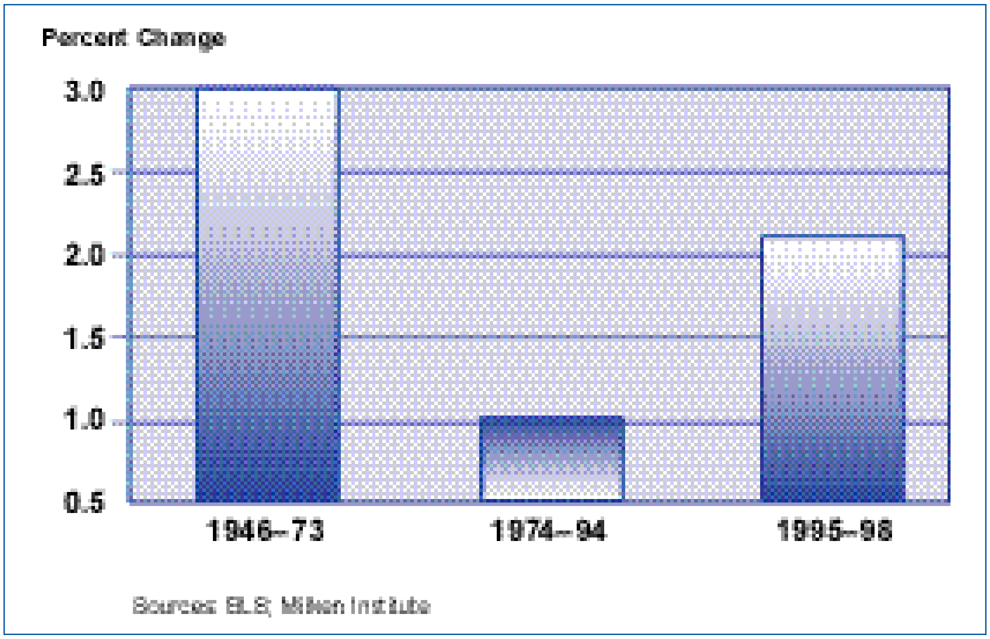
What does this imply for the role that advances in information technology and its diffusion play in long-term economic growth and productivity? Applying the production function, the elasticity of output with respect to IT investment should be higher than non-IT forms of investment. In other words, a buildup in the stock of information technology, both physical and human, should add proportionally more to enhancing long-term economic growth than an equal gain in the stock of other factor inputs. At the firm level, as businesses substitute IT for other inputs, they will lower production costs for a given level of output or increase production while holding overall costs constant. As firms throughout the economy employ IT more effectively over time, the aggregate potential growth path of the U.S. is boosted.

Historical Evidence of Technology and Growth

Despite the intellectual appeal of new growth theory, the historical evidence over the past several decades is mixed. The central inconsistency is that while there has been a massive investment in computers and other information technology since the late 1970s, the rate of productivity growth in the U.S. economy has slowed.

Labor productivity (output per man-hour) growth averaged over 3.0 percent annually during the postwar period through 1973, but fell to a sluggish 1.0 percent thereafter (see Figure 1.2). When measured on the basis of multifactor productivity (which measures output growth relative to all factor inputs), which fell from around 2.0 percent before 1973 to 0.3 percent annually through 1994, the productivity record is even worse. This led Solow himself to quip that "you can see the computer age everywhere but in the productivity statistics." Some economists have dubbed this inconsistency "the productivity paradox."

Figure 1.2
The Productivity Paradox
Output per Man-Hour (Nonfarm, Private)



IT Pessimists

One of the main arguments from the pessimists on information technology's impact on productivity growth stems from the relative size of IT compared to other factor inputs. Many contend that IT investment simply could not have an appreciable impact on productivity growth because it is too small. Daniel Sichel, an economist at the Federal Reserve Board, argues in a recent book that computers account for only about 2 percent of the United States' total capital stock (Sichel 1997). He suggests that even if the return on computers is above that on other investments, their overall contribution to economic growth will be modest. Furthermore, he argues that the high level of corporate spending on computers exaggerates their importance because of the rapid obsolescence of the investment. Consequently, the net investment of new computers is relatively small.

Other IT pessimists argue that firms have reacted as they should to declining prices of computers, namely by substituting them for other relatively more-expensive inputs such as labor or other types of capital. Thus, the computer revolution is mainly a story of substitution rather than productivity growth. This suggests that the frenetic pace of IT investment is merely wheel spinning — altering production inputs without increasing output rather than creating real advances in productivity. Some believe that firms are investing in IT on blind faith. They argue that productivity

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Some believe that firms are investing in IT on blind faith.

gains were realized from the investments made in the 1960s on large, transaction-heavy mainframe computers because a coherent, well-executed plan was implemented. By contrast, investment in today's decentralized personal computer world has not been thought out as well. The computer systems that have been purchased were not subjected to the proper investment appraisal process. It is even suggested by some that these funds could have been better invested in research and development, employee training, and managerial advances. They point to studies displaying no correlation between spending on information technology and profitability by industry.

IT optimists counter that measurement error may be hiding IT's contributions.

IT Optimists

The IT optimists offer counterarguments. The first one is the measurement-error problem. Measuring output is problematic, especially in the service sector, which is not only a growing segment of the economy but an area where IT should contribute significantly to productivity growth. Baily and Gordon (1988) attribute much of the dramatic slowdown in productivity growth in the United States after 1973 to improper measurement of quality-adjusted output. They note that productivity in computer manufacturing has increased dramatically in the official data, but productivity resulting from computer use is not apparent. The use of a hedonic price index (which measures computer-processing power in the computer industry) is a key reason for this. The hedonic index adjusts the price to reflect the increase in the quality of computers by focusing on the cost of performing a calculation in a constant time period. They conclude that IT is providing valuable customer services that are not reflected in the official output data. An increasing number of consumer services offers improved convenience as a result of IT investment, but it is unlikely to be measured accurately.

When measures other than the BEA's standards are used, strong productivity growth often is witnessed.

The best example of improved convenience is seen in the financial services industry. Information technology allows firms to provide sophisticated cash management accounts, almost costless portfolio diversification through no-load mutual funds, 24-hour money access machines, banking by phone, and, now, Internet banking. Nevertheless, in the banking, credit agencies, and securities industries, the Bureau of Economic Analysis (BEA) uses labor input to extrapolate real output changes. The only way the BEA could report an increase in overall productivity in the financial services industry is through a change in the composition of industry output. When other measures of output are utilized, such as total trades per employee in the stock brokerage industry, or number of checks processed per employee in the banking sector, strong productivity growth is witnessed.

The second major argument is the technology diffusion argument. This says that a new technological innovation such as IT may require a substantial time period before being absorbed throughout the economy. In this view, IT has not yet been exploited fully. The optimists say that there are three phases of technology improvement: invention, innovation, and diffusion. The invention of a technology may occur far in advance of developing a way to incorporate it into a new production process as an innovation. Even if this results in rapid productivity improvements for the firm that developed the innovation, it may take years before other firms observe and copy it. Optimists point to the innovation of the dynamo, the fundamental electromechanical conversion device, which was not immediately apparent in the productivity statistics, either. Several decades passed before industries began to apply this technology. The slow diffusion of the dynamo (electrification) delayed any significant impact on productivity growth until the 1920s. Optimists believe that in the case of IT, a combination of formal education and applications-oriented human capital will lead to the successful transformation of the IT revolution into sustained productivity gains. As more firms employ IT to innovate and are copied, aggregate productivity gains will become more apparent.

IT optimists observe three phases of technology improvement — invention, innovation, and diffusion - none of which may occur simultaneously.

If the optimists are correct and diffusion is the key to realizing productivity growth from IT investment, there should be some indication of this in the sectors of the economy that deployed an innovation first. The most encouraging evidence of IT boosting productivity growth is found in durable manufacturing. Output per man-hour in the durable manufacturing sector has grown at an average annual rate of 5.0 percent since 1990 (see Figure 1.3). During the 1980s, that sector's productivity grew at an average rate of 3.2 percent. Output growth in the

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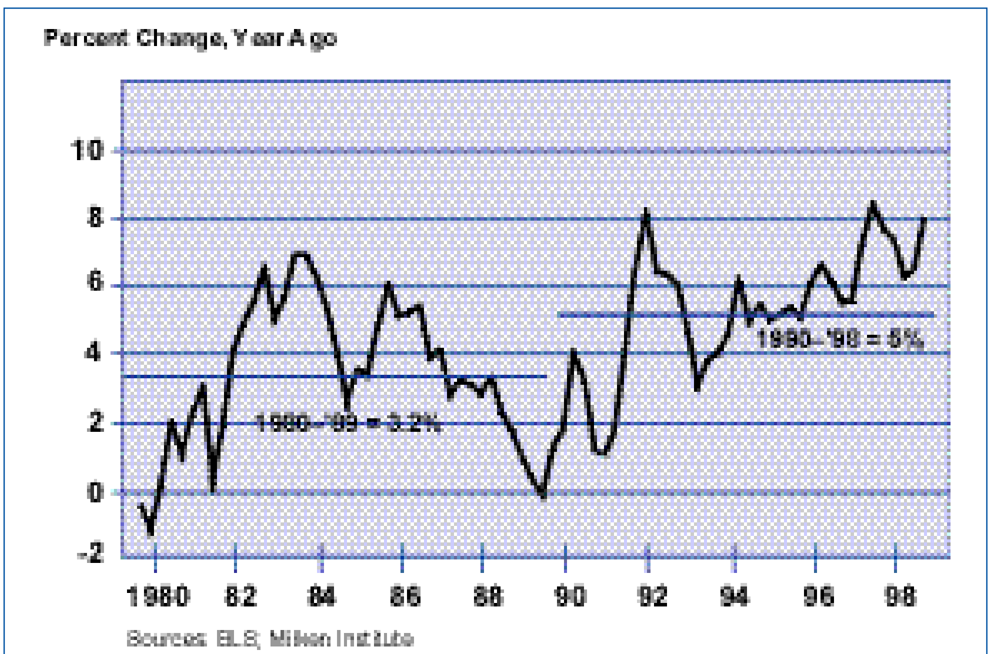
Figure 1.3
Productivity Increases Durable Goods
Output per Hour of all Persons



In the durable manufacturing sector, output per man-hour has grown at an average annual rate of 5.0 percent since 1990.

manufacturing sector is easier to define and accurately measure than growth in other sectors. The price deflators for most manufacturing industries better reflect the quality improvements in the finished product, increasing the reported real or inflation-adjusted output. This evidence supports the optimists' contention that measurement error is a problem because much of IT investment has been concentrated in service sectors, where new forms of output attributable to IT innovations are difficult to quantify.

Several recent studies at the firm level have documented gains in productivity from IT investment.

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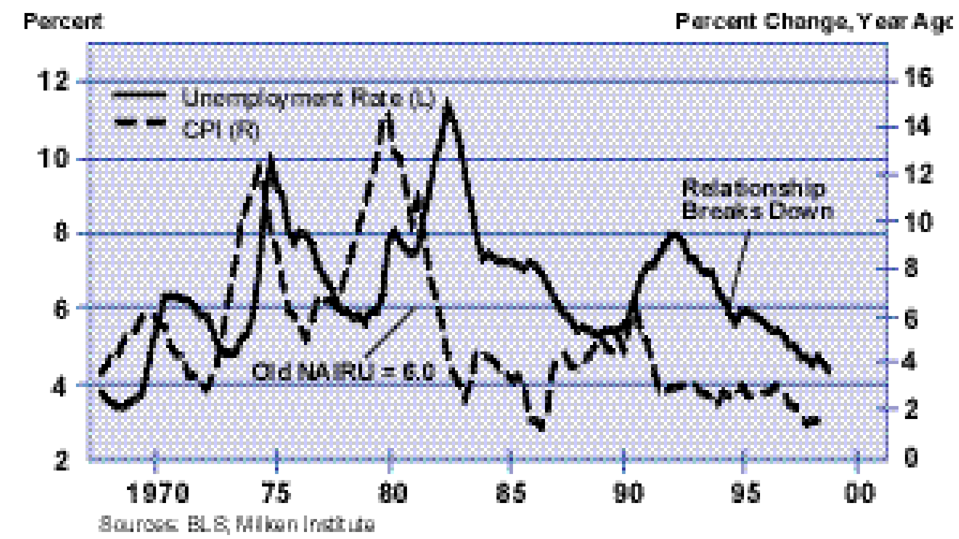
New Economy proponents believe that the U.S. economy can sustain faster growth, with labor and capital more heavily utilized, than was previously believed possible without triggering inflation.

Another way to examine if IT investment is having a productivity payoff is to analyze micro evidence. Several recent studies at the firm level have documented gains in productivity from IT investment. Brynjolfsson and Hitt (1996) performed one of the most compelling studies; they found strong evidence of firm-specific returns to IT investment. They collected data on firm investments in IT hardware and IT labor and combined them to create an overall measure of "IT Stock." They then applied a production function approach by relating three factor inputs (IT Stock, Non-Computer Capital, and Labor) to firm Value Added. Their results indicate that the output elasticity with respect to IT capital stock was very high and that productivity was much higher in firms with larger IT capital stocks. They estimated that the gross rate of return on IT investment was near 50 percent, compared to 15 to 20 percent for other investments. They concluded that the productivity paradox at the firm level has disappeared since 1991.

Other organization-level evidence supports their findings. Lichtenberg (1995) analyzed data for hundreds of companies for the period 1988-92. His results displayed that the organization-level rate of return on information technology investment was more than three times the rate of return on investment in other non-IT equipment or structures. Further, his results indicated that information systems employment made a larger contribution to output growth than any other type of employment. There is a substantial body of firm-level literature that strongly supports higher rates of return and productivity from information technology investment. This lends support to the IT optimists' position that there is an underreporting of output growth, causing a downward bias in the official aggregate productivity statistics.

Many economists are encouraged by the exemplary performance of the U.S. economy since the 1990-91 recession. By many measures, the 1990s have exhibited unanticipated prosperity. The dynamic nature of IT spending and its rising importance in total investment in the economy have caused some to herald the dawn of a New Economy, which would foster economic growth at a rate closer to that which prevailed during the 1950s and 1960s. New Economy proponents believe that the U.S. economy is able to sustain faster growth, with labor and capital more heavily utilized, than was previously believed possible without triggering higher inflation. In essence, the sustainable, noninflationary growth potential of the U.S. economy is higher.

Figure 1.4
NAIRU Falling
Unemployment Rate and CPI



A central piece of their supporting evidence is the benign behavior of inflation in the face of tight labor markets during the 1990s expansion. Most economists believed that the nonaccelerating inflation rate of unemployment (NAIRU), or the rate of unemployment that would cause inflation neither to accelerate nor decelerate, was between 6 percent and 6.5 percent. With the unemployment rate below 5.5 percent for over two years, core inflation has been benign (see Figure 1.4). Temporary auspicious developments such as plunging oil and commodity prices and moderating health care costs have helped restrain inflationary pressures. Nevertheless, most economists acknowledge that the NAIRU is lower than previously anticipated. New Economy proponents contend that innovative implementation of information technology is playing a large role in this improved inflation performance.

With the unemployment rate below 5.5 percent for over two years, core inflation has been benign.

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Another key piece of corroborating evidence from New Economy proponents is the improved productivity performance over the past three years. Output per man-hour in the nonfarm business sector rose by an average of 2.1 percent from 1996 through 1998. What is encouraging about this development is that it is occurring at a mature stage of an expansion, typically the time when productivity growth begins to wane, hinting at a possible long-term productivity improvement. Drawing conclusions on the basis of only three years of data is precarious; nevertheless, these observations suggest that something real might be happening. Some New Economy proponents believe that the long-term real GDP growth rate has risen to 3 percent, based upon 2 percent productivity growth and labor force growth of 1 percent.

Output per man-hour in the nonfarm business sector rose by an average of 2.1 percent during 1996-98.

Real output growth is understated in much of the service sector, partly because government agencies have not been adequately funded to develop appropriate ways to measure an information-age economy.

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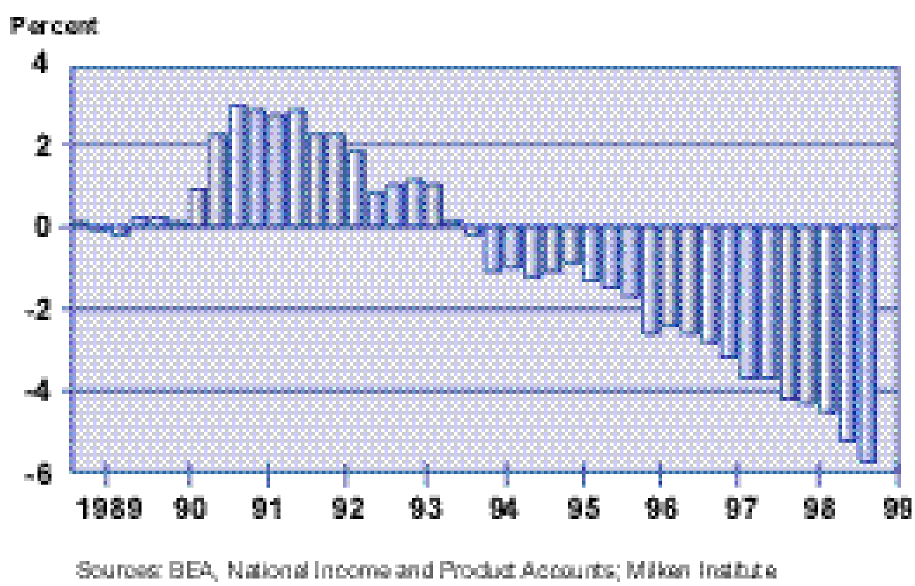
What to Conclude?

What should be concluded concerning the role of technology in promoting long-term economic growth? On the basis of macroeconomic evidence as officially reported by government agencies, it is difficult to statistically prove that the massive investment in information technology has caused a rise in long-term economic growth in the United States. This does not mean, however, that IT investment is not improving economic performance. Real output growth is understated in much of the service sector, partly because government statistical agencies have not been adequately funded to develop appropriate ways to measure an information-age economy. Nontraditional ways of measuring output in service industries show that these industries are displaying more rapid growth and, therefore, greater advances in productivity. If this underreporting of output growth were aggregated across all industries, the economywide performance of the United States would look much better.

Another way to gauge if some structural change is occurring in the economy is through the estimation of a potential GDP equation using production function methodology. If a standard production function approach, which does not differentiate between IT capital and non–IT capital, severely understates the current level of economic activity, it would support the notion that there has been some structural break in long-term economic growth. We estimated a potential GDP equation for the U.S. economy using a Cobb-Douglas production function. The size of

Figure 1.5
Actual GDP Above Potential
GDP Gap, Actual vs. Potential



the labor force is determined by use of 10-year population cohorts and labor force participation rates by age cohort and gender. The capital stock is determined by applying deprecation rates by type to estimate the net addition to the capital stock from current investment. The rate of technological change was introduced as a time trend. This equation explains the long-term path of real GDP very accurately, but actual GDP is currently above its estimated potential by the largest amount (5.7 percent) in the sample period (see Figure 1.5). It is possible that this could occur without an actual structural break in the relationship; however, it would be accompanied by accelerating inflation, certainly not decelerating inflation. IT investment may plausibly account for some of this discrepancy.

Actual GDP is currently above its estimated potential by the largest amount (5.7 percent) in the sample period.

Some New Economy proponents are overzealous in advocating their position. It is premature to conclude that sustainable productivity growth has improved from 1 percent of the past 25 years to 2 percent on the basis of three years of supporting data. Nevertheless, we must ask whether something is happening in the economy due to application of information technology. We consider ourselves to be cautious optimists. Modern technology is altering production processes throughout the economy and enabling truly globally integrated firms. With the exponential growth of the Internet, many efficiency gains and lower costs will be realized. Technological innovation has boosted productivity growth to the 1.5 to 2.0 percent range and may perhaps enable more improvement in the future. This will increase long-term economic growth to between 2.5 and 3.0 percent in our view.

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Technological innovation has boosted productivity growth to the 1.5 to 2.0 percent range and may enable more improvement in the future.

Section 2

National High-Tech Industry Performance

The U.S. economy is a dynamic living and breathing organism, constantly adapting itself to changes in its environmental conditions. Rapid epochs of technological change have occurred in the past, the industrial revolution and electrification beginning in the 1990s to name two, but currently the U.S. economy arguably is undergoing the most dramatic technology developments in its history. New technology industries should be among the top growth performers as they are diffused throughout the economy. History has demonstrated this to be the case. High-tech industries, however, are transforming the structure of the U.S. economy in an unparalleled dimension. Whether or not high-technology investments are substantially enhancing long-run economic growth, high-technology industries comprise a much larger share of the overall economy and, more importantly, account for a disproportionate share of economic growth in the United States.

High-tech industries are transforming the structure of the U.S. economy in an unparalleled dimension.

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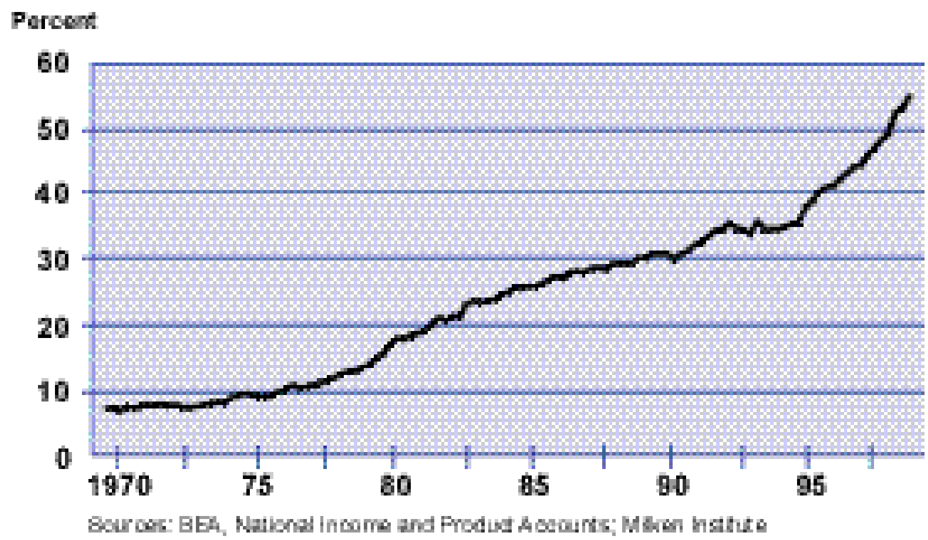
The Impact of Technology on Economic Growth

One of the most omnipresent influences of high technology has been in business investment patterns. Information technology hardware has accounted for a growing share of total business investment across a broad array of industries. In 1970, information processing equipment and related sectors represented 7 percent of real business equipment investment; however, last year it was responsible for over 50 percent of all capital spending. Most of this surge has occurred since 1980 as displayed in Figure 2.1. From 1995 through 1998, growth in real business investment in information-processing equipment averaged 25 percent, directly accounting for nearly 27 percent of total economic growth. This is a narrow definition of information technology investment that does not include a sophisticated, digitally controlled machine tool.

From 1995 through 1998, growth in real business investment in information processing equipment averaged 25 percent, directly accounting for nearly 27 percent of total economic growth.

The U.S. Bureau of Economic Analysis compiles a data set on net capital stock by industry. As part of this data collection effort, the BEA produces an estimate of the net information-technology capital stock. One weakness of this data set is that it is available only through 1994. Nevertheless, it does provide us with some perspective on IT equipment's importance relative to other equipment for many industries. In the

Figure 2.1
IT Dominates Capital Spending
Information Processing as a Percentage of Total Fixed Capital Spending



telecommunications industry, IT equipment accounted for over 86 percent of the capital stock in 1994; this percentage is probably even larger today. In the insurance and security brokers industries, IT accounted for over 80 percent of the capital stock. Industries such as motion pictures, wholesale trade, legal services, and health services all have IT capital stocks that account for more than 50 percent of their total equipment stock.

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Technology is allowing cheaper production and processing across the entire economy.

Due to rapid technological advances in computers, semiconductors, and other electronic components, prices of information technology equipment have been falling at an accelerated rate over the past several years. Because of the tremendous improvement in processing performance, the BEA adopted a quality-adjusted price index for information processing equipment in 1996. IT equipment prices adjusted for quality fell an average of 3 percent per year from 1985 through 1994. Price declines in IT equipment have accelerated over the past few years, averaging 8 percent since 1995. Prices fell by over 12 percent in 1998 for IT equipment. Declining prices in information processing equipment are restraining overall inflation in the U.S. economy. During 1997 and 1998, falling prices for IT equipment directly reduced overall inflation by over 1.0 percentage point. Technology is allowing cheaper production and processing across the entire economy.

Rapid growth in demand for knowledge-intensive workers, and the limited supply of workers with these skills, caused wages of IT workers to rise relative to non–IT workers in the 1990s (see Figure 2.2). Lower immigration of highly skilled foreign workers has worsened this problem in recent years. Within high-tech industries is a prevalence of technical and knowledge-intensive occupations. High-tech industries thus demand a substantial wage premium. One study by Princeton economist Alan Krueger demonstrated that workers who utilize computers earn 10 to 15 percent more than non–computer users, on average (Krueger 1993). IT workers earned $56,000 in 1998, more than 70 percent above the private-sector average. The average wage in prepackaged software was $84,000 in 1998. Wages in the IT sector rose 7.1 percent in 1998 versus 3.8 percent in the private sector as a whole. Lucrative stock options and profit-sharing plans are proliferating in many firms in these industries in an effort to attract premium talent. Therefore, the wage disparity alone understates the true total compensation differential between high tech and the rest of the economy.

IT workers earned $56,000 in 1998, more than 70 percent above the private-sector average.

There are many other ways that high-technology industries are impacting the U.S. economy. In order to foster leading-edge commercial application of new technology, these industries are at the top in research and development expenditures. Based upon data from the U.S. National Science Foundation, high-tech industries spent $43 billion on research and development in 1996, comprising 39 percent of company-funded research and development. High-tech service industries are accounting for a growing share of research and development expenditures. Information technology equipment exports rose dramatically over the past decade and account for a growing share of total U.S. exports. Foreign firms are purchasing U.S. IT equipment in an effort to acquire the latest technology

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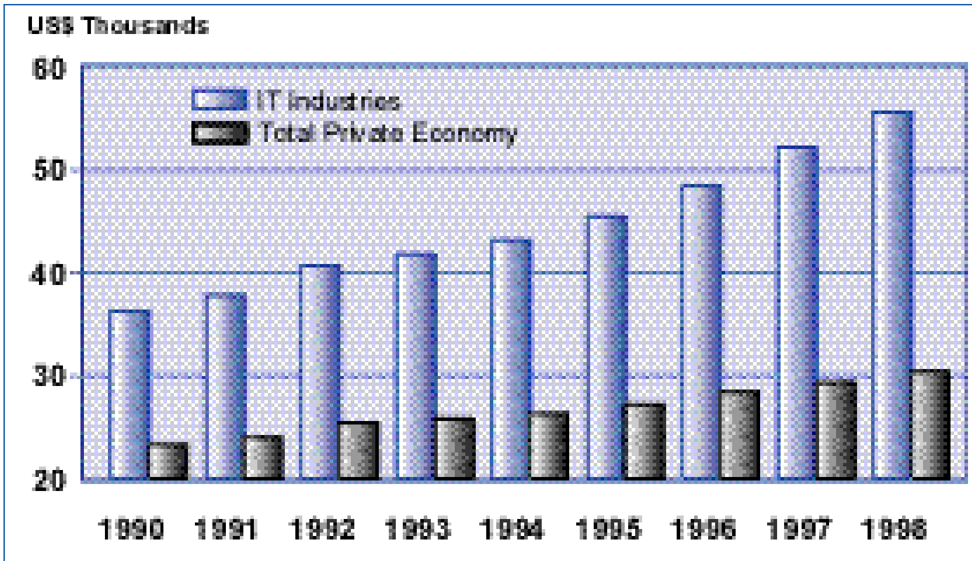
High-tech service industries are accounting for a growing share of research and development expenditures.

Figure 2.2
IT Industries Pay More
Average Annual Wages Per Worker



Sources: U.S. Department of Commerce, Milken Institute in order to improve their economic prospects. In 1998, IT equipment exports rose to $153.5 billion and represented 21 percent of total merchandise exports.

High-Tech Industries Included

One of the most difficult tasks in analyzing high-technology industries is determining which set of industries to include in the definition. This definition will vary depending upon the research interests and data availability across a number of dimensions. One approach is to focus on technology-using occupations. By this definition, electrical engineers, regardless of which industry is employing them, are included. Another approach is to include technology-using occupations that are in specific high-tech industries. Our research interests are in determining the individual contributions of high-tech industries to economic performance in the United States as a whole, but the central focus is on their impact on the relative growth of metropolitan areas. For these reasons, we are

Our definition of high tech industries includes industries that spend an above-average amount of revenue on R&D and that employ an above industry-average number of technology-using occupations.

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Table 2.1
High-Tech Industries

High-Tech Manufacturing Industries

SIC	Industry Definition
283	Drugs
357	Computer & Office Equipment
366	Communications Equipment
367	Electronic Components & Accessories
372	Aircraft & Parts
376	Guided Missiles, Space Vehicles & Parts
381	Search, Detection, Navigation, Guidance, Aeronautical Nautical Systems, Instruments, & Equipment
382	Laboratory Apparatus and Analytical, Optical, Measuring, & Controlling Instruments
384	Surgical, Medical, & Dental Instruments & Supplies

High-Tech Service Industries

SIC	Industry Definition
481	Telephone Communications Services
737	Computer Programming, Data Processing, & Other Computer Related Services
781	Motion Picture Production & Allied Services
871	Engineering, Architectural, & Surveying Services
873	Research, Development, & Testing Services

focusing on the value of output for industries that may be considered high technology. We have applied a methodology that includes industries that spend an above-average amount of revenue on research and development and that employ an above industry-average number of technology-using occupations — such as scientists, engineers, mathematicians, and programmers.

The industry groupings are based upon Standard Industrial Classification (SIC) coding . Because we needed a data set that would permit an estimation of variables at the metropolitan level, we selected a data set based on gross output and several other factors prepared by the Office of Employment Projections at the U.S. Bureau of Labor Statistics. The data conform to three-digit SIC definitions and measure output from a producer's perspective. The BLS data come from a number of sources and the output series is benchmarked to the BEA's input-output tables in order to be consistent with the national income and product accounts. The selected industries are listed in Table 2.1. Manufacturing industries such as drugs, computers and equipment, communications equipment, and electronic components and service industries such as communications services, computer and data processing services, and research and testing services are included (please see the appendix on Technology Industry

Our data set is based on gross output and other factors.

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Table 2.2
Gross Industry Output for High-Tech Industries
Compound Annual Growth Rate, 1968–1997

		Percent
1.	Electronic Components and Accessories	9.8
2.	Computer & Office Equipment	9.6
3.	Computer & Data Processing Services	9.4
4.	Medical Equipment, Instruments, and Supplies	6.5
5.	Total Technology Services*	5.2
6.	Communications Equipment	5.0
7.	Telephone Communications Services	4.8
8.	Total Technology*	4.6
9.	Drugs	4.6
10.	Measuring & Controlling Devices	4.4
11.	Research & Testing Services	4.1
12.	Total Technology Manufacturing*	4.1
13.	Engineering & Architectural Services	4.0
14.	Motion Pictures	3.9
15.	Search & Navigation Equipment	3.8
16.	Total for United States	2.4
17.	Aircraft & Parts	0.0
17.	Guided Missiles, Space Vehicles, & Parts	0.0

** Technology Aggregate*

Sources: BLS, Office of Employment Projections; Milken Institute

The three industries with the most rapid growth - electronic components and accessories, computer and office equipment, and computer and data processing services - are all vital IT industries.

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IT also is playing an increasingly important role in keeping us alive and in good health.

Profiles for a more thorough discussion).

These industries are among the fastest growing in the United States, as displayed in Table 2.2. The three industries with the most rapid growth — electronic components and accessories, computer and office equipment, and computer and data processing services — are all vital information technology industries. Computers and peripheral equipment are at the core of the information processing revolution. Rapid technology improvements in processing capabilities promise to sustain a high rate of growth. Electronic components provide the building blocks for the entire information technology industry. These devices comprise the vital components in computers, telecommunications, instrumentation, medical, and transportation equipment. Computer and data processing services include software, data management consulting, programming consulting, computer integrated systems design, and Internet-related activity and offer immense prospects for future growth. Communications equipment is undergoing a virtual explosion in demand for its products, led by satellite communications, wireless services, digital technology, and fiber optics. If computers are the vehicles by which we travel the information superhighway, communications equipment is the pavement that links the system together. Telecommunication services is experiencing stellar growth as the demand for wireless services and the Internet explodes.

Information technology also is playing an increasingly important role in keeping us alive and in good health. Medical devices, used to perform diagnoses and complex and delicate surgeries such as "minimally invasive" procedures, employ many of the same technologies as computers. The discovery and commercial development of many life-saving medications from company-funded research labs have created enormous demand for pharmaceuticals. Whether to stimulate infection-fighting cells or block a destructive internal process, bioengineered proteins can be injected into the body to induce desired reactions. Biotechnology offers the potential to produce breakthrough treatments in the future. Measuring and controlling devices are increasingly technical in nature, including laboratory, scientific, and optical apparatuses used for medical and biotechnology research, environmental testing, and telecommunications.

Research and testing services include physical and biological research, market research, clinical laboratory testing, and economic think tanks. Engineering services have suffered from defense cutbacks but have grown faster than the aggregate economy over the past 30 years. One might not believe motion picture production and services to be a high-technology industry, but technology drives the industry in terms of production (special effects, digital photography, sound effects, and editing) and offers new venues for film marketing (multimedia, such as video and computer games, DVD, and satellite). Search and navigation equipment includes

Table 2.3
Gross Industry Output for High-Tech Industries
As a Percentage of Total, 1977, 1987, and 1997

Rank	Industry	1977	1987	1997
1.	Total Technology	5.7	8.6	10.8
2.	Total Technology Services	3.1	4.4	5.8
3.	Total Technology Manufacturing	2.6	4.2	5.0
4.	Telephone Communications Services	1.9	2.2	2.6
5.	Computer & Data Processing Services	0.2	0.7	1.5
6.	Electronic Components & Accessories	0.2	0.5	1.2
7.	Aircraft & Parts	0.9	1.2	0.9
7.	Guided Missiles, Space Vehicles, & Parts	0.9	1.2	0.9
8.	Computer & Office Equipment	0.2	0.6	0.8
9.	Engineering & Architectural Services	0.5	0.8	0.7
10.	Communications Equipment	0.2	0.4	0.6
11.	Drugs	0.5	0.5	0.6
12.	Research & Testing Services	0.2	0.3	0.5
13.	Medical Equipment, Instruments, & Supplies	0.2	0.3	0.4
14.	Measuring & Controlling Devices	0.3	0.3	0.4
15.	Motion Pictures	0.3	0.4	0.4
16.	Search & Navigation Equipment	0.1	0.4	0.2

Sources: BLS, Office of Employment Projections; Milken Institute

radar and sonar systems, control equipment for aircraft and missiles, flight and navigation products, gyroscopes, and instruments. These devices employ the latest in computer and electronic hardware and software. The aerospace industry is one of the oldest high-technology sectors in the U.S. economy. For the purposes of this study it includes aircraft and parts, as well as guided missiles, space vehicles, and parts. Defense downsizing has devastated this industry, but it is rapidly reconfiguring itself for commercial applications.

Over the past 20 years, these industries have almost doubled their share of value of industry output in the United States to nearly 11 percent as displayed in Table 3. Technology services, at 5.8 percent of national output, is a larger sector than technology manufacturing.

Over the past 20 years, high-tech industries have almost doubled their share of value of U.S. industry output to nearly 11 percent.

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Section 3

Technology and Metropolitan Economic Performance

As prowess in technological innovation and assimilation will likely determine the relative success of nations in the future, it is already having profound impacts on the regional economic landscape of the United States.

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Geographic clustering is becoming central to the creation and understanding of international comparative advantage in an information-age economy.

Technology is having a pervasive influence on the spatial distribution of economic activity, and, more importantly, the relative rate of growth among metropolitan areas within the United States. As prowess in technological innovation and assimilation will likely determine the relative success of nations in the future, it is already having profound impacts on the regional economic landscape of the United States. Regional high-tech clusters may be more important in fostering innovative economic activity than the large multinational corporations that engage in promoting it (Audretsch 1998). Many multinationals used to view regions as merely low-cost platforms for exporting. These same corporations now attempt to gain a competitive advantage by investing in regions not only for lower costs or for market potential but for their labor skills, supplier networks, and technologies.

At a time when globalization was thought to be the preeminent economic theme — promising to make us more similar — it is somewhat paradoxical that the study of the region is emerging as an important area for understanding the success of nations. Perhaps the best indicator of the region's ascendance is that policymakers from Kuala Lumpur to Jerusalem are busy attempting to clone the next Silicon Valley. Geographic clustering is becoming central to the creation and understanding of international comparative advantage in an information-age economy.

Spatial distribution of economic activity is being impacted by technology through three primary channels.

- First, metropolitan areas housing a disproportionate share of industries or firms proficient at deploying information technology results in competitive advantage; regions are experiencing superior economic performance, ceteris paribus.

- Second, information technology itself is allowing some metropolitan areas to exploit a key locational advantage, such as lower business costs or some quality-of-life attribute, by permitting some forms of economic activity to be performed from more remote locations.

- Third, and central to our assertion, metropolitan areas that are experiencing the highest rate of economic growth are those that have demonstrated an ability to attract, nurture, and expand high-technology-based industry clusters.

In this section, we examine a number of important dimensions of technology industries as they relate to metropolitan economic development. The primary focus, however, will be to demonstrate how important geographic clustering of high-tech industries has become in determining the relative economic success of metropolitan areas–particularly in the 1990s, as technology accounts for an increasing proportion of national output. We analyze data on over 300 metropolitan areas in the United States in order to determine which ones lead in technology industry vertical density (concentration) and horizontal depth (breadth) and develop a composite measure of technology-production centers (Tech-Poles). Key questions we explore include:

- What factors determine where high tech is concentrated and where the greatest growth is occurring?
- Is there a difference between high-tech manufacturing and services?
- How large is the multiplier impact from technology industries in promoting growth in local non-high-tech sectors?
- Are agglomeration (centripetal) forces causing high-tech industries to be more concentrated in a few metropolitan areas or are countervailing disagglomeration (centrifugal) forces resulting in a dispersion of high-tech industries?

Economic Geography: Theoretical Underpinnings

Standard macroeconomic analysis of the U.S. economy would lead us to believe that economic activity occurs on a homogenous, continuous geographic plane. The reality is quite different: space is central to understanding how our economy works. Without a spatial dimension, there is no economic activity. A remarkable feature of the geographic distribution of economic activity in the United States is that the bulk of it is concentrated in a few clusters of metropolitan areas. In many respects, the U.S. economy is really a collection of regional economies linked to a national system. The structure of regional economies has more dis-similarities than similarities to that of the nation as a whole (DeVol 1997).

We analyze over 300 U.S. metropolitan areas to determine which ones lead in technology industry vertical density (concentration) and horizontal depth (breadth) and develop a composite measure of technology-production centers (Tech-Poles).

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Analysis of spatial activities are central to understanding how our economy works.

New economic geography attempts to provide the theoretical underpinnings to explain the processes that result in highly specialized economic activity.

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Paul Krugman is the best-known proponent and researcher of new economic geography.

In the field of economic analysis, economic geography — or the study of the location of production in space — has been notably neglected. Much of the scant analysis of spatial economics goes back to German roots, particularly Johann von Thuenen, Walter Christaller, and Alfred Webber. These researchers attempted to address the question of how the economy fits into space. Standard location theory, or the study of what factors determine where businesses locate, has been an important component of the literature. Central-place theory, or the idea that there should be a hierarchy of central places, with nested market areas, has had an influence in economic thought. Walter Isard championed a new field of regional science in the late 1950s by expanding on the work of the early Germans, but after some initial accomplishment, his influence on the literature has waned. On balance, however, the field of economic geography can accurately be said to have played a marginal part in the development of economic theory over time.

Beginning in the late 1980s, interest in the spatial dimension of economics began to reemerge. This resurgence has been termed "new economic geography" and has important applications for the study of high-tech industry concentrations. In essence, new economic geography attempts to provide the theoretical underpinnings to explain the agglomeration processes that result in highly specialized economic activity within regions. A growing recognition of the similarities between the study of international economics and regional (sub-national) economics helped in the resurgence of interest in this area. Nevertheless, perhaps the most compelling reason for the rediscovery of economic geography is the rich and vast empirical data laboratory that it furnishes. The central component of this theory is based upon the Marshallian notion of increasing returns.

This renewed interest was assisted by the prominence of the economists that initiated much of the research in spatial economics. This list includes Robert Barro, Barry Eichengreen, Michael Porter, Oliver Blanchard, Lawrence Katz, and Paul Krugman. Krugman has devoted much of his research over the past decade to new economic geography and deserves much of the credit for its popularization. He is seeking to construct a theory that explains spatial agglomeration of economic activity centered on increasing returns and positive externalities (Krugman 1991). Porter hypothesizes that the extent of spatial clustering of industries within a country is a principal determinant of that country's international competitive position (Porter 1996). Porter is almost evangelical in his promotion of the importance of economic geography in the discipline of economics. Others have applied elements of "endogenous growth theory" that emphasize intra-regional transfers of human capital or localized technology innovation as the key components of spatial concentration of economic activity.

Krugman and other proponents of new economic geography might describe the individual determinants of how specialized economic activity concentrates in space differently, but they would be in agreement on the central questions that must be answered: (1) Why is geographic agglomeration so commonly observed, and (2) What factors might ultimately limit the extent of this process and cause some degree of convergence in regional growth rates? Agglomeration results from the process of economic agents seeking geographic proximity with others engaged in a similar or related activity. Increasing returns lead to some competitive or market advantage for the economic agents. Agglomeration economies result from localized external effects arising from three main sources (labor-force pooling, supplier networks, and technology spillovers.) Industry clusters are formed by these agglomeration economies. Industry clusters are geographic concentrations of sometimes competing, sometimes collaborating firms, and the related supplier-network (DeVol 1997b).

Industry clusters are geographic concentrations of sometimes competing, sometimes collaborating firms and the related supplier-network.

An exogenous force (such as a government research center locating nearby) may precipitate an endogenous process of agglomeration, as agents might then act to achieve agglomeration economies by close geographic proximity. Since the location of particular activities may be highly flexible, an initial historical accident can have enduring "lock-in" effects that can sustain growth even when there is a major change in the factors that might determine the optimal location of that activity. The process (cumulative agglomeration phenomenon) is endogenous in the sense that once initiated, it develops the capacity to grow without further external propagation (Baumont, Beguin, and Huriot 1998). As additional firms enter a location, they make the location more attractive for subsequent firms. In other words, agglomeration begets agglomeration through a snowball effect.

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Industry clustering permits a pooled labor force of workers that possess industry-specific skills. As labor migrates from other regions into a local geographic cluster, it reinforces the initial advantages that the migration-destination enjoyed, stimulating further localized growth to the detriment of the migrant-originating region. In a local high-velocity labor market, workers benefit by having the opportunity to move next door to another position. Firms benefit by attracting local human capital that possesses the industry-specific skills that they require and reduce the firms' recruiting costs.

Industry clustering permits a pooled labor force of workers that possess industry-specific skills.

Technology spillovers can result from a local high-velocity labor market. New process and product innovations within a cluster can be shared through informal relationships. As labor moves between firms, labor-market network relationships are formed by ex-colleagues remaining in informal contact. Sharing technology or knowledge might be perceived by some member firms to be a negative externality at times, but it usually generates a competitive advantage that helps keep the cluster's members ahead of other competing geographic clusters. The formation of localized supplier networks is key to success of industry clusters and to fostering sustained agglomeration processes. As the breadth and depth of industry suppliers and services increase, industry-specific efficiencies that reinforce the initial strengths of the cluster are created. For example, as local financial services develop skills relevant to the unique characteristics of the industry cluster they serve, they enhance the cluster's position relative to others.

"Externalities" play a particularly acute role in determining the geographic concentration of technology industries.

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In summary, the centripetal forces causing agglomeration relate to the presence of beneficial externalities — whether pecuniary or technological — between firms. In the case of technology industries, these externalities appear to play a particularly acute role in determining geographic concentration. An important externality may stem from the initial presence of a research facility that leads to other facilities being established in close geographic proximity and, ultimately, to agglomeration of firms as their research receives commercial application. A sizable local market creates so-called "backward linkages" — sites with preferential access to large markets for the production of goods that benefit from economies of scale (Holmes 1999). Large local markets provide enough critical mass to support a network of local suppliers, a highly specialized local labor market, and benefit from deep information spillovers, termed "forward linkages."

There are countervailing forces to agglomeration, otherwise all economic activity would ultimately be pulled into a few immense geographic clusters.

There are countervailing forces to agglomeration, otherwise all economic activity would ultimately be pulled into a few immense geographic clusters. For example, financial services are highly concentrated in New York, London, and Hong Kong, but most financial-service activities are delivered from locations outside of those three cities. Silicon Valley is the preeminent high-technology industry cluster in the world but accounts for slightly less than 6 percent of the value of all U.S. high-tech output, as shown later.

Table 3.1
Agglomeration and Dispersion Forces in Competition

Agglomeration or Centripetal Forces
• Labor-Force Pooling
• Supplier Networks
• Technology Spillovers
Dispersion or Centrifugal Forces
• Immobile Factors
• Supply-Side Factors
• Demand-Side Factors

These countervailing or centrifugal forces (causing location dispersion) stem from product-market and factor-market competition (see Table 3.1). Immobile factors, including land, natural resources, and international migration, oppose the forces of concentration of production (Krugman 1998). A supply-side factor may play a role since some intermediate goods and services must come from outside the region, and, if supplier costs are lower elsewhere, production might ultimately disperse to peripheral regions. Demand-side factors will influence the degree of dispersion forces, as some production must be close to where consumption is concentrated. As economic activity concentrates, land rents are bid up. This forces firms to pay more for space and workers to pay more for housing. If firms cannot increase productivity sufficiently to offset the higher wages that workers will demand to locate there in order to offset higher housing costs, labor will be less likely to migrate to the region. This also creates a barrier to new firms entering the local market, and may lead to the optimal location being somewhere else.

As economic activity concentrates, land rents are bid up.

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Denser concentrations of economic activity can ultimately create negative externalities, such as congestion. Close proximity can increase productivity of economic agents, but as the frictional forces rise, they can initiate a dispersion process. Congestion can arise in many forms, but a critical manifestation is in transportation. As congestion increases, the demand for transportation services can grow nearly geometrically, ultimately stretching beyond the capacity of the existing infrastructure. Even if infrastructure improvements can help alleviate the congestion, assuming that the funding is available, the long lag between its planning and completion will not mitigate the congestion rapidly enough. Knowledge workers are highly remunerated; therefore, when their commuting times increase, the lost productivity and the opportunity cost of their time are substantial.

Denser concentrations of economic activity can ultimately create negative externalities, such as congestion.

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In economic geography, there are two main opposing forces at work: those that promote concentration and those that promote dispersion. Agglomeration forces cause economic activity to cluster because of increasing returns, and centrifugal (or congestion) forces push economic activity outward. The opposing forces are in constant competition attempting to determine a spatial equilibrium. The relative dominance of one over the other creates a landscape of economic activity, but ultimately leads to the countervailing force exerting a stronger influence, causing the geographic landscape to change.

Agglomeration forces cause economic activity to cluster because of increasing returns, and centrifugal (or congestion) forces push economic activity outward.

Applications to High-Tech Industries

How does this translate into the real economic landscape of high-technology industries? The new economic-geography theory has important applications for the development of high-technology industries and their spatial patterns. Much of standard location theory is applicable to where high-tech industries locate and whether sufficient critical mass is

Those forces that are critical in the initial states of technology industry location may wane in influence as a cluster is fully established.

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Historical accident or an exogenous force can provide a critical advantage for one location.

achieved to develop clustering. Many factors interact in a complex, dynamic environment that ultimately determines the geographic evolution of technology industries. The relative importance of the factors alters over the stages of development. Those forces that are critical in the initial stages of technology industry location may wane in influence as a cluster is fully established. Some of the initial factors may regain importance at the mature stage of a technology-industry cluster's life cycle, and, ultimately, determine its longevity. The relative weights placed upon the array of location factors will differ according to the specific high-tech industry, the major divide being whether it is a manufacturing or service industry.

Happenstence or an exogenous force can provide a critical advantage for one location. Government or private nonprofit research facilities engaged in cutting-edge work are an important precondition for the creation of high-tech industries and also can determine where they eventually locate. Many times the location of government research facilities is by historical accident. NASA's rocket-research center in Huntsville was a key advantage for that city's technology concentration in space and navigation equipment; Bell Labs in New Jersey has spawned many technology clusters; the Advanced Research Program at the University of Texas has played a critical role in the development of the high-tech industry cluster

Table 3.2
What Factors Attract and Sustain High-Tech Industries?

Existing High-Tech Presence
Traditional Cost-of-Doing Business Measures
• Tax Structure
• Compensation Costs
• Space Costs
• Capital Costs
• Business Climate
Specific to High-Tech
• Proximity to Excellent Research Institutions
• Access to Venture Capital
• Educated Workforce
• Network of Suppliers
• Technology Spillovers
• Climate and "Quality of Life"

in Austin. Boston has the highest concentration of research centers in the country, and despite the relative decline in high-tech industries from the mid-1980s to mid-1990s, it still is a major tech center. A skilled labor pool left from a previous high-tech presence can be an impetus to a new success. For example, Boston had a high concentration of engineers, scientists, and researchers left over from its past mini-computer and search and navigation equipment strength. This knowledge-intensive human capital is helping the region achieve mastery in new forms of information technology and Internet-related activity. High-tech regional clusters such as Silicon Valley and the Research Triangle owe much of their prosperity to research centers and universities. They enable cutting-edge research to be combined with locally produced knowledge-intensive graduates to form new innovative firms.

High-tech regional clusters such as Silicon Valley and the Research Triangle owe much of their prosperity to research centers and universities.

. . .

Many of the traditional location factors that attract any industry are also important to high-tech firms. These factors are generally referred to as "cost-of-doing-business measures": tax rates or incentives, compensation costs, land and office space costs, energy costs, capital costs, and firms' perception of the general business climate. In a study of four-digit manufacturing industries, Ellison and Glaeser (1999) determined that industry locations were related to resource or labor market advantages between regions. They attribute approximately one-fifth of the observable concentration of industries at the state level to natural or cost-of-doing-business measures. There are other factors that appear to be the most important to high-tech firms' location decisions. They include access to a trained / educated workforce, close proximity to excellent educational facilities and research institutions, an existing network of suppliers, availability of venture capital, climate and other quality-of-life factors, and the general cost of living (see Table 3.2 for a summary listing). Mature high-tech manufacturers will place a higher weight on the traditional cost-of-doing-business measures than high-tech service firms in determining their location. Silicon Valley is evolving toward a high-tech service industry cluster and is flourishing despite very low scores on traditional cost-of-doing-business measures.

Factors most important to high-tech firms' location decisions are: access to a trained / educated workforce, close proximity to excellent educational facilities and research institutions, a network of suppliers, availability of venture capital, and climate and other quality-of-life factors.

One of factors critical to incubating and sustaining an entrepreneurial-based high-tech cluster is access to venture capital. This is generally understood, but financial risk taking and venture capital's importance are not fully recognized in technology industries. Many new ideas for innovative products or services can be funded and developed internally at existing firms, but senior management may not share the same passion for the innovator's ideas. As these innovators attempt to embark on their own path, traditional sources of financing can be difficult to attain. This is where risk or venture capital plays a vital role. By financing new ideas, venture capitalists are instrumental catalysts in maintaining or enhancing a cluster's dynamism: they provide the means for new firms to be formed.

By financing new ideas, venture capitalists are instrumental catalysts in maintaining or enhancing a "cluster" dynamism.

. . .

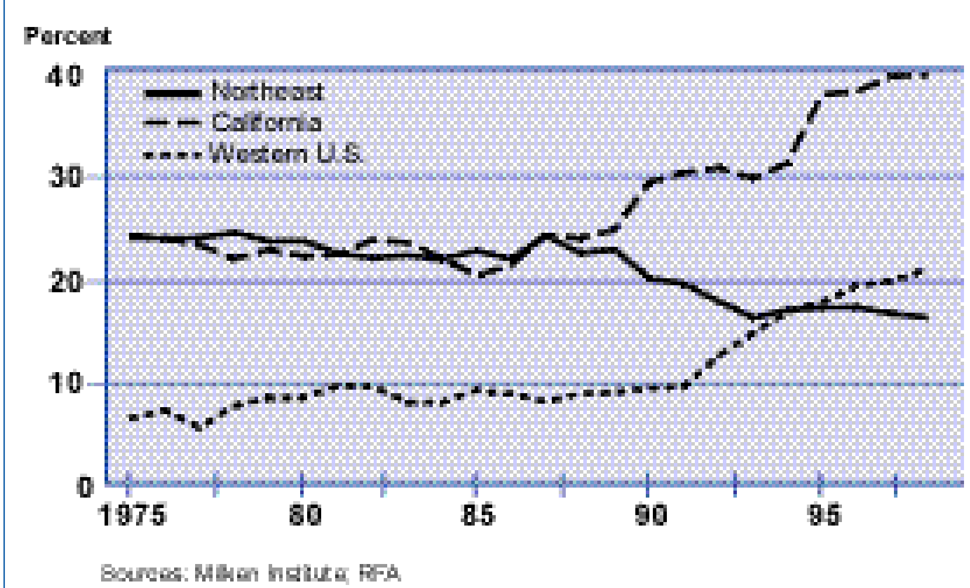
Retention or attraction of knowledge-intensive human capital is essential to the vitality of high-tech industry clusters.

A typical venture capital firm will diversify its bets across industries and regions, fully expecting that out of 20 bets, three might be marginally profitable and one will deliver huge returns (e.g., eBay.com). Even commercial banks have formed technology venture capital divisions. Venture capital's highest returns are to the regions where they invest. The regional return is not what motivates a venture capitalist, but this is where Smith's invisible hand is felt. Without a well-functioning venture capital infrastructure, a region's technology cluster is at risk of not achieving its potential. Silicon Valley's extensive venture capital network is one of its greatest assets and distinguishes the region from all others.

Quality-of-life factors are important to knowledge workers in high-tech industries. In order to retain or attract scientists, engineers, top-level programmers, managers, and other technicians, firms must pay close attention to quality of life. Retention or attraction of knowledge-intensive human capital (through migration) is essential to the vitality of high-tech industry clusters. Therefore, climatic conditions and other geographic characteristics, commuting time (congestion), violent crime rates, air quality, education quality, and other hard-to-define measures influence their location decisions.

High-tech industry clusters can be subject to life cycles. These life cycles can be painful for individual firms but might help sustain the cluster in the long term. Some firms lose their competitive advantage and die while new ones emerge, permitting capital — both physical and human — to be

Figure 3.1
Production of Computers and Office Equipment
Percentage of National Total



re-deployed. Turnover of personnel and businesses may even be a sign of innovation-driven vitality. Some clusters do not adjust quickly enough to rapidly changing technology in their industry. Clusters can lose their spirit of innovation and not continue to invest in research and development. Overly centralized control can impede innovative activities in firms. Technological lock-in can preclude a cluster from developing new ideas. Prime examples of this are computer firms Digital, DEC, and IBM, all located in the Northeast. A type of intellectual lock-in caused them to focus on mainframes and completely miss the shift to mini-computers (see Figure 3.1). Some argue that Northeastern firms' intellectual myopia was a key reason for the California dominance of the personal computer industry. There is evidence that high-tech clusters, like individual firms, are susceptible to a form of technology lock-in, leading to their demise; new ideas may need new geography.

Turnover of personnel and businesses may even be a sign of innovation-driven vitality.

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Some clusters develop a culture that is accepting of new ideas. For example, in her study of Silicon Valley, Analee Saxenian (1994) argues that a culture of greater integration and information exchange in the region is central to its exceptional innovative position relative to Boston's Route 128 corridor, or to any other region's. An extended association of regional institutions forms a key support infrastructure for a region's high-tech industry clusters. Trade associations, local business organizations (including public-private partnerships), highly specialized consulting firms, research institutions, and venture capital firms all contribute to the formal and informal flow of communications between economic agents. Various types of forums provide the opportunity for relationships to be established and maintained, technology ideas to be exchanged, and new enterprises chartered.

Some clusters develop a culture that is accepting of new ideas.

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While these factors are listed as individual elements of the regional high-tech industry clustering and growth process, they interact and feed on one another to develop a dynamic and self-sustaining process of growth and decline. The initial location advantages of a region may be thwarted by its eventual growth. Regional cost advantages that were the impetus to a concentration of high-tech manufacturing industries may eventually be reversed by its rapid growth, diminishing the attractiveness of the region. A regional high-tech cluster that is dominated by a few large firms may be a key competitive advantage for a period of time, but lead to its relative decline as technology changes and its large firms do not adapt. In the evolution of the spatial distribution of high-tech industry clusters, economic geography's two main opposing forces, concentration and dispersion, are in constant competition.

A regional high-tech cluster that is dominated by a few large firms may be a key competitive advantage for a time but ultimately may lead to relative decline if firms fail to adapt to changing technology.

High-Technology Production Spatial Patterns

Our analysis of the spatial distribution of high-tech production is based upon the Census Bureau's definition of Metropolitan Statistical Areas (MSAs). Industry clusters are not the geographic phenomenon of states

Metros are more appropriate than cities for analyzing tech industry clusters because of the broader regional linkages that are essential to high-technology clusters.

but of more compact concentrations of geography. It can be argued that an analysis of individual high-tech industry clusters should be based upon a spatial definition smaller than a metro area. In our opinion, metros are the appropriate geography for analyzing high-tech industry clusters because of the broader regional linkages that are essential for cluster vitality. State-level policies play an instrumental role in supporting high-tech development at the metro level, but they are not the primary determinants of a metro area's success in fostering the formation of technology-industry clusters. Agglomeration economies result from spatial proximity of economic agents, and this happens at the metro or sub-metro area. Despite the attention that high-tech industry clusters receive in discussions of metro economies, there is a dearth of research analyzing them across metros and on the economic stimulus they provide.

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We have compiled a comprehensive data set on high-tech industries at the metropolitan level. It is based upon national information from the BLS and BEA and metro data created by Regional Financial Associates (RFA). We have augmented the RFA data by benchmarking it back to BLS's and BEA's national data set. The resulting data set includes nominal and real (1992 dollars) value of output, employment, and productivity, by industry, for 315 metropolitan areas. This allows us to examine high-tech industries along a number of dimensions. Most studies of high-tech industries at the metro level are based upon employment. This is clearly an important component but does not allow for variation in productivity within the same industry between regions. When analyzing the economic stimulus that high-tech industries provide, the value of output is a better overall indicator than employment.

When analyzing the economic stimulus that high-tech industries provide, the value of output is a better overall indicator than employment.

Technology's Importance in Metro Growth Patterns

How important is geographic clustering of high-tech industries in determining the relative success of metropolitan areas, and how can this be quantified? We assert that achievement in high-tech is a critical determinant of overall growth patterns in metros. Because of the growing role of high-tech industries in the national economy, metros that do not achieve some level of attainment in these critical industries will likely experience substandard economic growth in the future. We are not suggesting that high-tech is the only development strategy to pursue, but it will be the key distinguishing feature of metropolitan vitality.

We have applied a series of econometric approaches to examine the importance of high-tech industries in determining the relative economic growth of metros. We altered the time period and the dependent variable in the equations in order to check the robustness of the relationships. If similar results are observed after making these adjustments, we can be more confident that the relationships are both consistent and strong and are not spurious — in other words, we can ensure that the results are meaningful and interpreted properly. The strength of the explanatory power of high-tech industries in determining the relative economic growth of metros is high and the relationship is robust across most dimensions in these regressions.

In regression analysis, one evaluates how closely changes in one or more independent variables can explain the movement of a dependent variable (the variable we are attempting to explain) and whether the relationship is statistically significant. The first econometric approach we applied was a pooled, time-series cross-sectional method. It is pooled in the sense that economic growth across 315 metros is evaluated over the period 1975 to 1998. This yields over 7,200 observations on which to test the relationship.

The strength of the explanatory power of high-tech industries in determining the relative economic growth of metros is high and the relationship is robust.

POOLED, TIME-SERIES CROSS-SECTIONAL RESULTS

In the first specification, real non-high-tech gross metro output was the dependent variable. The first independent variable was real high-tech metro output. In the case of computers and office equipment and electronic components, we used nominal output as the measure. We did this in order to adjust for the rapidly declining price deflators due to actual price declines and quality adjustments that are reflected in the deflator. When attempting to measure the impact of rising output in these two industries on metro growth, nominal values are an appropriate base. The second independent variable was a trailing moving average of the high-tech industry location quotient for the metros. A location quotient measures the concentration of an industry in a geographic location relative to its national concentration. For example, a high-tech industry location quotient of 1.0 for a metro says that high-tech activity has the same concentration as the U.S. average. A location quotient of 2.0 means that high tech is twice as concentrated in a metro relative to the U.S. average, while a location quotient of 0.5 means that it is one-half as important. The inclusion of the location quotient terms attempts to adjust for the importance of high-tech industries to the local economy. Stated another way, if high-tech output is twice as important to one metro relative to another, it should generate more relative economic growth.

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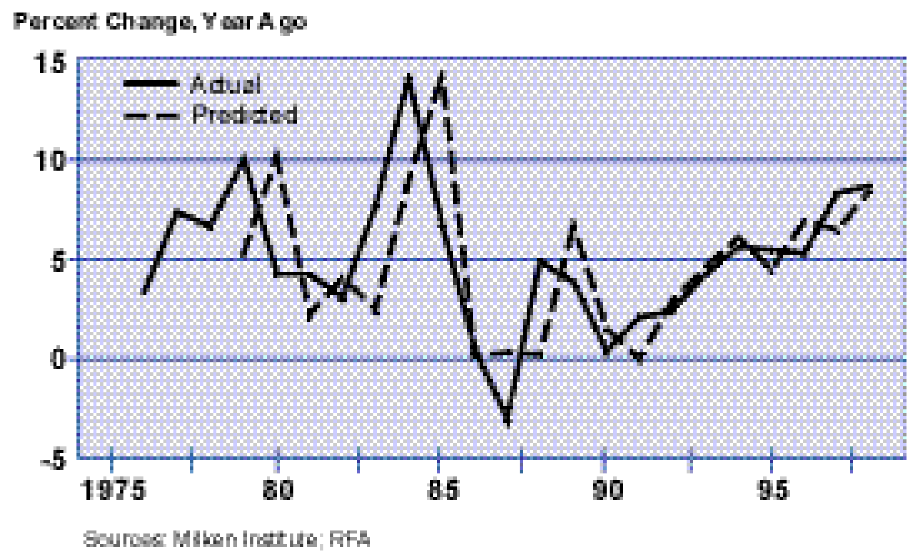
A location quotient measures the concentration of an industry in a geographic location relative to its national concentration.

In this specification we explained 44 percent of the change (R-Squared) in non-high-tech metro output on the basis of movement in high-tech output and the relative importance of high-tech to a metro. If the dependent variable is total gross metro output, the explained variation rises to 51 percent. This overall relationship is highly significant in a statistical sense and would occur only one in 10 thousand times if it were not the true relationship. Figure 3.2 shows the percentage change in the actual versus predicted values from the equation for Dallas. When using other industries, such as wholesale trade or non-high-tech services, to explain

Figure 3.2
Dallas Non-High-Tech Output
Actual vs. Predicted (Pooled)



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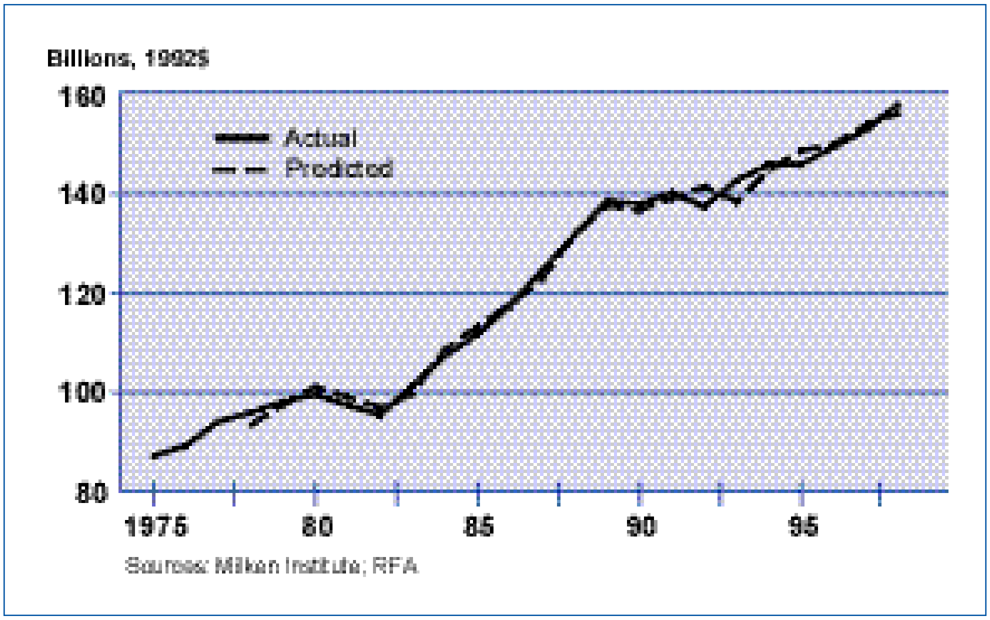
Our equation explained 51 percent of the change in non-high-tech metro output on the basis of movement in high-tech output and the relative importance of high tech to a given metro. This relationship was highly statistically significant.

the changes in non-high-tech output, roughly 15 percent of the movement could be explained. The coefficient on high-tech output implies an elasticity of 0.2 with respect to changes in non-high-tech output. This suggests that if high-tech output increases by 1 percent, non-high-tech output rises by 0.2 percent in a metro at mean high-tech density. This is a strong relationship when one considers that high-tech output represented 5 percent of total output in 1975 and slightly nearly 11 percent in 1998. The explanatory power of the equation improved to 58 percent of the change in gross metro product if the sample period is shortened to 1989–98.

TIME-SERIES RESULTS

Next, we ran a series of individual regressions for metros with a similar specification. Each equation was estimated independently in this approach. The coefficients on the high-tech term did not vary much between metros, suggesting a fairly robust relationship. The overall explanatory power of these equations was higher than in the pooled, time-series cross-sectional specification, as variations in individual relationships are permitted. The highest elasticity on the high-tech output term was 0.5. The most important finding was that the mean elasticity on the high-tech output term was 0.22 across metros, nearly identical to the one from the pooled regression. Figure 3.3 displays the actual versus the predicted values from the regression for the Washington, D.C., metro area.

Figure 3.3
Washington D.C. Non-High-Tech Output
Actual vs. Predicted (Time Series)



CROSS-SECTIONAL RESULTS

The last specification employed was a cross-sectional technique. By cross-sectional we mean that it is not based on a historical time series. This method attempts to explain economic performance between metros. We created a series of metro growth indices relative to the national growth pattern. In the case of high-tech output, the relative metro growth index is created by comparing growth in metros relative to the national average from 1990 to 1998. We chose the 1990s as the period of analysis because this is the period during which high tech became vital in determining performance between metros. For example, if a metro matched the national growth in high-tech output between 1990 and 1998, it would have a value of 100. If its relative high-tech output growth index was 120, then it exceeded national performance by 20 percent, but if its value was 80, its growth was 20 percent less than the national average. The same approach was applied to total gross metro output and non-high-tech metro output. In many respects, the interpretations of the results from this approach are more straightforward than from the first two that we utilized, as well as computationally less demanding.

We ran a series of regressions by altering the dependent variable and the time period for which the relative growth indices were calculated. In the first equation, the dependent variable was the relative total real-output growth index for the 315 metros. The first explanatory variable was the relative metro high-tech output growth index. The second explanatory

The most important finding was that the mean elasticity on the high-tech output term was 0.22 across metros.

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In the case of high-tech output, the relative metro growth index is created by comparing growth in metros relative to the national average from 1990 to 1998.

variable was the initial high-tech output industry location quotient in 1990. It is important to standardize the relationship by the concentration of high-tech industries in a metro because if a metro had a low initial high-tech density, a given percentage gain in high-tech growth would not provide the same incremental stimulus as in a metro with a large initial high-tech density.

We found that 65 percent of the total output growth differential between metros was explained on the basis of their relative growth in high-tech and the initial high-tech density.

Based upon this equation, we found that 65 percent of the total output growth differential between metros was explained on the basis of their relative growth in high-tech and the initial high-tech density. This relationship is very strong; it would happen only in one out of ten thousand times if it were not the true relationship. Figure 3.4 displays the actual versus predicted values from this equation. The *x*-axis shows the 315 metros ranked in descending order by the actual values of their total relative output growth index. The *y*-axis compares the actual relative total industry output growth index with that predicted from the equation. This chart visually depicts the close relationship between high-tech growth and relative economic performance in the 1990s. When the dependent variable was non-high-tech output rather than total output, the explanatory power fell to 54 percent of the variation between metros.

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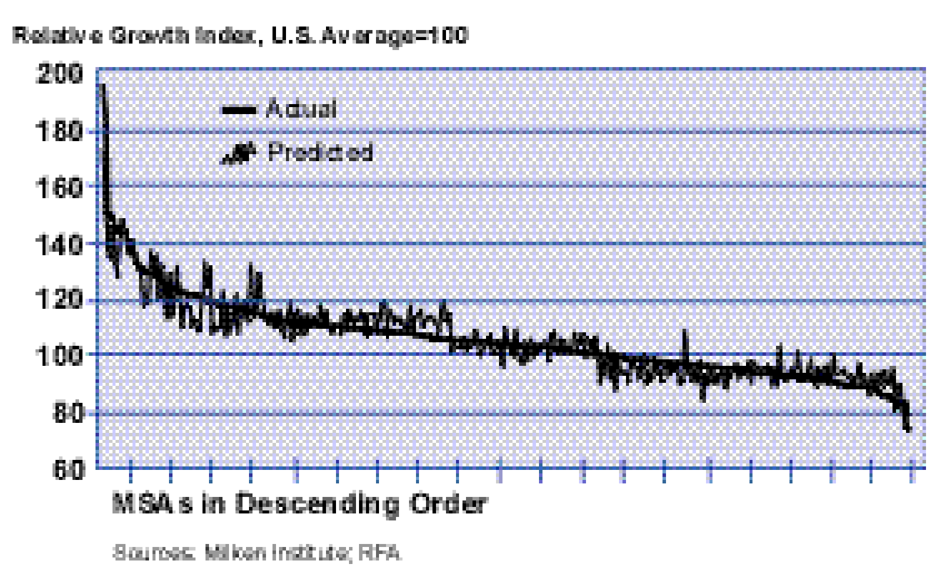
The x-axis shows the 315 metros ranked in descending order by the actual values of their total relative output growth index.

The equation results indicate that at mean high-tech density, a high-tech output growth rate 5 percentage points above the U.S. average translates into a 1.0 percentage point advantage in total real output growth relative to the U.S. average. The interpretation of this result is nearly identical to the first two approaches, highlighting its robustness. The coefficient on the

Figure 3.4
Metro Growth Explained by High-Tech
Actual vs. Predicted (Cross-sectional)



relative high-tech output term had a *t*-statistic (measuring whether the relationship is strong) of 11.2; a t-statistic of 1.85 would be considered significant at the 5 percent significance level. In other words, this relationship is immensely stronger than it would need to be in order to be considered statistically significant. If the high-tech density in a metro is double the U.S. average (measured by a high-tech output location of 2.0), it adds 0.15 percentage point to the overall relative metro growth rate from a 1 percentage point relative gain in high-tech growth. We found no difference in the relative explanatory power of high-tech manufacturing compared to high-tech services. There was some indication, however, that the relative importance of high-tech services was increasing.

A high-tech output growth rate 5 percent above the U.S. average translates into a 1 percent advantage in total real output growth relative to the U.S. average.

We estimated the same equation by creating the relative indices between 1975 and 1989. Based upon these results, 8 percentage points of high-tech output growth advantage would be required to translate into a 1 percentage point gain in total metro output growth above the U.S. average. These results are consistent with the hypothesis that high-tech growth is becoming a more important determinant of the relative economic success of metros. The overall explanatory power of the equation for relative metro growth fell to 35 percent in this specification, down from 65 percent when calculated over 1990 to 1998.

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We should, however, interpret these results with some caution. In the equation where high-tech output growth explains 65 percent of the variation in output growth between metros, the use of the term "causes" should be avoided. This is because many of the traditional location factors (cost-of-doing-business measures) that are especially attractive to high-tech manufacturing industries also are important to non-high-tech manufacturing industries. So, there is some evidence of co-movement between the two. Put another way, low cost-of-doing-business measures might be responsible for some of the variation in output growth between metros that is being assigned to high-tech output growth variation. Nevertheless, we can conclude that high-tech output growth is closely associated with total output growth of metros and that the relationship is robust.

We can conclude that high-tech output growth is closely associated with total output growth of metros and that the relationship is robust.

WHY IT MATTERS: THE HIGH-TECH MULTIPLIER

High-tech industries have large direct economic impacts on metro economies, but the indirect and induced effects are critical to a complete synthesis of their role in promoting growth. The indirect effect (or the incremental stimulus to non-high-tech industries) from high-technology industries on metro economies is substantial. The induced effects stem from the purchase of more goods and services by non-high-tech firms and their employees as a result of higher sales and increases in personal income. Because of the high value-added production and the greater demand for high-skilled labor, high-tech industries compensate their

As high-tech industries grow and clusters develop, a vast supplier-network infrastructure is formed.

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The impacts of high-tech clustering are dynamic and can lead to virtuous circle of positive feedback on the local economy.

employees well. Additionally, technology firms use stock options more extensively in their total compensation mix, which can result in even clerical staff becoming millionaires!

As high-technology industries grow and clusters develop, a vast supplier-network infrastructure is formed. The demand for locally produced professional services expands. The demand for legal services with expertise in technology-specific industries rises. Other professional services such as accounting, auditing, engineering and testing services, management consulting, and finance grows in the local economy. These are highly compensated occupations that further stimulate local economies. Other services benefit, including telephone communications, air transportation, hotel and other related travel services, and even electricity services. High-tech manufacturing firms foster gains in manufacturers that supply inputs to them. Many high-tech services such as software development have larger multipliers than high-tech manufacturing because more of their inputs are purchased locally and labor represents a greater share of their total purchased inputs. High-tech service firms do not purchase components from non-local sources, either domestic or foreign; therefore, there is less linkage external to the metro economy. Another important channel through which high-tech industries promote growth locally is the in-migration of knowledge workers, other labor, and their families.

The impact on construction markets can be large. Residential construction is stimulated from high rates of in-migration resulting in greater building of single-family homes, condominiums, and apartments. The construction of new high-tech manufacturing facilities is a massive investment. A new semiconductor plant can cost $3 billion to construct. High-tech plants under construction purchase large quantities of local building materials and provide employment to many construction workers. High-tech service firms can absorb an immense amount of office space leading to a decline in vacancy rates and, ultimately, new construction. Retail trade benefits indirectly from high-tech growth because of the greater purchasing power of tech workers and the stimulus to personal income throughout the metro area.

These impacts are dynamic and can lead to a virtuous circle of positive feedback on the local economy. It may be impossible to trace all of the linkages throughout a metro economy, but the total multiplier can be very large. We believe that the multiplier impact stemming from high-technology industry clusters is a key determinant of the relative metro economic growth differential observed in the United States.

High-Technology Spatial Concentration

The extent of high-technology industry concentration in metros and the ranking of metros by various categories can be examined using many methods. We approach the issue from several perspectives. First, we analyze metro high-tech concentration, or vertical density, by the relative size of high tech in the local economy compared to the U.S. average. A second method examines what proportion high-tech output in a metro represents of the total for the nation. This represents a measure of horizontal depth or breadth of high-tech activity. Lastly, we compile a composite measure of technology production centers that incorporates the two components. From this, we analyze the metros that are the leading "Tech-Poles."

Location quotients display the relative importance of an industry to a metro economy.

The concentration of high-tech industry output in metros is based upon location quotients (LQ). Location quotients compare the value of high-tech output as a share of total output in a metro relative to the same calculation for the United States. Location quotients are an effective method for displaying the relative importance of an industry to a metro economy. The disadvantage of location quotients is that they do not adjust for the size of a metro area relative to others. For example, in a small metro, one or two large high-tech manufacturing plants can yield a large location quotient. Analysis by location quotient showed a high degree of spatial disparity in U.S. high-tech output concentration. In a study of agglomeration in capital goods industries, Black and Henderson (1999) found that high-tech capital goods industries were the most concentrated of any in the United States There is evidence, however, that high-tech production activity is becoming more geographically dispersed.

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Rochester, MN, has the highest location quotient (5.6) of all metros studied.

Table 3.3 lists the top 50 out of 315 metros on the basis of the high-tech output location quotient for 1998 along with some other key measures. Tables 3.4 and 3.5 break out high-tech manufacturing and services separately, and Table 3.6 displays the top 10 metros for each of the 14 high-tech industries. At the top of Table 3.3 is a somewhat surprising metro, Rochester, MN, with a high-tech LQ of 5.6, indicating that high tech is 5.6 times more concentrated than the U.S. average. Rochester is first mainly because of its computer and office equipment, with an LQ that is almost off the scale at 143.0. This is due to the presence of IBM and data-storage devices manufacturer Western Digital. In total, 6,900 workers are employed in the industry locally. Rochester also has a medical research-related cluster centered around the Mayo Clinic.

The preeminent high-tech cluster in the world, Silicon Valley, places San Jose second on the list, with an LQ of 4.1. High-tech output represents 37.2 percent of San Jose's gross metro product. It is the breadth of technology industries that distinguishes San Jose. It contains 10 high-tech industries with LQs over 1.0, of a possible 14 high-tech industries. Albuquerque, NM, is next on the list with a high-tech LQ of 3.6. Electronics firms such as Intel have built new facilities there, resulting in an LQ of 37.6 for the industry in the metro. Sandia National Laboratory has helped foster this expansion as it works closely with a consortium of electronic firms. This is the main

Table 3.3
Top 50 High-Tech Metros, by Concentration
Total High-Tech Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	Rochester, MN	5.56	2.41	50.54	0.35	10.48
2	San Jose, CA	4.09	39.78	37.17	5.79	279.06
3	Albuquerque, NM	3.55	9.62	32.30	1.40	35.73
4	Lubbock, TX	3.08	2.16	28.00	0.31	3.63
5	Cedar Rapids, IA	3.07	2.05	27.93	0.30	16.10
6	Boulder-Longmont, CO	2.89	2.67	26.28	0.39	31.88
7	Boise City, ID	2.68	3.66	24.32	0.53	19.76
8	Kalamazoo-Battle Creek, MI	2.66	2.82	24.21	0.41	10.67
9	Richland-Kennewick-Pasco, WA	2.41	1.11	21.92	0.16	23.06
10	Middlesex-Somerset-Hunterdon, NJ	2.30	10.14	20.92	1.48	78.70
11	Seattle-Bellevue-Everett, WA	2.06	17.31	18.72	2.52	216.36
12	Melbourne-Titusville-Palm Bay, FL	2.00	1.75	18.16	0.25	28.54
13	Raleigh-Durham-Chapel Hill, NC	2.00	0.00	18.16	0.95	77.27
14	Pocatello, ID	1.99	0.35	18.11	0.05	1.82
15	Albany, GA	1.97	0.62	17.91	0.09	1.85
16	South Bend, IN	1.96	1.16	17.78	0.17	5.56
17	Burlington, VT	1.94	1.14	17.67	0.17	12.5
18	Dallas, TX	1.92	25.21	17.49	3.67	210.18
19	Wichita, KS	1.89	2.62	17.22	0.38	54.15
20	Flagstaff, AZ-UT	1.89	0.35	17.14	0.05	1.39
21	Colorado Springs, CO	1.85	2.17	16.80	0.32	29.01
22	Tucson, AZ	1.83	2.52	16.66	0.37	24.04
23	Huntsville, AL	1.78	1.69	16.14	0.25	34.38
24	Atlantic-Cape May, NJ	1.72	1.74	15.59	0.25	4.94
25	Sherman-Denison, TX	1.60	0.38	14.50	0.05	3.58
26	Binghamton, NY	1.57	0.94	14.28	0.14	15.83
27	Austin-San Marcos, TX	1.56	7.83	14.16	1.14	74.19
28	Boston, MA	1.51	28.72	13.71	4.18	329.28
29	Provo-Orem, UT	1.49	0.78	13.57	0.11	13.91
30	Phoenix-Mesa, AZ	1.46	12.24	13.29	1.78	120.32
31	Washington, DC-MD-VA-WV	1.45	24.01	13.20	3.50	264.98
32	Oakland, CA	1.43	10.65	12.97	1.55	90.69
33	Orange County, CA	1.40	12.68	12.75	1.85	123.44
34	Denver, CO	1.39	8.93	12.66	1.30	90.55
35	San Diego, CA	1.37	9.66	12.49	1.41	104.36
36	Atlanta, GA	1.37	17.40	12.42	2.53	154.49
37	Williamsport, PA	1.36	0.28	12.34	0.04	1.01
38	Rocky Mount, NC	1.36	0.42	12.33	0.06	5.29
39	Los Angeles-Long Beach, CA	1.35	35.11	12.28	5.11	402.14
40	Newark, NJ	1.33	9.29	12.11	1.35	84.55
41	Monmouth-Ocean, NJ	1.31	2.88	11.90	0.42	28.46
42	Santa Cruz-Watsonville, CA	1.30	0.83	11.84	0.12	7.49
43	Portland-Vancouver, OR-WA	1.30	7.04	11.82	1.02	82.11
44	Mansfield, OH	1.29	0.43	11.69	0.06	3.28
45	Indianapolis, IN	1.28	5.75	11.62	0.84	43.8
46	Ventura, CA	1.26	2.14	11.44	0.31	22.77
47	Dutchess County, NY	1.26	0.93	11.43	0.14	16.28
48	Glens Falls, NY	1.25	0.28	11.37	0.04	3.13
49	Elkhart-Goshen, IN	1.25	0.74	11.36	0.11	4.84
50	Trenton, NJ	1.25	1.40	11.34	0.20	16.49

** Each metro must contain either a place with a minimum population of 50,000 or a Census Bureau defined urbanized area and total population of at least 100,000 (75,000 in New England). Ametro comprises one or more counties.*

*** The Location Quotient (LQ) equals % output in metro divided by % output in the U.S. If LQ > 1.0, the industry is more concentrated in the metro area than in the U.S. on average.*

Sources: Milken Institute; RFA

Table 3.4
Top 25 High-Tech Manufacturing Metros, by Concentration
High-Tech Manufacturing Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	**Rochester, MN**	**13.98**	**2.36**	**49.38**	**0.88**	**7.48**
2	San Jose, CA	7.66	28.95	27.05	10.85	195.35
3	Albuquerque, NM	7.58	7.98	26.79	2.99	13.45
4	Lubbock, TX	6.95	1.89	24.55	0.71	1.00
5	Kalamazoo-Battle Creek, MI	6.59	2.71	23.26	1.01	7.92
6	Boise City, ID	6.39	3.40	22.57	1.27	16.09
7	Cedar Rapids, IA	5.93	1.54	20.96	0.58	10.62
8	Pocatello, ID	4.78	0.33	16.88	0.12	1.43
9	Albany, GA	4.77	0.58	16.86	0.22	0.85
10	Flagstaff, AZ-UT	4.64	0.34	16.38	0.13	1.09
11	South Bend, IN	4.27	0.98	15.08	0.37	2.92
12	Sherman-Denison, TX	3.94	0.36	13.93	0.14	3.24
13	Wichita, KS	3.88	2.08	13.70	0.78	48.34
14	Atlantic-Cape May, NJ	3.81	1.50	13.45	0.56	0.86
15	Tucson, AZ	3.73	2.00	13.18	0.75	14.03
16	Boulder-Longmont, CO	3.58	1.28	12.64	0.48	15.60
17	Burlington, VT	3.41	0.78	12.06	0.29	8.49
18	Melbourne-Titusville-Palm Bay, FL	3.39	1.15	11.98	0.43	20.29
19	Binghamton, NY	3.27	0.76	11.57	0.29	11.92
20	Williamsport, PA	3.17	0.25	11.20	0.09	0.61
21	Glens Falls, NY	3.01	0.26	10.63	0.10	2.6
22	Elkhart-Goshen, IN	2.93	0.67	10.35	0.25	4.13
23	Raleigh-Durham-Chapel Hill, NC	2.88	3.65	10.19	1.37	40.71
24	Dutchess County, NY	2.71	0.78	9.56	0.29	13.79
25	Phoenix-Mesa, AZ	2.63	8.55	9.29	3.21	73.12

** Each metro must contain either a place with a minimum population of 50,000 or a Census Bureau defined urbanized area and total popula - tion of at least 100,000 (75,000 in New England). Ametro comprises one or more counties.*

*** The Location Quotient (LQ) equals % output in metro divided by % output in the U.S. If LQ > 1.0, the industry is more concentrated in the metro area than in the U.S. on average.*

Sources: Milken Institute; RFA

reason for Albuquerque's LQ of 5.6 in research and testing services. In fourth place is Lubbock, TX, due primarily to electronic components, which account for 25 percent of local economic activity. Cedar Rapids, IA, is a high-tech Prairie Powerhouse. Its fifth-place rank is due to a high concentration of communications equipment (LQ of 24.4), and an above-average concentration of telephone communications and research and testing services. Cedar Rapids is home to navigational systems stalwart, Rockwell-Collins.

Boulder-Longmont, CO, (sixth) has a diverse high-tech base, but computers and office equipment is the most important industry, with an LQ of 22.2. Sun Microsystems, a leader in computer network systems, has opened operations in Broomfield. Boulder-Longmont has 10 high-tech industries with a concentration above the U.S. average, a remarkable achievement for a metro its size. Boise City, ID, ranks seventh due to

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High-tech output represents 37.2 percent of San Jose's gross metro product; it has fully 10, of a possible 14, industries with location quotients over 1.0.

Table 3.5
Top 25 High-Tech Services Metros, by Concentration
High-Tech Services Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	Richland-Kennewick-Pasco, WA	3.93	1.11	2.71	0.26	22.64
2	Middlesex-Somerset-Hunterdon, NJ	3.04	8.18	16.87	1.95	57.97
3	Boulder-Longmont, CO	2.45	1.38	13.64	0.33	16.28
4	Seattle-Bellevue-Everett, WA	2.36	12.14	13.12	2.89	87.38
5	Washington, DC-MD-VA-WV	2.17	21.93	12.06	5.22	242.23
6	Denver, CO	2.10	8.21	11.65	1.96	75.21
7	Provo-Orem, UT	2.00	0.64	11.10	0.15	10.49
8	Monmouth-Ocean, NJ	1.91	2.58	10.63	0.61	23.13
9	Huntsville, AL	1.85	1.08	10.27	0.26	17.05
10	Colorado Springs, CO	1.83	1.32	10.20	0.31	14.61
11	San Jose, CA	1.82	10.82	10.11	2.58	83.71
12	Atlanta, GA	1.77	13.78	9.83	3.28	123.40
13	Kansas City, MO-KS	1.75	5.45	9.71	1.30	48.13
14	Dallas, TX	1.70	13.61	9.44	3.24	123.45
15	Birmingham, AL	1.65	2.40	9.18	0.57	21.14
16	Los Angeles-Long Beach, CA	1.61	25.51	8.92	6.08	244.08
17	Trenton, NJ	1.60	1.10	8.91	0.26	12.65
18	Oakland, CA	1.57	7.19	8.75	1.71	60.79
19	Little Rock-North Little Rock, AR	1.51	1.32	8.41	0.31	11.80
20	San Francisco, CA	1.48	8.06	8.25	1.92	75.70
21	Newark, NJ	1.46	6.22	8.11	1.48	50.9
22	Raleigh-Durham-Chapel Hill, NC	1.43	2.86	7.97	0.68	36.55
23	Orlando, FL	1.43	3.31	7.96	0.79	29.02
24	Monroe, LA	1.43	0.28	7.96	0.07	2.47
25	New York, NY	1.37	28.00	7.61	6.67	163.58

** Each metro must contain either a place with a minimum population of 50,000 or a Census Bureau defined urbanized area and total population of at least 100,000 (75,000 in New England). Ametro comprises one or more counties.*
*** The Location Quotient (LQ) equals % output in metro divided by % output in the U.S. If LQ > 1.0, the industry is more concentrated in the metro area than in the U.S. on average.*

Sources: Milken Institute; RFA

TOP 10 HIGH-TECH INDUSTRY METROS, BY CONCENTRATION

Table 3.6 A
Drugs (SIC #283) Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	Albany, GA	28.43	0.52	15.10	1.30	0.56
2	Kalamazoo-Battle Creek, MI	26.88	1.66	14.28	4.14	5.86
3	Atlantic-Cape May, NJ	25.28	1.50	13.43	3.74	0.71
4	Elkhart-Goshen, IN	18.00	0.62	9.57	1.54	1.57
5	Greenville, NC	16.71	0.28	8.88	0.70	2.74
6	New London-Norwich, CT	11.71	0.48	6.22	1.20	2.12
7	Lafayette, IN	10.28	0.24	5.46	0.60	1.73
8	Indianapolis, IN	8.06	2.12	4.28	5.28	9.17
9	Rocky Mount, NC	7.43	0.13	3.95	0.34	2.46
10	Newark, NJ	6.22	2.53	3.30	6.31	24.11

Table 3.6 B
Computers & Office Equipment (SIC #357) Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	Rochester, MN	143.01	2.35	55.41	7.15	6.90
2	Boulder-Longmont, CO	22.22	0.94	8.61	2.86	7.20
3	San Jose, CA	21.17	8.47	8.20	25.72	47.73
4	Raleigh-Durham-Chapel Hill, NC	16.34	2.48	6.33	7.55	19.80
5	Boise City, ID	15.20	0.84	5.89	2.54	6.09
6	Eau Claire, WI	14.22	0.21	5.51	0.63	4.10
7	Dutchess County, NY	11.30	0.37	4.38	1.11	8.40
8	Austin-San Marcos, TX	10.56	1.63	4.09	4.95	14.22
9	Binghamton, NY	7.24	0.20	2.81	0.61	3.23
10	Fort Collins-Loveland, CO	6.81	0.17	2.64	0.52	1.37

Table 3.6 C
Communications Equipment (SIC #366) Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	Cedar Rapids, IA	24.43	1.50	20.44	2.37	9.79
2	Melbourne-Titusville-Palm Bay, FL	9.51	0.77	7.96	1.21	6.86
3	San Jose, CA	8.46	7.58	7.08	11.99	20.26
4	Omaha, NE-IA	4.81	0.93	4.02	1.47	2.98
5	Lynchburg, VA	3.89	0.15	3.26	0.24	1.54
6	Lawrence, KS	3.27	0.05	2.74	0.08	1.13
7	Dallas, TX	3.16	3.81	2.64	6.03	23.38
8	Chicago, IL	2.59	6.17	2.17	9.76	32.71
9	Santa Rosa, CA	2.58	0.24	2.16	0.38	1.12
10	Longview-Marshall, TX	2.34	0.11	1.96	0.17	1.22

Table 3.6 D
***Electronic Components & Accessories* (SIC #367) Real Output, 1998**

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	Albuquerque, NM	37.59	7.85	29.33	11.85	9.69
2	Lubbock, TX	34.51	1.89	26.93	2.85	0.94
3	Boise City, ID	23.05	2.55	17.98	3.85	9.85
4	Pocatello, ID	22.69	0.33	17.71	0.49	1.41
5	Burlington, VT	14.51	0.75	11.32	1.14	7.91
6	Sherman-Denison, TX	12.54	0.28	9.78	0.42	2.60
7	San Jose, CA	10.64	8.57	8.30	12.93	66.95
8	Glens Fall, NY	10.54	0.21	8.22	0.32	0.29
9	Phoenix-Mesa, AZ	9.60	7.35	7.49	11.08	42.83
10	Austin-San Marcos, TX	9.52	2.96	7.43	4.47	23.29

Table 3.6 E
Aircraft & Parts (SIC #372) Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	South Bend, IN	6.64	0.96	14.69	3.11	1.99
2	Wichita, KS	5.81	1.96	12.85	6.36	45.95
3	Kalamazoo-Battle Creek, MI	4.00	1.03	8.85	3.35	0.51
4	Williamsport, PA	3.10	0.15	6.85	0.50	0.23
5	Seattle-Bellevue-Everett, WA	2.15	4.40	4.76	14.31	105.67
6	West Palm Beach-Boca Raton, FL	1.69	1.10	3.74	3.58	4.11
7	Indianapolis, IN	1.65	1.80	3.64	5.86	4.86
8	Johnstown, PA	1.49	0.12	3.29	0.39	0.10
9	Nassau-Suffolk, NY	1.25	2.06	2.77	6.69	2.98
10	Dayton-Springfield, OH	1.06	0.65	2.34	2.11	2.81

Table 3.6 F
Guided Missiles, Space Vehicles, & Parts (SIC #376) Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	Tucson, AZ	185.68	1.56	10.31	37.25	7.05
2	Colorado Springs, CO	20.29	0.15	1.13	3.47	2.54
3	Huntsville, AL	15.16	0.09	0.84	2.11	4.10
4	San Jose, CA	11.51	0.68	0.64	16.31	11.93
5	Melbourne-Titusville-Palm Bay, FL	10.08	0.05	0.56	1.29	3.23
6	Las Cruces, NM	9.43	0.01	0.52	0.27	3.23
7	Terre Haute, IN	6.37	0.01	0.35	0.27	0.24
8	Boston, MA	5.35	0.62	0.30	14.84	11.14
9	Orange County, CA	4.35	0.24	0.24	5.73	6.33
10	Sacramento, CA	4.19	0.09	0.23	2.26	2.11

Table 3.6 G
Search & Navigation Equipment (SIC #381) Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	Binghamton, NY	66.66	0.47	7.13	5.82	4.59
2	Salem, OR	13.23	0.09	1.42	1.10	0.09
3	Melbourne-Titusville-Palm Bay, FL	8.20	0.08	0.88	1.05	2.32
4	Los Angeles-Long Beach, CA	6.79	2.08	0.73	25.70	36.50
5	Sherman-Denison, TX	6.25	0.02	0.67	0.21	0.10
6	Utica-Rome, NY	5.31	0.03	0.57	0.39	0.93
7	San Jose, CA	4.59	0.53	0.49	6.51	7.54
8	Fort Walton Beach, FL	3.74	0.02	0.40	0.19	0.42
9	Syracuse, NY	3.56	0.07	0.38	0.91	1.34
10	Orange County, CA	3.47	0.37	0.37	4.57	7.45

Table 3.6 H
Measuring & Controlling Devices (SIC #382) Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	Mansfield, OH	54.82	0.30	8.27	2.66	1.34
2	Benton Harbor, MI	38.22	0.19	5.77	1.70	0.51
3	Rockford, IL	32.20	0.47	4.86	4.10	2.05
4	Williamsport, PA	25.80	0.09	3.89	0.76	0.26
5	Altoona, PA	20.67	0.08	3.12	0.70	0.20
6	Lafayette, IN	16.66	0.11	2.51	0.98	1.38
7	Parkersburg-Marietta, WV-OH	16.23	0.08	2.45	0.73	0.51
8	Roanoke, VA	16.10	0.17	2.43	1.49	0.83
9	Spokane, WA	13.22	0.18	1.99	1.61	1.00
10	Santa Rosa, CA	11.81	0.20	1.78	1.72	4.08

Table 3.6 I
Medical Instruments & Supplies (SIC #384) Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	Flagstaff, AZ	125.09	0.34	16.36	3.41	1.09
2	Sumter, SC	36.57	0.09	4.78	0.91	0.67
3	San Angelo, TX	29.36	0.12	3.84	1.25	1.01
4	Sherman-Denison, TX	20.00	0.07	2.62	0.69	0.55
5	Yuba City, CA	14.96	0.04	1.96	0.40	0.05
6	Goldsboro, NC	10.90	0.03	1.43	0.30	0.13
7	Glens Falls, NY	9.54	0.03	1.25	0.31	2.09
8	Augusta-Aiken, GA-SC	7.95	0.11	1.04	1.11	0.43
9	Ocala, FL	7.18	0.03	0.94	0.32	1.00
10	Milwaukee-Waukesha, WI	5.72	0.36	0.75	3.60	6.03

Table 3.6 J
Telephone Communications Services (SIC #481) Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	Middlesex-Somerset-Hunterdon, NJ	4.75	4.99	10.30	3.05	24.24
2	Birmingham, AL	2.96	1.68	6.41	1.03	9.18
3	Kansas City, MO-KS	2.92	3.55	6.33	2.17	21.78
4	Denver, CO	2.84	4.33	6.14	2.65	22.61
5	Jackson, MS	2.79	0.72	6.05	0.44	4.68
6	Monroe, LA	2.70	0.20	5.85	0.12	1.19
7	Monmouth-Ocean, NJ	2.51	1.32	5.44	0.80	7.42
8	Atlanta, GA	2.45	7.45	5.32	4.55	44.12
9	Orlando, FL	2.42	2.18	5.24	1.33	12.06
10	Dallas, TX	2.33	7.29	5.06	4.46	43.77

Table 3.6 K
Computer & Data Processing Services (SIC #737) Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	Provo-Orem, UT	5.51	0.54	9.30	0.42	8.08
2	Boulder-Longmont, CO	4.84	0.83	8.16	0.65	10.24
3	Seattle-Bellevue-Everett, WA	4.10	6.39	6.91	5.02	44.72
4	San Jose, CA	4.08	7.37	6.89	5.79	50.62
5	Washington, DC-MD-VA-WV	3.01	9.24	5.08	7.25	122.30
6	San Francisco, CA	2.76	4.54	4.65	3.57	40.73
7	Huntsville, AL	2.44	0.43	4.11	0.34	7.02
8	Santa Cruz-Watsonville, CA	2.42	0.29	4.09	0.22	2.85
9	Columbus, GA-AL	2.22	0.23	3.75	0.18	5.75
10	Middlesex-Somerset-Hunterdon, NJ	2.18	1.78	3.67	1.40	17.16

Table 3.6 L
Motion Picture Production & Services (SIC #781) Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	Los Angeles-Long Beach, CA	14.69	11.30	3.95	55.61	121.83
2	Tyler, TX	10.98	0.14	2.95	0.67	0.16
3	New York, NY	3.75	3.71	1.01	18.26	38.98
4	Tallahassee, FL	3.50	0.06	0.94	0.30	0.07
5	Lubbock, TX	2.49	0.05	0.67	0.25	0.06
6	Provo-Orem, UT	2.45	0.04	0.66	0.19	0.98
7	Ventura, CA	2.00	0.10	0.54	0.50	1.70
8	San Francisco, CA	1.60	0.42	0.43	2.07	3.87
9	Grand Rapids-Muskegon-Holland, MI	1.55	0.13	0.42	0.63	0.46
10	Middlesex-Somerset-Hunterdon, NJ	1.36	0.18	0.37	0.87	0.36

Table 3.6 M
Engineering and Architectural Services (SIC #871) Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)M.
1	Richland-Kennewick-Pasco, WA	16.03	0.69	13.65	1.07	10.65
2	Huntsville, AL	4.50	0.40	3.83	0.62	6.66
3	Melbourne-Titusville-Palm Bay, FL	3.92	0.32	3.33	0.50	5.08
4	Santa Fe, NM	3.17	0.10	2.70	0.15	1.88
5	Houston, TX	2.82	3.78	2.40	5.89	42.75
6	Baton Rouge, LA	2.51	0.38	2.14	0.59	4.08
7	Ventura, CA	2.40	0.38	2.04	0.59	3.31
8	Detroit, MI	2.35	2.74	2.00	4.26	38.17
9	Beaumont-Port Arthur, TX	2.34	0.20	2.00	0.31	2.54
10	Lawrence, KS	2.31	0.04	1.96	0.06	0.71

Table 3.6 N
Research and Testing Services (SIC #873) Real Output, 1998

	Metro*	Location Quotient**	Output (Bill., 1992$)	% of MSA Total Output	% of U.S. Industry Total	Empl. (Thou.)
1	Richland-Kennewick-Pasco, WA	10.31	0.27	5.43	0.69	9.50
2	Trenton, NJ	5.96	0.39	3.14	0.98	4.64
3	Fort Walton Beach, FL	5.74	0.12	3.02	0.30	2.46
4	Albuquerque, NM	5.56	0.87	2.93	2.19	10.92
5	Boulder-Longmont, CO	4.86	0.26	2.56	0.65	3.30
6	San Diego, CA	4.85	1.97	2.55	4.96	23.36
7	Wilmington, NC	4.12	0.12	2.17	0.30	1.98
8	Barnstable-Yarmouth, MA	3.58	0.09	1.88	0.23	1.67
9	Johnstown, PA	3.54	0.07	1.86	0.17	2.02
10	Yuma, AZ	3.29	0.04	1.73	0.10	0.98

** Each metro must contain either a place with a minimum population of 50,000 or a Census Bureau defined urbanized area and total popula - tion of at least 100,000 (75,000 in New England). Ametro comprises one or more counties.*

*** The Location Quotient (LQ) equals % output in metro divided by % output in the U.S. If LQ > 1.0, the industry is more concentrated in the metro area than in the U.S. on average.*

Sources: Milken Institute; RFA

electronic components and accessories (LQ of 23.1) and computers and office equipment (LQ of 15.2). Boise is home to Micron Technologies, and Hewlett Packard has a major presence. Kalamazoo-Battle Creek, MI, is eighth on the list primarily due to pharmaceuticals. For 100 years, it has been the home to Upjohn, which more recently merged with Pharmacia of Sweden to become Pharmacia & Upjohn. Aircraft and parts is highly concentrated in Kalamazoo, too. Fairly unnoticed, Richland-Kennewick-Pasco, WA, is ninth on the total high-tech concentration list and first for high-tech services. Engineering and architectural services (LQ of 16.0) and research and testing services (LQ of 10.3) are responsible for its high ranking. Middlesex-Somerset-Hunterdon, NJ, has a medical industry cluster, telecommunications services (AT&T), and computer and data processing services, all of which placed it tenth on the list.

Other prominent members of the top 50 high-tech concentration list are Seattle-Bellevue-Everett, WA, at 11th. Boeing's dominance in aircraft and parts give Seattle an LQ of 11.7 in this category. Microsoft's presence is felt in computer and data processing services with a LQ of 4.1. Seattle has four industries in high-tech services with an LQ above 1.0 out of a possible five. Raleigh-Durham-Chapel Hill, NC, is 13th with its Research Triangle. Dallas, TX, is number 18 on the list. Other large metros in the top 50 include Austin-San Marcos, TX; Boston, MA; Phoenix, AZ; Washington, DC - VA - MD; Oakland, CA; Orange County, CA; Denver, CO; San Diego, CA; Atlanta, GA; Los Angeles, CA; Portland-Vancouver, OR - WA; and Indianapolis, IN. Led by San Jose, California has seven metros in the top 50 on the basis of high-tech concentration, the highest of any state.

Boulder-Longmont has 10 high-tech industries with a concentration above the U.S. average, a remarkable achievement for a metro its size.

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Seattle has four high-tech service industries, of a possible five, with an LQ above 1.0.

Table 3.7
Top 50 High-Tech Metros, by Size
Percent of National High-Tech Real Output, 1998

	Metro*	Percent
1	San Jose, CA	5.79
2	Los Angeles-Long Beach, CA	5.11
3	New York, NY	4.23
4	Boston, MA	4.18
5	Chicago, IL	3.76
6	Dallas, TX	3.67
7	Washington, DC-MD-VA-WV	3.50
8	Atlanta, GA	2.53
9	Seattle-Bellevue-Everett, WA	2.52
10	Philadelphia, PA	2.09
11	Orange County, CA	1.85
12	Houston, TX	1.84
13	Phoenix-Mesa, AZ	1.78
14	Oakland, CA	1.55
15	Middlesex-Somerset-Hunterdon, NJ	1.48
16	San Francisco, CA	1.45
17	San Diego, CA	1.41
18	Albuquerque, NM	1.40
19	Newark, NJ	1.35
20	Denver, CO	1.30
21	Detroit, MI	1.20
22	Minneapolis-St. Paul, MN-WI	1.14
23	Austin-San Marcos, TX	1.14
24	New Haven-Bridgeport-Stamford, CT	1.07
25	Portland-Vancouver, OR-WA	1.03
26	Nassau-Suffolk, NY	1.02
27	St. Louis, MO-IL	0.98
28	Raleigh-Durham-Chapel Hill, NC	0.95
29	Kansas City, MO-KS	0.88
30	Indianapolis, IN	0.84
31	Orlando, FL	0.67
32	Sacramento, CA	0.66
33	Pittsburgh, PA	0.64
34	Fort-Worth-Arlington, TX	0.64
35	Tampa-St. Petersburg-Clearwater, FL	0.58
36	Bergen-Passaic, NJ	0.57
37	Baltimore, MD	0.57
38	Boise City, ID	0.53
39	San Antonio, TX	0.51
40	Cincinnati, OH-KY-IN	0.50
41	Columbus, OH	0.49
42	Charlotte-Gastonia-Rock Hill, NC-SC	0.46
43	Cleveland-Lorain-Elyria, OH	0.45
44	Hartford, CT	0.43
45	Salt Lake City-Ogden, UT	0.42
46	Monmouth-Ocean, NJ	0.42
47	West Palm Beach-Boca Raton, FL	0.41
48	Kalamazoo-Battle Creek, MI	0.41
49	Fort Lauderdale, FL	0.40
50	Milwaukee-Waukesha, WI	0.40

** Each metro must contain either a place with a minimum population of 50,000 or a Census Bureau defined urbanized area and total population of at least 100,000 (75,000 in New England). Ametro comprises one or more counties.*

Sources: Milken Institute, RFA

A metro area's proportion of national high-tech output is another way of examining the spatial dimension (horizontal depth). Large metros have an advantage in this approach. Table 3.7 lists the top 50 metros on the basis of what percentage of national high-tech output they represent. There is no surprise on which is at the top of this list — namely San Jose. It accounts for 5.8 percent of total national high-tech output and an astonishing 10.9 percent of national high-tech manufacturing output. San Jose's computer firms account for 25.7 percent of the value of national industry output.

San Jose accounts for 5.8 percent of total national high-tech output and an astonishing 10.9 percent of national high-tech manufacturing output.

Los Angeles is second on the list, although its relative ranking is probably inflated by the inclusion of motion picture production and services in the high-tech industries. Motion picture production and services is included in an attempt to capture new multimedia and entertainment technologies. These technologies combine film, television, and amusements with computer animation and digital-audio sound effects; Los Angeles dominates this industry. New York placed third on the list representing 4.2 percent of national high-tech industry output, but when adjusted for the size of its economy, this figure is not as impressive. Boston, with a smaller economic base, accounts for the same share of national output as New York. Chicago, Dallas, Washington, Atlanta, and Seattle round out the top 10. California's dominant position in high-tech industries is displayed in this ranking. It has six metros in the top 20, and they account for over 17 percent of national high-tech output.

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Los Angeles is second on the list, aided by multimedia and entertainment technologies.

Measures of concentration of high-tech activity in a metro economy, such as location quotients, can present a misleading perspective of the importance of smaller-sized metros in the national picture. Shares of national high-tech production, however, can be a deceptive measure because a very large metro can rank high merely because of its immense size (e.g., New York). The central problem becomes how to develop an index that combines the two approaches to spatial concentration measurement. The ultimate composite measure that is derived will be dependent upon how much weight is placed upon the location quotient versus the share of national high-tech output. We examined several different approaches and weighting schemes in order to develop a composite measure. A straightforward approach seemed to be the most appropriate. Combining the location quotient with the share of national high-tech output in a multiplicative fashion yields our composite measure of technology production centers, or as we term them, Tech-Poles. They are Tech-Poles in the sense of the relative technology gravitation pull that they exert. Table 3.8 shows the numeric results for the top 50 Tech-Poles while Figure 3.5 maps their location.

The dominance of Silicon Valley (San Jose metro) as a high-tech industry center is well documented. But our composite index of 23.7 is more than three times the size of the second-ranked metro, which is barely larger than the third-place metro. As a Tech-Pole, the gravitational pull of the San

Silicon Valley created the personal-computer industry and is developing another — electronic networking — which has the potential to exceed the first.

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The Dallas metro area includes six of the nation's 20 largest telecommunication services companies.

Figure 3.5
Milken Institute Tech-Poles

Jose metro area, home to Hewlett-Packard, Applied Materials, Sun Microsystems, Intel, Cisco Systems, Oracle, and Silicon Graphics, is unparalleled. Based upon our definition of high-tech industries, San Jose's real (1992 dollars) value of production is $39.8 billion; it employs 279.1 thousand workers, and its value of production per employee is $142.5 thousand. Silicon Valley created the personal-computer industry and is developing another industry — electronic networking — that has the potential to exceed the size of the PC market.

Dallas's position, second on the index, might surprise. But with a diversified high-tech base — seven industries out of a possible 14 are more concentrated than the national average — it deserves to be high on the list. The Dallas metro area includes six of the nation's 20 largest telecommunication services companies. GTE's global headquarters is based in Dallas, while Nortel, Ericsson, Fujitsu, and Alcatel have U.S. headquarters there (Rossell and Walker 1998). Austin is thought by many to be the center of Texas's electronic components industry, but Dallas exceeds Austin's production by over 20 percent in terms of value of output and exceeds its employment by 4,200 workers.

Despite the loss of defense-related high-tech firms in the early 1990s, Los Angeles ranks third on the index. The ranking is somewhat inflated, perhaps, by the inclusion of non-high-tech portions of motion picture production and services. But even if the entire entertainment industry were excluded, Los Angeles would rank seventh.

Table 3.8
Top 50 Milken Institute Tech-Poles
Composite Index, 1998

	Tech-Poles	Composite Index*	Number of High-Tech LQs Over 1**
1	San Jose, CA	23.69	10
2	Dallas, TX	7.06	7
3	Los Angeles-Long Beach, CA	6.91	5
4	Boston, MA	6.31	11
5	Seattle-Bellevue-Everett, WA	5.19	6
6	Washington, DC-MD-VA-WV	5.08	5
7	Albuquerque, NM	4.98	3
8	Chicago, IL	3.75	4
9	New York, NY	3.67	2
10	Atlanta, GA	3.46	4
11	Middlesex-Somerset-Hunterdon, NJ	3.40	7
12	Phoenix-Mesa, AZ	2.60	1
13	Orange County, CA	2.59	10
14	Oakland, CA	2.21	8
15	Philadelphia, PA	2.19	4
16	Rochester, MN	1.95	1
17	San Diego, CA	1.93	9
18	Raleigh-Durham-Chapel Hill, NC	1.89	7
19	Denver, CO	1.81	3
20	Newark, NJ	1.80	5
21	Austin-San Marcos, TX	1.78	4
22	San Francisco, CA	1.62	5
23	Houston, TX	1.62	2
24	Boise City, ID	1.43	2
25	New Haven-Bridgeport-Stamford, CT	1.33	10
26	Portland-Vancouver, OR-WA	1.33	2
27	Boulder-Longmont, CO	1.12	9
28	Kalamazoo-Battle Creek, MI	1.09	2
29	Indianapolis, IN	1.07	4
30	Nassau-Suffolk, NY	1.05	7
31	Kansas City, MO-KS	1.03	2
32	Minneapolis-St. Paul, MN-WI	0.98	4
33	Lubbock, TX	0.97	2
34	St. Louis, MO-IL	0.93	4
35	Cedar Rapids, IA	0.92	5
36	Orlando, FL	0.82	4
37	Sacramento, CA	0.82	6
38	Detroit, MI	0.79	2
39	Wichita, KS	0.72	3
40	Tucson, AZ	0.67	5
41	Fort Worth-Arlington, TX	0.66	4
42	Colorado Springs, CO	0.58	9
43	Monmouth-Ocean, NJ	0.55	4
44	Bergen-Passaic, NJ	0.51	6
45	Melbourne-Titusville-Palm Bay, FL	0.51	7
46	San Antonio, TX	0.49	3
47	Pittsburgh, PA	0.48	2
48	Atlantic-Cape May, NJ	0.44	1
49	West Palm Beach-Boca Raton, FL	0.43	3
50	Huntsville, AL	0.43	7

** Composite Index is equivalent to the percent of national high-tech real output multiplied by the high-tech real output location quotient for each metro.*

*** The Location Quotient (LQ) equals % output in metro divided by % output in the U.S. If LQ > 1.0, the industry is more concentrated in the metro area than in the U.S. on average.*

Sources: Milken Institute, RFA

Boston is enjoying renewed vigor due to its Internet-related prowess.

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Virtually unnoticed, Washington, DC, has become a communications hub.

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Atlanta, ranking 10th, is the undisputed high-tech capital of the Southeast.

Boston places fourth, with an above-average concentration in 11 high-tech industries. It is home to some of the leading universities and research centers in the nation. Although the joint impact of defense downsizing and heavy dependence on the lagging mainframe computer industry has been sizable, Boston is enjoying renewed vigor due to its Internet-related prowess. Internet portal giant Lycos is headquartered in Waltham, while many other startups are emerging on Route 128. The fifth-ranking Tech-Pole is the Seattle-Bellvue-Everett triad. Thanks to Boeing, aircraft is still a major industry in Seattle, but software's rapid growth has made computer and data processing services a vital part of the region's economy. Microsoft, of course, is at the nucleus of the Seattle software cluster.

From sixth place on down, the rankings are full of surprises. On a composite ranking of high-tech services, Washington, DC, places first in the country, and sixth overall in high tech. Virtually unnoticed, Washington has become a communications hub. Its Virginia suburb of Fairfax County is home to America Online, UUNET, and PSINet. Over one-half of the nation's Internet traffic passes through local firms. Software and data processing are major sectors of the local economy as well.

Albuquerque's high ranking (seventh) derives from its success in attracting electronic component manufacturers. Chicago is an important center of communications equipment, courtesy of Motorola, and ranks eighth. The windy city also has an above-average concentration in pharmaceuticals and in research and testing services. New York's ninth rank is in part due to its major presence in telecommunications services. The city has very little high-tech manufacturing, which brings into question how much silicon is really in Silicon Alley.

Atlanta, ranking 10th, is the undisputed high-tech capital of the Southeast, with a foothold in telecommunication services, computers, and data processing services. Oakland's 14th position places it just behind Orange County, California — a fact that may surprise those accustomed to thinking of it as an aging seaport and home to a struggling underclass. San Diego, with it highly diversified high-tech economy, ranks 17th. Raleigh-Durham-Chapel Hill, Denver, Austin, San Francisco, Houston, and Boise round out the top 25.

High-Technology Spatial Growth

Another important topic with regard to metropolitan economies is the determination of which economies are recording the strongest growth in high-tech industry output. Spatial concentration is important, but it does not guarantee mastery in maintaining superior high-tech growth. Analyzing high-tech growth in metros would not seem to be a complex task, but it can become one very easily. For example, if the initial concentration of high-tech production is very low, a comparatively small

Table 3.9
Top 50 High-Tech Metros, by Growth
Relative High-Tech Real Output Growth, 1990 to 1998

	Metro*	Relative Growth**
1	Albuquerque, NM	4.37
2	Pocatello, ID	3.08
3	Boise City, ID	2.93
4	Cedar Rapids, IA	2.68
5	Harrisburg-Lebanon-Carlisle, PA	2.58
6	Columbus, GA-AL	2.39
7	Merced, CA	2.23
9	Richland-Kennewick-Pasco, WA	2.02
9	Yuma, AZ	1.95
10	Austin-San Marcos, TX	1.92
11	Eugene-Springfield, OR	1.88
12	Albany, GA	1.87
13	Yolo, CA	1.80
14	Tyler, TX	1.78
15	Flint, MI	1.78
16	Portland-Vancouver, OR-WA	1.77
17	Killeen-Temple, TX	1.77
18	Iowa City, IA	1.75
29	Phoenix-Mesa, AZ	1.71
20	New London-Norwich, CT	1.67
21	Little Rock-North Little Rock, AR	1.64
22	Texarkana, TX-AR	1.64
23	San Antonio, TX	1.64
24	Waco, TX	1.64
25	Clarksville-Hopkinsville, TN-KY	1.64
26	Dallas, TX	1.60
27	Kenosha, WI	1.58
28	Colorado Springs, CO	1.55
29	Waterloo-Cedar Falls, IA	1.53
30	Lancaster, PA	1.52
31	Lynchburg, VA	1.51
32	Tallahassee, FL	1.50
33	Atlanta, GA	1.50
34	Brazoria, TX	1.50
35	Sacramento, CA	1.48
36	Houston, TX	1.48
37	Grand Forks, ND-MN	1.47
38	Denver, CO	1.47
39	Springfield, MO	1.47
40	Longview-Marshall, TX	1.45
41	Lubbock, TX	1.45
42	Greeley, CO	1.44
43	Bismarck, ND	1.43
44	Lafayette, LA	1.41
45	Johnstown, PA	1.41
46	San Luis Obispo-Atascadero, CA	1.40
47	Boulder-Longmont, CO	1.39
48	Goldsboro, NC	1.37
49	Vallejo-Fairfield-Napa, CA	1.36
50	San Jose, CA	1.36

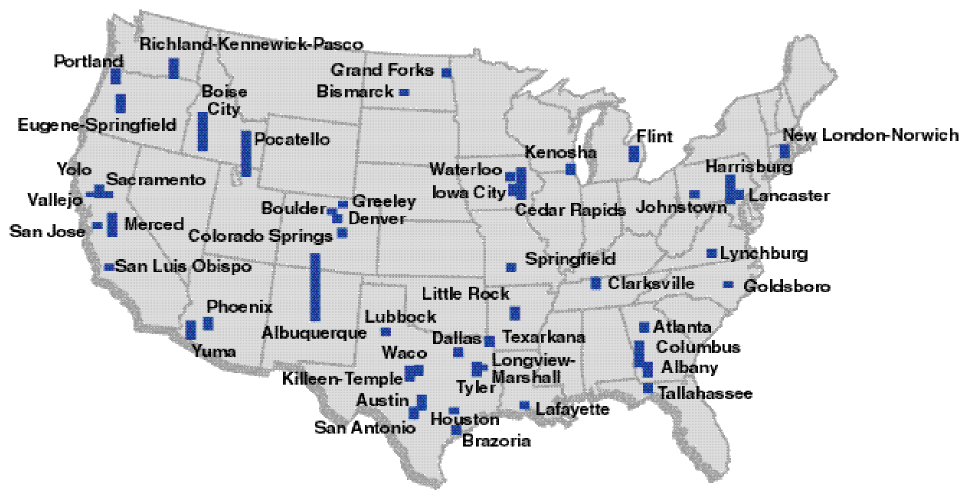
** Each Metro must contain either a place with a minimum population of 50,000 or a Census Bureau defined urbanized area and total population of at least 100,000 (75,000 in New England). Ametro comprises one or more counties.*

*** Relative growth in high-tech real output is equivalent to metro output indexed to 1990 then divided by U.S. index. Ametro with a value of >1 grew faster than the national average from 1990 to 1998.*

Sources: Milken Institute, RFA

Figure 3.6

Relative High-Tech Real Output Growth, 1990 to 1998



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Albuquerque has recorded a compound annual growth rate of 12.7 percent in high-tech output in the 1990s.

change will yield a high growth rate and skew the results in the direction of lower initial concentrations. Results obtained without adjusting for initial concentration may very well lack economic significance. We therefore developed two approaches to high-tech growth measurement. The first approach was to examine high-tech output growth in metros relative to the U.S. average without any adjustment. In the second, we adjusted for the initial density of high-tech in metros before analyzing the relative growth patterns.

Table 3.9 and Figure 3.6 exhibit the top 50 metros based upon the unadjusted growth in high-tech output between 1990 and 1998 relative to the U.S. average. If high-tech growth in a metro matched the U.S. average over this period, it would have an index of 1.0. At the top of this list is Albuquerque. It has recorded a compound annual growth rate of 12.7 percent in high-tech output in the 1990s. This is almost entirely attributable to electronic components and accessories. Pocatello and Boise City, ID, are second and third, respectively. Boise City is home to the Hewlett-Packard laser-jet printer division and semiconductor manufacturer Micron Technologies. Rapid growth in communications equipment production in Cedar Rapids, IA, places it fourth on the list. Quietly, Harrisburg, PA, is next in the rankings with rapid growth in electronic components. Columbus, GA, ranks sixth due to computer and data processing services. Merced, CA, recorded strong growth in drugs; however, it had a very small base. The Richland, WA, metro area witnessed increases in engineering and architectural services. Austin is in the 10th position and is a center of computer and electronics production.

Table 3.10
Top 50 Metros, by Adjusted Relative Growth Index

	Metro*	Adjusted Relative Growth**
1	Albuquerque, NM	6.92
2	San Jose, CA	5.86
3	Boise City, ID	4.94
4	Rochester, MN	4.75
5	Lubbock, TX	4.43
6	Boulder-Longmont, CO	4.13
7	Cedar Rapids, IA	3.65
8	Pocatello, ID	2.97
9	Richland-Kennewick-Pasco, WA	2.86
10	Kalamazoo-Battle Creek, MI	2.78
11	Middlesex-Somerset-Hunterdon, NJ	2.56
12	Dallas, TX	2.48
13	Raleigh-Durham-Chapel Hill, NC	2.42
14	Colorado Springs, CO	2.34
15	Albany, GA	2.31
16	Austin-San Marcos, TX	2.31
17	Seattle-Bellevue-Everett, WA	2.21
18	Phoenix-Mesa, AZ	2.10
19	Flagstaff, AZ	2.08
20	Tucson, AZ	2.06
21	Burlington, VT	2.04
22	South Bend, IN	2.02
23	Provo-Orem, UT	1.94
24	Wichita, KS	1.88
25	Melbourne-Titusville-Palm Bay, FL	1.87
26	Huntsville, AL	1.81
27	Sherman-Denison, TX	1.77
28	Atlanta, GA	1.76
29	Denver, CO	1.69
30	Fort Collins-Loveland, CO	1.63
31	Portland-Vancouver,OR-WA	1.63
32	Boston, MA	1.55
33	Atlantic-Cape May, NJ	1.55
34	Oakland, CA	1.49
35	Santa Cruz-Watsonville, CA	1.42
36	Indianapolis, IN	1.41
37	Orange County, CA	1.41
38	Washington, DC-MD-VA-WV	1.39
39	Elkhart-Goshen, IN	1.39
40	Orlando, FL	1.38
41	Harrisburg-Lebanon-Carlisle, PA	1.36
42	San Diego, CA	1.34
43	Binghamton, NY	1.32
44	Kansas City, MO-KS	1.31
45	Monmouth-Ocean, NJ	1.30
46	Omaha, NE-IA	1.30
47	Newark, NJ	1.27
48	Fort Worth-Arlington, TX	1.27
49	Greenville, NC	1.27
50	Glens Falls, NY	1.26

** Each metro must contain either a place with a minimum population of 50,000 or a Census Bureau defined urbanized area and total population of at least 100,000 (75,000 in New England). Ametro compromises one or more counties.*

*** Adjusted relative growth index is equivalent to relative high-tech real output growth (1998 value) multiplied by high-tech real output location quotient (1990 value).*

Sources: Milken Institute, RFA

Houston has the distinction of being the largest metro ranking in the top 50 on high-tech growth in the 1990s.

Starting from a low high-tech base, Eugene-Springfield, OR, has witnessed large percentage gains in computers and office equipment, communications equipment, and computer and data processing services. Albany, GA, a small metro, experienced solid increases in drugs and aircraft and parts. Flint, MI, does not often come to mind when one thinks about high-tech growth, but it ranks high in the 1990s due to strong growth in computer and data processing services. Portland, OR, is among the best performers in high-tech growth in the 1990s. Electronics firms have invested billions of dollars in semiconductor chip and wafer plants in the Portland area; electronics production during the same period grew at a compound annual rate of 13.9 percent. Houston's past is based upon energy, but its future will have a high-tech component. Houston has the distinction of being the largest metro ranking in the top 50 on high-tech growth in the 1990s. Compaq, the largest supplier of PCs in the U.S. market, is based in Houston and has fueled tremendous growth in computers.

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In developing the concentration-adjusted composite relative growth index, we used the high-tech location quotient to incorporate a measure of initial density. Table 3.10 presents this composite growth index. If a metro area has an above-average initial concentration of high-tech activity, its relative growth will be bolstered. Albuquerque is in the top position by this measure as well, courtesy of its 29.3 percent compound annual growth rate in electronic components and accessories during the 1990s. Ranking 50th in the unadjusted growth index, San Jose moves up to second place after its high-tech concentration is taken into account. Rochester, MN, is third on this list despite witnessing high-tech output growth slightly below the U.S. average. Its large location quotient accounts for this elevated position. Boise City, ID; Cedar Rapids, IA; Pocatello, ID; and the Richland, WA, metro areas remain in the top 10 even after adjusting for high-tech concentration.

The Raleigh, NC, metro area has experienced rapid growth in the high-tech services of telephone communications and computer and data processing.

Lubbock, TX, ranks fifth on this list with a very large initial high-tech concentration. Boulder, CO, ranking sixth, experienced strong growth in computers and office equipment and in telephone communications. Kalamazoo-Battle Creek, MI, completed the top 10. Dallas was high on the list with solid growth across a number of high-tech industries. This balanced growth pattern is elevating Dallas into the elite of high-tech metros. The Raleigh, NC, metro area has experienced rapid growth in the high-tech services of telephone communications and computer and data processing, but not in its traditional area of strength — computers. Colorado Springs, CO, ranks 14th due to a 15.8 percent compound annual growth rate in telephone communications.

Phoenix ranked in the top five metros on job growth in the 1990s. Much of Phoenix's overall success is based upon the expansion of high tech. Motorola's semiconductor components group is based in Phoenix. Electronic components and accessories output growth has averaged 10 percent in the 1990s, and the industry employs 42.8 thousand employees. Atlanta is another high-tech growth leader among large metro areas. Atlanta's growth is in high-tech services, where it recorded a 5.3 percent compound annual rate of growth since 1990. Denver, another large metro also is witnessing sustained growth in technology services. Denver is among the metro leaders in telephone communications and computer and in data processing. Silicon Valley–based computer and communications equipment firms have moved production into Oakland in order to take advantage of lower costs, but retain operations in the Bay Area.

There is evidence that high-tech manufacturing is becoming less spatially concentrated, but that high-tech services are becoming more concentrated.

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The mean of the location quotients for the top 10 high-tech manufacturing metros declined from 8.3 in 1978 to 7.0 in 1998.

The Forces of Concentration and Dispersion: Who's Winning?

We have demonstrated the importance of high-technology industries in determining economic growth between metros, which metros have the highest concentrations of technology industries, and which metros are experiencing the most rapid growth in high-tech output. However, there remains an unanswered question: Is high-tech production becoming more spatially concentrated or more dispersed? This is a complex issue and must be analyzed from several perspectives. There is evidence that high-tech manufacturing is becoming less spatially concentrated, but that high-tech services are becoming more concentrated. Even though manufacturing seems to be dispersing to peripheral regions, it remains highly geographically concentrated and clearly shows that agglomeration forces are continuing to exert influence.

We analyzed the changing spatial patterns of high-technology industries from 1978 to 1998. Each industry was inspected individually, but we found a major distinction between high-tech service and manufacturing industries. We calculated location quotients and their standard deviations and medians based on data from the years 1978 to 1998. A standard deviation that fell over time was indicative of a dispersion process at work; one that rose was indicative of concentration. In the case of high-tech manufacturing, the standard deviation of the location quotient for output fell from 1.76 in 1978 to 1.46 in 1998. The mean of the location quotients for the top 10 high-tech manufacturing metros declined from 8.3 in 1978 to 7.0 in 1998. In high-tech services, the standard deviation of the location quotients rose from 0.45 in 1978 to 0.49 in 1998, pointing toward a slight advantage for the forces of agglomeration. For total high-tech production, the standard deviation of the location quotients decreased from 0.76 in 1978 to 0.67 in 1998, suggesting a mild disagglomeration pattern.

Each metro area's high-tech evolution has its own unique characteristics, and broad generalizations must be drawn cautiously, but there appears to be a common pattern among metros that were the leaders in high-tech

Between 1978 and 1998, only four metros experienced no decline in high-tech concentration.

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In both Los Angeles and in Orange County, the collapse of aerospace and other defense-related high-tech manufacturing is seen.

Table 3.11
Top 25 High-Tech Metros in 1978
Ranked by 1978 Location Quotient

	Metro*	1978 LQ	1998 LQ**	1998 LQ Rank	Difference, 1978 to 1998	Percent Change, 1978 to 1998
1	Rochester, MN	6.36	5.56	1	-0.80	-12.61
2	Williamsport, PA	4.05	1.36	37	-2.69	-66.48
3	Kalamazoo-Battle Creek, MI	3.82	2.66	8	-1.16	-30.31
4	San Jose, CA	3.71	4.09	2	0.38	10.13
5	Sherman-Denison, TX	3.45	1.60	25	-1.85	-53.74
6	South Bend, IN	3.29	1.96	16	-1.33	-40.47
7	Boulder-Longmont, CO	3.18	2.89	6	-0.29	-9.03
8	Wichita, KS	3.10	1.89	19	-1.20	-38.82
9	Lubbock, TX	3.03	3.08	4	0.05	1.52
10	Rockford, IL	2.87	0.96	70	-1.91	-66.42
11	Melbourne-Titusville-Palm Bay, FL	2.82	2.00	12	-0.82	-29.20
12	Binghamton, NY	2.81	1.57	26	-1.24	-44.05
13	Dutchess County, NY	2.56	1.26	47	-1.30	-50.86
14	Huntsville, AL	2.47	1.78	23	-0.69	-28.10
15	Glens Falls, NY	2.43	1.25	48	-1.18	-48.58
16	Burlington, VT	2.35	1.94	17	-0.40	-17.14
17	Seattle-Bellevue-Everett, WA	2.28	2.06	11	-0.22	-9.65
18	Middlesex-Somerset-Hunterdon, NJ	2.28	2.30	10	0.03	1.10
19	Albany, GA	2.27	1.97	15	-0.30	-13.02
20	West Palm Beach-Boca Raton, FL	2.24	1.06	60	-1.19	-52.92
21	Nassau-Suffolk, NY	2.24	1.03	63	-1.20	-53.74
22	Richland-Kennewick-Pasco, WA	2.19	2.41	9	0.23	10.29
23	Tucson, AZ	2.17	1.83	22	-0.33	-15.37
24	Los Angeles-Long Beach, CA	2.05	1.35	39	-0.70	-34.10
25	Orange County, CA	2.05	1.40	33	-0.65	-31.56

** Each metro must contain either a place with a minimum population of 50,000 or a Census Bureau defined urbanized area and total population of at least 100,000 (75,000 in New England). Ametro compromises one or more counties.*

*** The Location Quotient (LQ) equals % output in metro divided by % output in the U.S. If LQ > 1.0, the industry is more concentrated in the metro area than in the U.S. on average.*

Sources: Milken Institute, RFA

concentration 20 years ago: the majority witnessed a decline in concentration. Table 3.11 displays the top 25 metros in high-tech concentration based upon location quotients in 1978, their 1998 location quotients, and the change between the two periods. Between 1978 and 1998, only four metros experienced no decline in high-tech concentration. The mean decline in concentration based upon location quotients for the 25 metros was 0.8, a 28 percent decrease. Most of these large concentration reductions were attributable to a high-tech manufacturing sector. In the cases of Dutchess County and Binghamton, NY, the waning importance of mainframe computing is the culprit. The rise of the personal computer is seen in the San Jose figures; it had the largest increase in concentration. In both Los Angeles and in Orange County, the collapse of aerospace and other defense-related high-tech manufacturing is seen. In contrast, high-tech services experienced a decline in concentration in 12 out of the top 25 metros. Few metros showed sizable declines, but it appears that once a critical mass of services is achieved, agglomeration forces are able to sustain a location advantage for a longer period of time.

Tables 3.12 and 3.13 display those metros with the greatest increases and decreases in high-tech concentration between 1978 and 1998. High-tech services are shown in Table 3.12, while manufacturing is shown in Table 3.13. As the table shows, smaller and generally lower-cost metros experienced the largest increase in manufacturing concentration. Albuquerque, Boise City, and Pocatello witnessed large gains. Twelve of the top 25 metros experiencing gains in manufacturing concentration were in the West, while seven were in the South. The majority of the 25 metros with the biggest decline in manufacturing were in the East and Midwest. Both high-tech service concentration and overall concentration showed similar patterns: the West and South saw gains in concentration while the East and Midwest saw declines.

The processes behind the variance in spatial concentration of high-tech industries are complex and numerous. An analysis of the data reveals that

Table 3.12
Change in High-Tech Services Location Quotient
Top and Bottom 25 Metros

Top 25			Bottom 25		
	Metro*	LQ Difference, 1978 to 1998**		Metro*	LQ Difference, 1978 to 1998**
1	Seattle-Bellevue-Everett, WA	1.23	1	Melbourne-Titusville-Palm Bay, FL	-1.58
2	Denver, CO	0.99	2	Huntsville, AL	-1.38
3	Middlesex-Somerset, NJ	0.98	3	Springfield, IL	-1.34
4	Oakland, CA	0.89	4	Albuquerque, NM	-1.18
5	Kansas City, MO-KS	0.84	5	Pine Bluff, AR	-0.95
6	Monroe, LA	0.75	6	Cheyenne, WY	-0.67
7	Raleigh-Durham-Chapel Hill, NC	0.72	7	Myrtle Beach, SC	-0.64
8	Provo-Orem, UT	0.70	8	Jonesboro, AR	-0.62
9	Atlanta, GA	0.55	9	San Jose, CA	-0.61
10	Little Rock-North Little Rock, AR	0.55	10	Dover, DE	-0.61
11	Washington, DC-MD-VA-WV	0.54	11	Boise City, ID	-0.61
12	Flint, MI	0.53	12	Asheville, NC	-0.60
13	Monmouth-Ocean, NJ	0.48	13	Champaign-Urbana, IL	-0.60
14	Cedar Rapids, IA	0.47	14	Reading, PA	-0.60
15	San Antonio, TX	0.46	15	Casper, NY	-0.57
16	Tallahassee, FL	0.45	16	Jacksonville, FL	-0.55
17	Lawrence, KS	0.44	17	Gainesville, FL	-0.55
18	Sacramento, CA	0.43	18	Bloomington, IN	-0.54
19	Fort Walton Beach, FL	0.41	19	Las Vegas, NV-AZ	-0.54
20	Lansing-East Lansing, MI	0.40	20	Sioux Falls, SD	-0.53
21	Columbus, GA-AL	0.37	21	Visalia-Tulare-Porterville, CA	-0.53
22	Richland-Kennewick-Pasco, WA	0.36	22	Florence, SC	-0.52
23	Tyler, TX	0.33	23	Grand Junction, CO	-0.51
24	San Diego, CA	0.32	24	Bakersfield, CA	-0.51
25	Jersey City, NJ	0.31	25	Topeka, KS	-0.51

** Each metro must contain either a place with a minimum population of 50,000 or a Census Bureau defined urbanized area and total population of at least 100,000 (75,000 in New England). Ametro comprises one or more counties.*

*** The Location Quotient (LQ) equals % output in metro divided by % output in the U.S. If LQ > 1.0, the industry is more concentrated in the metro area than in the U.S. on average.*

Sources: Milken Institute, RFA

Smaller and generally lower-cost metros experienced the largest increase in manufacturing concentration.

Table 3.13
Change in High-Tech Manufacturing Location Quotient 1978
Top and Bottom 25 Metros

Top 25			Bottom 25		
	Metro*	LQ Difference, 1978 to 1998**		Metro*	LQ Difference, 1978 to 1998**
1	Albuquerque, NM	7.15	1	Williamsport, PA	-6.44
2	Boise City, ID	4.82	2	Rockford, IL	-4.61
3	Pocatello, ID	4.55	3	Sherman-Denison, TX	-4.30
4	Cedar Rapids, IA	3.67	4	Binghamton, NY	-3.49
5	Flagstaff, AZ	3.00	5	Dutchess County, NY	-3.26
6	San Jose, CA	1.99	6	Hartford, CT	-3.16
7	Austin-San Marcos, TX	1.86	7	South Bend, IN	-3.05
8	Greenville, NC	1.82	8	West Palm Beach-Boca Raton, FL	-3.02
9	Atlantic-Cape May, NJ	1.7	9	Wichita, KS	-2.91
10	New London-Norwich, CT	1.54	10	Utica-Rome, NY	-2.86
11	Eau Claire, WI	1.42	11	Pittsfield, MA	-2.85
12	Duluth-Superior, MN-WI	1.35	12	Nassau-Suffolk, NY	-2.79
13	Santa Cruz-Watsonville, CA	1.35	13	Glens Falls, NY	-2.77
14	Harrisburg-Lebanon-Carlisle, PA	1.18	14	Seattle-Bellevue-Everett, WA	-2.45
15	Phoenix-Mesa, AZ	1.14	15	Kalamazoo-Battle Creek, MI	-2.33
16	Colorado Springs, CO	1.12	16	Altoona, PA	-2.00
17	Sumter, SC	0.99	17	Kankakee, IL	-1.86
18	Sacramento, CA	0.99	18	Erie, PA	-1.82
19	Roanoke, VA	0.93	19	Jonesboro, AR	-1.72
20	Raleigh-Durham-Chapel Hill, NC	0.79	20	Rochester, MN	-1.70
21	Dallas, TX	0.78	21	Fort Wayne, IN	-1.53
22	Spokane, WA	0.71	22	Los Angeles-Long Beach, CA	-1.48
23	Portland-Vancouver, OR-WA	0.71	23	Middlesex-Somerset-Hunterdon, NJ	-1.46
24	Killeen-Temple, TX	0.69	24	Trenton, NJ	-1.43
25	Tacoma, WA	0.69	25	Fort Worth-Arlington, TX	-1.37

** Each metro must contain either a place with a minimum population of 50,000 or a Census Bureau defined urbanized area and total population of a least 100,000 (75,000 in New England). Ametro comprises one or more counties.*

*** The Location Quotient (LQ) equals % output in metro divided by % output in the U.S. If LQ > 1.0, the industry is more concentrated in the metro area than in the U.S. on average.*

Sources: Milken Institute, RFA

technology lock-in has played a role in the changing spatial distribution of these high-tech industries. Computers and data processing equipment offer a prime example. Many of the leading mainframe firms were located in the Northeast. These firms either did not see the PC revolution unfolding or believed that they would not be severely harmed. The risk associated with dependence on a single segment of an industry can be high for a metro economy. There also is evidence that new ideas require new geography in order to be developed fully.

In high-tech manufacturing, some evidence suggests that rising costs are pushing production to lower-cost metros. In the early stages of the development of a high-tech manufacturing cluster, agglomeration forces will tend to dominate. Research and development activities as well as production activities concentrate in a metro area. At some point, production costs and other forms of congestion-related costs can increase sufficiently to offset the initial location advantage of a metro. New manufacturing capacity will be developed in lower business-cost and less-expensive metros, but they must meet key basic criteria. In the case of semiconductors, new production facilities are extremely large and costly. New semiconductor facilities are being developed in Albuquerque, Austin, Boise City, Phoenix, and other lower-cost metros. Portland has experienced a boom in electronics capacity expansion, but there already are signs that rising costs will limit future growth. Industry leaders such as Intel retain much of their research and development activities in Silicon Valley but build their new plants elsewhere. Austin, Dallas, and Sacramento owe some of their achievement in computer manufacturing to cost-of-doing-business advantages.

The majority of the 25 metros with the biggest decline in manufacturing were in the East and Midwest.

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Further examination of the list of metros experiencing the fastest growth in high-tech industries reveals a high mix of small to medium-sized metros that are developing some concentration of these industries. Most of the metros (38 out of the top 50 in high-tech growth) are in the South and West, and they rank high on most measures of cost of doing business, cost of living, and on the elusive concept of quality of life. In essence, high-tech manufacturing concentration is being partially reallocated across the geographic landscape. This pattern is true for some non-high-tech manufacturing industries as well. This is a dynamic, nonlinear process that exerts its influence on the geographic landscape. New centers of high-tech manufacturing emerge, agglomeration forces foster further growth, and, ultimately, sustained success of these centers depends upon the degree to which they can avoid high congestion-related and production costs.

In high-tech manufacturing, there is evidence that rising costs are pushing production to lower-cost metros.

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Similar to high-tech manufacturing, the pace of high-tech services growth is fastest in small to medium-sized metro areas that have developed a critical mass of concentration. Contrary to manufacturing, however, the overall concentration of high-tech services is rising. Large high-tech service metros are sustaining growth and accounting for a larger share of national output. Information technology may be a contributing factor to this process. The expansion of digital communication capabilities, together with their decline in costs, is permitting services to exploit agglomeration economies in new ways. Service activities should benefit more from geographic proximity than manufacturing. Computer and data processing services are becoming more spatially concentrated, and the software and Internet-related activities especially so.

Most of the metros (38 out of the top 50 in high-tech growth) are in the South and West.

Despite some evidence of rising spatial dispersion in high-tech manufacturing, it is remarkable how concentrated it remains. Agglomeration forces have an amazing ability to sustain themselves, only to be thwarted at some point by very high congestion-related costs. A

The expansion of digital communication capabilities, together with their decline in costs, is permitting services to exploit agglomeration economies in new ways.

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Locations that are attractive to knowledge assets will play a vital role in regional economic success.

combination of high costs and either obsolete technology or firms is almost required before high-tech activity goes into a state of decline in a metro area. The factors that determine the spatial patterns are difficult to model, but further research on their relative importance is crucial to a more thorough understanding of how metros can develop and expand high-technology-based industry clusters. Some degree of modeling attainment also may allow metro areas to identify the point at which cost factors are approaching critical values, alerting them to a potential erosion of their high-tech industry clusters.

As we enter the age of human capital, where firms merely lease knowledge assets, firms' location decisions will be increasingly based upon quality-of-life factors that are important to attracting and retaining this most vital economic asset. In high-tech services, strict business-cost measures will be less important to growing and sustaining technology clusters in metro economies. Locations that are attractive to knowledge assets will play a vital role in regional economic success.

SECTION 4

High-Tech Industries and Economic Risks

The risks emanating form high tech, and the focus of this section, relate to the industry's inherent volatility, its growing importance in the overall economy, and the closer relationship between it and U.S. business cycle.

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If a synchronous shock were to spread across a number of related technology industries, an economywide recession could occur.

Technology and high-tech industries are promoting favorable economic developments throughout the U.S. economy on many dimensions. Technology is improving the economy's long-term growth rate and determining the relative success of metropolitan areas within the country. On balance, the benefits to the economy far exceed the less-noticed negative aspects of technology-driven economic development. The technology-driven economy — or New Economy as referred to by many — is causing a widening of income disparity along educational attainment levels, reducing job security and job tenure in many industries, and resulting in greater risk of unemployment among workers in their 50s (Benner, Brownstein, and Dean 1999). However, the risks emanating from high tech that we will focus on in this section relate to the industry's inherent volatility, its growing importance in the overall economy, and the closer relationship between it and the business cycle of the U.S. economy. Will these risks prove to be severe for metropolitan areas that have developed high-tech clusters which are prone either to technology cycles or to fluctuations emanating from the broader economy, or is high-tech immune to the business cycle?

Life cycles in technology products are shortening, and major swings in the introduction of new technology products can cause a high degree of volatility. After a period of rapid growth attributable to a new product innovation, the absence of another major innovation can cause a dramatic slowdown, as witnessed in 1985 and 1989 in the computer and semiconductor industries. High-tech industries have a large multiplier effect on the overall economy and a slowdown can have a significant impact on the non-high-tech sector, both nationally and regionally.

Because high-tech industries account for so large a share of national output today, the economy is more vulnerable to a contraction in high tech than ever before. If there were a synchronous shock that was spread across a number of related technology industries, such as computers and semiconductors, and combined with some other inauspicious development, an economywide recession could occur. As reported in *BusinessWeek*, no less an authority than Andy Grove, Chairman and former CEO of Intel, has commented on this: "every time we thought something about our business was less cyclical, the next cycle was bigger than the earlier one."

Many high-tech manufacturing sectors export a high proportion of their product. Exports accounted for 34 percent of computer industry shipments in 1997 prior to the Asia crisis, reducing foreign sales in 1998 (see Figure 4.1). Twenty years ago exports accounted for less than 15 percent of industry shipments. This leaves technology industries subject to international developments such as a major appreciation in the dollar, a downturn in prices due to massive oversupply abroad, or a global-scale recession. The high-tech sector has grown so large that the feedback linkage to the rest of the economy cannot be dismissed.

The high-tech sector has grown so large that the feedback linkage to the rest of the economy cannot be dismissed.

Even though the application of information technology may dampen business cycles in the future, evidence shows that high-tech industries will not be immune to these cycles. The assimilation of technology into virtually all economic sectors leaves high-tech industries more exposed to fluctuations in the broad economy than ever before. For example, semiconductors and other electronic components are used extensively in cars, appliances, machine tools, and other non-high-tech products. Investment in information technology, such as computers and peripherals and telecommunications equipment, accounts for over half of all business capital spending on equipment. In the past, government, universities, and large corporations controlled the bulk of spending on these products. Now, all industries and firms, regardless of their size, are major purchasers of high-tech equipment. Capital spending is more sensitive to fluctuations

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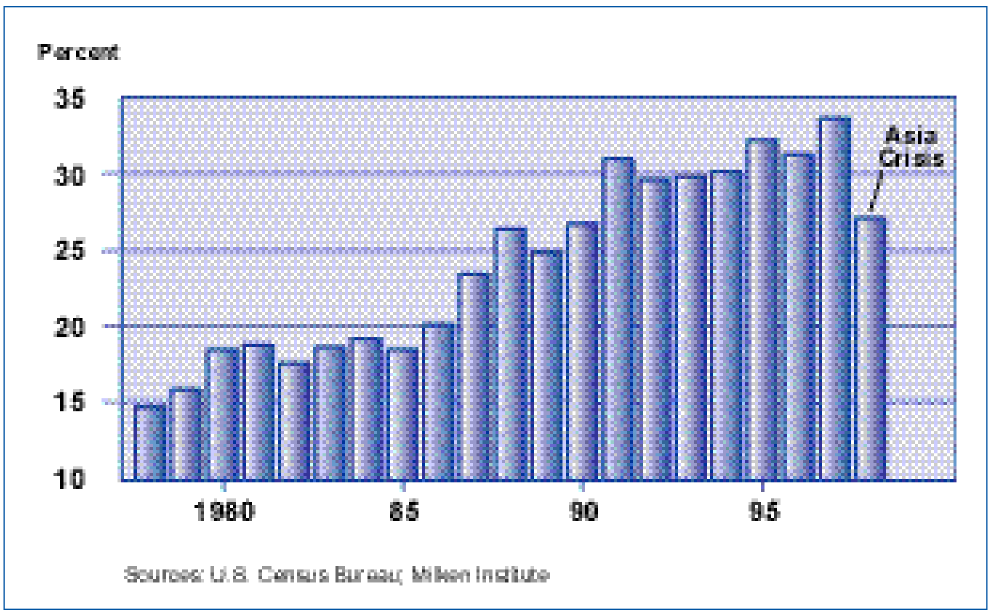
All industries and firms, regardless of size, are major purchasers of high-tech equipment.

Figure 4.1
Exports are Important to Computers
Exports as Percentage of Total Shipments, 1978 to 1998



in economic activity than any other component of the U.S. economy (Huffman 1994). Furthermore, information technology will make a tempting target for cost cutting if an economic slowdown materializes.

We analyze the 14 high-tech sectors previously defined in order to determine their sensitivity to the business cycle. We apply a series of statistical techniques in order to examine the risk that a recession might pose to metropolitan economies. Could clusters of particular technology industries leave some metros far more exposed to an economic contraction than they realize?

Is the Business Cycle Still Relevant?

Some have suggested that the business cycle has been repealed or at least appreciably dampened.

Before analyzing the likely impact of a recession on technology industries and metro high-tech clusters, it is important to establish that the business cycle is still relevant. Some have suggested that the business cycle has been repealed or at least appreciably dampened (Weber 1997). These arguments include factors such as: (1) globalization of production, (2) sector shifts in production to less-cyclical industries such as services, (3) financial services innovations and deregulation, (4) automatic fiscal stabilizers, (5) high growth in emerging markets, (6) more stable monetary policy, and (7) the application of information technology itself.

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Forecasts of unending economic expansion have always proved incorrect.

There is much optimism that the business cycle has been repealed — in other words, that economic and financial cycles have been eliminated. Victor Zarnowitz (1998, 1999) has pointed out that this notion is hardly a new development. These ideas were expressed in the mid- and late 1920s, just before the onset of the Great Depression; again during the long expansion of the 1960s, which then was followed by the 1970 and the severe mid-1970s recessions; and even in the late 1980s, prior to the 1990 downturn. Forecasts of unending economic expansion have always proved incorrect. Business cycle peaks are nearly impossible to see in advance, and, indeed, difficult to recognize in the rear-view mirror. The belief that the business cycle has been repealed can cause ill-conceived and misguided policies, complacency, and, ultimately, can worsen the severity of a recession. Expansions have become longer, however, and contractions shorter, on average, in the postwar period.

The developments listed above will tend to mitigate the severity of recessions in the future but are unlikely to eliminate them. Information technology is improving businesses' ability to manage inventories and thus reduce a key source of contractions in the broad economy. Changes in inventory investment are responsible for a very large proportion of the change in total business investment over the business cycle. Although changes in inventory investment may not have been the major impulse mechanism behind postwar recessions, they were the major propagation force in worsening them (Blinder 1981). Information technology and just-

An economic contraction or recession occurs when aggregate output falls for two consecutive quarters or more, loosely defined.

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Because high-tech manufacturing products are purchased for investment by firms, or by consumers as durable goods, the output of these goods should be highly susceptible to the business cycle.

in-time production techniques permit firms to match production more closely with expected sales and reduce unplanned inventory accumulation. Sometimes this is referred to as supply-chain management, the function of which is to track many variables and produce an optimal production schedule. A major unanticipated shock to the economy, however, could still lead to an inventory accumulation that must be liquidated.

What is the "business cycle?" There are many possible definitions, but, in general terms, it refers to fluctuations in U.S. aggregate economic activity around their trend values. An economic contraction or recession occurs when aggregate output falls for two consecutive quarters or more, loosely defined. Much research on the nature and causes of business cycles has been performed. Even so, there is still much to be learned. Economists have been successful in isolating key features and sectors of the economy that explain much of the observed pattern of business cycles.

Economists disagree to some extent about which sources are primary in causing the observed business cycle patterns. Some point to "real" business cycles, which are caused by changes in technology and supply shocks. New Keynesians emphasize imperfect competition in input and output markets, which leads to nominal and real rigidities that contribute to the business cycle. Others emphasize monetary and fiscal policy errors in responding to exogenous shocks. We will not attempt to resolve this debate but only to display characteristics of the sectoral components of the economy over the business cycle as they pertain to technology industries.

Some industries are much more cyclical than others, but it is remarkable how little systematic research has been performed. Bruce Peterson and Steven Strongin (1996) conducted one of the most thorough studies on this subject. They combined industrial organization concepts with labor economics and macroeconomics to address this issue using panel data for 296 highly disaggregated manufacturing industries. They included demand-side conditions such as the durability of output, supply-side conditions, and various elements of market structure. They found that durable-goods industries were three times more cyclical than nondurable goods, and that nondurable goods industries were roughly as cyclical as the overall economy. The degree to which the purchase of goods can be postponed explains much of this observed pattern. Furthermore, they concluded that aggregate investment accounted for the majority of the decline in real GDP during recessions. In another study, Judy Berman and Janet Pfleeger (1997) examined the degree to which the timing and amplitude of those industries that are characterized as cyclical vary. They concluded that cyclical industries experience dramatically divergent impacts from the business cycle on both dimensions. Because high-tech manufacturing products are purchased for investment by firms, or by consumers as durable goods, the output of these goods should be highly susceptible to the business cycle.

High-Tech Industries and the Business Cycle

We analyze the behavior of high-tech industries over the business cycle by applying several quantitative approaches. We utilize the national data set from the BLS's Office of Employment Projections on real gross industry output. This provides annual data back to 1958, and we augment it by applying quarterly patterns from manufacturing shipments, sales, and employment information in a few industries. We isolate the cyclical component from the trend and irregular or random component of each high-tech industry output series, compare the standardized cyclical component of each industry to the economy overall, and run regressions to determine their relative cyclicality. Lastly, we test to see if the relationship with the business cycle is becoming stronger over time.

We calculated the standard deviation of the annual growth rate of real output for each of the high-tech industries and compared it to the same measure for total output. This is one way of examining whether technology industries are more volatile than the broad economy. In high-tech manufacturing, the standard deviation of the growth rate in all eight industries was higher than total output, and only the drug segment was less volatile than total manufacturing output. As an example, Figure 4.2 compares the annual growth rate of electronic components and accessories with manufacturing overall and total output. The standard deviation of output growth in electronic components is three times the size of manufacturing's and nearly six times larger than total output's. Computer and office equipment was slightly more volatile than electronics, as displayed in Table 4.1. Growth in high-tech services was not as volatile as high-tech manufacturing but was more volatile than total output. Computer and data processing services' annual growth was more variable than that of measuring and controlling devices. High-tech services are becoming more volatile as they are increasingly integrated throughout the economy.

When analyzing the sensitivity of individual high-tech industries relative to the aggregate business cycle, removing the irregular and trend components is appropriate. The irregular component, by definition, is not affected by the business cycle. We accomplished this by running each of the high-tech output series through a seasonal adjustment process (Census X-11 variant B). This leaves us with the trend / cycle component of the original series. The next step is to remove the trend component. One method is to regress the trend / cycle against a time trend. This assumes a deterministic trend that is constant over time. Economists in recent years have concluded that this may be an inappropriate method for removing the trend. The current view is that trends also change during business cycles (Carlino and Sill 1997). Inaccurate removal of variable trends of economic time series can result in incorrect cyclical components being used in the analysis.

In high-tech manufacturing, the standard deviation of the growth rate in all eight industries was higher than total output.

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The current view is that trends also change during business cycles.

If a variable is trend stationary, current economic shocks will have no long-term effects on the series.

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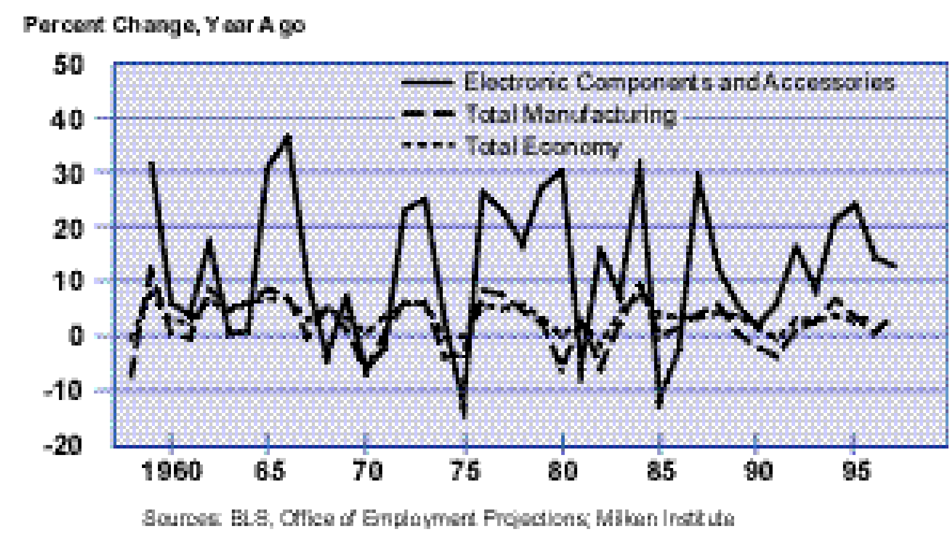
We found that several high-tech industries did not move closely with the overall economy between 1965 and 1985, but that relationship tightened after 1985.

Figure 4.2
Electronics Highly Volatile
Real Gross Industry Output



If a variable is trend stationary, current economic shocks, regardless of the source, will have no long-term effects on the series. Stochastic, or nondeterminist, trends can be removed by a variety of methods. We chose to estimate the trend by a polynomial method. We regressed the trend/cycle for each high-tech industry against the polynomial time trends raised to a power until they were no longer individually significant (Enders 1995). The predicted values from these equations were then subtracted from the trend/cycle, leaving us with the estimated cycle.

Lastly, to control for differences in amplitude between industries and total output, and to be able to examine the timing and duration of the industry cycles, we standardized the cyclical component. Standardization was accomplished by dividing each industry's cyclical component by its standard deviation. This process does not change the general cyclical pattern; however, it does permits us to see turning points and commonality of cycles more closely.

Graphing the standardized cyclical components of the high-tech industry output against manufacturing, other sectors, and the overall economy allows us to visually inspect the relationships. A few high-tech industries lagged the cyclical movement in the overall economy, but many moved coincident with it. We found that several high-tech industries did not move closely with the overall economy between 1965 and 1985, but that the relationship tightened after 1985. Computers and office equipment has been cycling much more closely with the overall economy since 1985, as displayed in Figure 4.3. The cyclical movement in computers approximately matched that of the overall economy in the most recent

HIGH-TECH RELATIONSHIP WITH THE BUSINESS CYCLE

Table 4.1 A
Tech Manufacturing

SIC		
283	Drugs	3.4
357	Computer & Office Equipment	13.7
366	Communications Equipment	9.8
367	Electronic Components and Accessories	13.0
372	Aircraft and Parts	10.0
376	Guided Missiles, Space Vehicles, & Parts	10.0
381	Search & Navigation Equipment	20.8
382	Measuring and Controlling Devices	8.0
384	Medical Equipment, Instruments, & Supplies	5.9

Table 4.1 B
Tech Services

SIC		
481	Telephone Communications Services	3.5
737	Computer & Data Processing Services	8.6
781	Motion Pictures	7.4
871	Engineering and Architectural Services	6.8
873	Research & Testing Services	9.1

Table 4.1 C
Totals

SIC	
Technology Manufacturing	6.5
All Manufacturing	4.3
Technology Services	3.1
All Services	2.0
All Technology	4.4
Total Economy	2.2

Sources: BLS, Office of Employment Projections; Milken Institute

business cycle. Industries such as communications equipment, electronic components and accessories, and computer and data processing services exhibit this pattern as well. Figure 4.3 also displays the standardized cyclical component of total high-tech industry output and highlights the closer co-movement with the overall economy in recent years.

These visual inspections allow us to make qualitative judgements regarding the relationships between co-movement in output in high-tech

VOLATILITY IN HIGH-TECH INDUSTRIES

Table 4.1 A
Tech Manufacturing

SIC		Period Estimated	Explained Variation*
283	Drugs	68-97	0.21
357	Computer & Office Equipment	86-97	0.61
366	Communications Equipment	86-97	0.38
367	Electronic Components & Accessories	86-97	0.45
372	Aircraft & Parts	68-97	0.45
376	Guided Missiles, Space Vehicles, & Parts	68-97	0.45
381	Search & Navigation Equipment	68-97	0.11
382	Measuring & Controlling Devices	68-97	0.43
384	Medical Equipment, Instruments, & Supplies	68-97	0.57

Table 4.1 B
Tech Services

SIC		Period Estimated	Explained Variation*
481	Telephone Communications Services	86-97	0.19
737	Computer & Data Processing Services	86-97	0.49
781	Motion Pictures	68-97	0.15
871	Engineering & Architectural Services	86-97	0.21
873	Research & Testing Services	86-97	0.13

** 1.0 is perfect explained variation.*
Sources: BLS, Office of Employment Projections; Milken Institute

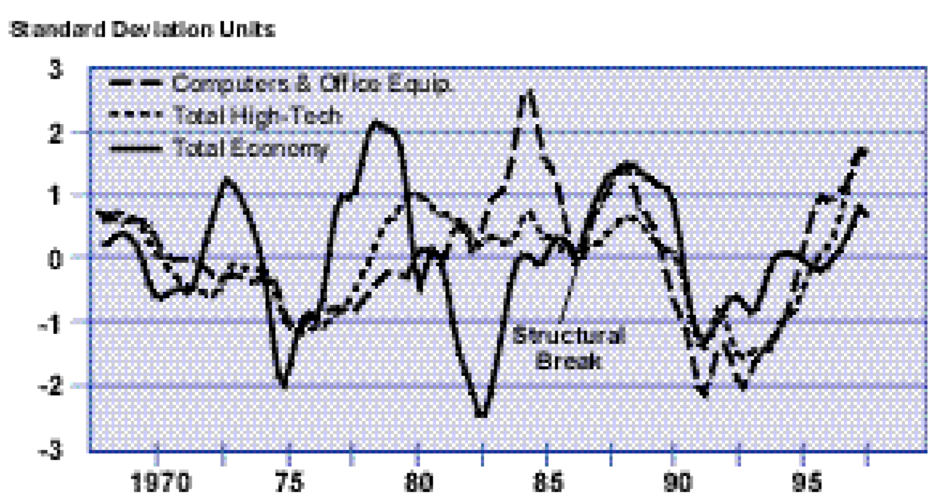
industries and the overall business cycle. However, they do not permit us to test the relationships in a statistical sense. To quantitatively establish the degree of co-movement between high-tech industries and the business cycle, we ran a series of regressions. The dependent variable in these regressions was the estimated cyclical component of output for each of the high-tech industries, and the explanatory variable was the cyclical component of total economic output. Various lead/lag relationships were tested and the time period adjusted over which the relationships were estimated.

We first estimated these equations using quarterly data from the period 1968 through 1997. In several high-tech industries, the explanatory power of the overall business cycle was relatively weak, but there was a statistically significant relationship in all cases. The cyclical movement of aerospace lagged the overall business cycle by approximately five quarters, mainly attributable to the long lead times between ordering commercial aircraft and their delivery. Measuring and controlling devices moved very closely with the overall business cycle beginning in 1968, and the relationship was very stable. Within high-tech services, research and testing services followed the business cycle fairly consistently.

The last step was to estimate the regressions over a shorter time period to test whether there was a structural break occurring between the cyclical movement of individual high-tech industries and the overall economy. We performed a statistical test that can determine if the estimated relationships were significantly different in previous historical periods relative to more recent experience. We found that a clear structural break occurred in seven out of the 14 high-tech industries. This strongly suggests that high-tech industries are more impacted by the business cycle as they are assimilated throughout the entire economy. This structural break generally appeared around 1986. Table 4.2 shows the overall explained variation between each of the high-tech industries and the business cycle. If the relationship were perfect, the explained variation (R-Squared) would approach 1.0. The table also displays which industries experienced a structural break.

In high-tech manufacturing, the subcategories of computers and office equipment, communications equipment, and electronic components and accessories experienced structural breaks; in other words, they began to be significantly affected by the overall business cycle. Telecommunication

Figure 4.3
Computers Align with the Business Cycle
Cylical Component Divided by Its Standard Deviation



Sources: BLS, Office of Employment Projections; Milken Institute

We found that a clear structural break occurred in seven out of the 14 high-tech industries.

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The cyclical movement in computers approximately matched that of the overall economy in the most recent business cycle.

services, computer and data processing services, engineering and architectural services, and research and testing services experienced a structural break after 1986. In most high-tech industries, nearly half of the overall variation in their cyclical components can be explained by the overall business cycle (Table 4.2). After 1986, the cyclical components of computers and office equipment, electronic components, medical equipment, and computer and data processing services moved closely with the business cycle. This finding has major implications for the future: software, data management consulting, and programming consulting are likely to be impacted by movements in the overall economy.

In most high-tech industries, nearly half of the overall variation in their cyclical components can be explained by the overall business cycle.

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Recession Risk: High-Tech Industries and Metros

We have demonstrated that high-tech industries are more closely tied to the cyclical behavior of the overall economy, but what might this mean for the future of these industries and clusters around the country? To attempt to address this question, we simulated a hypothetical recession at some point in the future to see how individual high-tech industries might behave. As stated earlier, future recessions are likely to be less severe as information technologies are applied, thus dampening swings in inventories by improving communication flows. We chose to simulate a 1990–91 style recession, which was mild by historical standards with just a 1.0 percent peak-to-trough decline. It is possible to argue that the next–recession could be even milder, but imposing a 1990–91 type recession does allow a relative benchmarking. We chose to impose a recession in the first quarter of 2000, lasting until the third quarter of the same year.

Future recessions are likely to be less severe as information technologies are applied.

The equations estimated in the previous section linking the cyclical components of high-tech industries with the overall economy were used in this hypothetical simulation. The results of the simulation are displayed in Table 4.3. This table displays the percentage peak-to-trough decline and the percentage decline in the cycle relative to the trend for each of the high-tech industries versus the total output in the economy. The total economy experiences a peak-to-trough decline of 1.0 percent and a 4.9 percent decline in the cyclical component relative to trend. This is an important distinction because most high-tech industries have a strong upward trend, but their cyclical component can still experience a large decline.

Based upon our estimated relationships, high-tech manufacturing industries would experience a substantially more severe decline than the overall economy, and could even exacerbate the overall decline in the economy. For example, the estimated peak-to-trough decline in computers and office equipment is 11.9 percent, closely followed by aerospace. Output of electronic components falls by more than the overall economy.

Table 4.3
High-Tech Sensitivity to Recession
Ranked by Peak to Trough

	SIC		Percent Decline, Peak to Trough	Percent Decline, Cycle Relative to Trend
1	357	Computer & Office Equipment	-11.9	-21.2
2	372	Aircraft & Parts	-10.7	-15.7
3	376	Guided Missiles, Space Vehicles, & Parts	-10.7	-15.7
4	871	Engineering and Architectural Services	-8.5	-4.7
5	381	Search & Navigation Equipment	-3.2	-8.2
6	367	Electronic Components & Accessories	-2.6	-14.5
7	382	Measuring & Controlling Devices	-2.4	-8.6
8	366	Communications Equipment	-1.9	-10.7
9		Total Economy	-1.0	-4.9
10	481	Telephone Comunications Services	0.8	-3.7
11	781	Motion Pictures	1.3	-3.7
12	737	Computer & Data Processing Services	1.9	-7.5
13	283	Drugs	3.9	-1.0
14	384	Medical Equipment, Instruments, & Supplies	3.9	-0.5
15	873	Research & Testing Services	8.4	-3.6

Source: Milken Institute

Drugs and medical equipment are the only manufacturing industries that continue to grow during the recession. Engineering and architectural services experience a peak-to-trough decline of 8.5 percent in this simulation. Output continues to grow in the other five high-tech service industries, but growth slows substantially. High-tech manufacturing witnesses the largest percentage decline in cycle relative to trend, but several service industries are close behind. For example, output in computer and data processing services falls by 7.5 percent relative to its trend rate of growth. This could remove a major source of growth for some metros that have been relying on this sector to stimulate their economies.

High-tech manufacturing shows the largest percentage decline in cycle relative to trend, but several service industries are close behind.

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The last step is to transfer this hypothetical recession from high-tech industries to metropolitan economies. We accomplish this by imposing the same national percentage decline, by industry, to a metro economy. This impacts metros disproportionately, depending upon the mix of high-tech

Missing Pull Quote

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In this simulation, Rochester, MN, would experience the most severe peak-to-trough decline.

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High-tech service clusters in Dallas, Los Angeles, Washington, Chicago, and New York leave these metros less exposed to a future recession.

industries and their proportion of the local economic base. This method is subject to some criticism. It assumes that output would decline proportionately around the country within the same industry. Industry structure is more complicated than this. If a metro economy has more recently added capacity within an industry, and is therefore more efficient, output likely will fall less than the national average during a recession. Nevertheless, this method does provide a means of benchmarking the relative sensitivity of metropolitan economies with a large high-tech base.

Table 4.4 displays the relative sensitivity of the Milken Institute Tech-Poles described earlier. It highlights the risk associated with concentration within one major tech industry in the case of Rochester, MN, especially to the most cyclical of all tech industries: computers and office equipment. Based upon this simulation, Rochester would experience the most severe peak-to-trough decline of the Tech-Poles, falling by 11.6 percent. Wichita, KN, is the second most impacted because of its high concentration of aircraft. Tucson, AZ, experiences a peak-to-trough decline in high-tech of 7.8 percent due to guided missiles and space vehicles. West Palm Beach-Boca Raton, FL, is negatively impacted by its high concentration of aircraft and parts and communications equipment. Boise, ID, also has high exposure due to electronic components and to computers and office equipment. Raleigh-Durham-Chapel Hill is sensitive to the business cycle because of computers, as is Sacramento. Austin's success in computers and semiconductors leaves it exposed to a recession in the future.

San Jose (Silicon Valley) has the most exposure to a future recession among the top 15 Tech-Poles. It is diversifying its economic base away from high-tech manufacturing to services but still has a very high concentration of computers, electronics, and communications equipment. High-tech service clusters in Dallas, Los Angeles, Washington, Chicago, and New York leave these metros less exposed to a future recession. The collapse of Los Angeles's aerospace industry in the early 1990s — although structurally painful — leaves it much less sensitive to the business cycle.

Table 4.5 displays the 50 metro high-tech economies exposed most severely to a future recession. Rochester is at the top, followed by Eau Claire, WI. The most severely impacted metros have dense concentrations of computers and office equipment, aircraft, communications equipment, and electronic components. Metros with a heavy reliance on high-tech services are generally not on the list, but because of high-tech services' growing susceptibility to the business cycle, they will be more exposed in the future. This analysis suggests that metros that have experienced a high degree of success in developing clusters of computer, semiconductor, and other high-tech manufacturing industries should be more aware of the potential risks that a recession could pose to their local economies. Most economic development and government officials have encouraged these

Table 4.4
Tech-Poles Sensitivity to Recession
Ranked by Composite Index

	Tech-Pole	Composite Index*	Percent Decline, Peak to Trough	Percent Decline, Cycle Relative to Trend
1	San Jose, CA	23.69	-3.30	-12.28
2	Dallas, TX	7.06	-1.63	-8.50
3	Los Angeles-Long Beach, CA	6.91	-1.12	-6.88
4	Boston, MA	6.31	-2.38	-9.85
5	Seattle-Bellevue-Everett, WA	5.19	-2.70	-8.83
6	Washington, DC-MD-VA-WV	5.08	-0.02	-6.40
7	Albuquerque, NM	4.98	-1.75	-12.75
8	Chicago, IL	3.75	-0.72	-7.44
9	New York, NY	3.67	-0.66	-4.78
10	Atlanta, GA	3.46	-2.79	-7.41
11	Middlesex-Somerset-Hunterdon, NJ	3.40	-0.26	-4.64
12	Phoenix-Mesa, AZ	2.60	-2.40	-11.43
13	Orange County, CA	2.59	-2.89	-8.88
14	Oakland, CA	2.21	-1.26	-7.61
15	Philadelphia, PA	2.19	-0.12	-5.86
16	Rochester, MN	1.95	-11.61	-20.85
17	San Diego, CA	1.93	-0.66	-8.63
18	Raleigh-Durham-Chapel Hill, NC	1.89	-4.54	-12.18
19	Denver, CO	1.81	-1.58	-5.95
20	Newark, NJ	1.80	0.22	-4.72
21	Austin-San Marcos, TX	1.78	-3.57	-12.44
22	San Francisco, CA	1.62	0.53	-6.71
23	Houston, TX	1.62	-3.96	-8.85
24	Boise City, ID	1.43	-4.73	-15.31
25	New Haven-Bridgeport-Stamford, CT	1.33	-1.55	-7.79
26	Portland-Vancouver, OR-WA	1.33	-2.95	-10.75
27	Boulder-Longmont, CO	1.12	-3.34	-11.80
28	Kalamazoo-Battle Creek, MI	1.09	-1.67	-6.57
29	Indianapolis, IN	1.07	-2.49	-7.37
30	Nassau-Suffolk, NY	1.05	-3.61	-10.52
31	Kansas City, MO-KS	1.03	-2.04	-5.37
32	Minneapolis-St. Paul, MN-WI	0.98	-0.90	-7.04
33	Lubbock, TX	0.97	-2.35	-13.16
34	St. Louis, MO-IL	0.93	-3.05	-7.86
35	Cedar Rapids, IA	0.92	-1.58	-9.45
36	Orlando, FL	0.82	-3.69	-7.76
37	Sacramento, CA	0.82	-4.13	-10.74
38	Detroit, MI	0.79	-2.59	-7.30
39	Wichita, KS	0.72	-8.74	-13.33
40	Tucson, AZ	0.67	-7.84	-13.44
41	Fort Worth-Arlington, TX	0.66	-2.89	-9.12
42	Colorado Springs, CO	0.58	-3.49	-10.10
43	Monmouth-Ocean, NJ	0.55	-0.16	-5.62
44	Bergen-Passaic, NJ	0.51	-0.09	-5.81
45	Melbourne-Titusville-Palm Bay, FL	0.51	-3.28	-10.24
46	San Antonio, TX	0.49	-1.02	-6.12
47	Pittsburgh, PA	0.48	-1.75	-7.06
48	Atlantic-Cape May, NJ	0.44	3.10	-1.76
49	West Palm Beach-Boca Raton, FL	0.43	-5.72	-11.41
50	Huntsville, AL	0.43	-3.69	-10.69

** Composite Index is equivalent to the percent of national high-tech real output multiplied by the high-tech real output location quotient for each metro.*
Sources: Milken Institute, RFA

industries to locate within their borders, hoping that these industries would help insolate them from future business cycles. While these high-tech industries will assist metro long-term relative performance, they are unlikely to shield them from fluctuations in aggregate economic activity.

While these high-tech industries will assist metro long-term relative performance, they are unlikely to shield them from fluctuations in aggregate economic activity.

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Table 4.5
Metros Most Sensitive to High-Tech Recession
Ranked by Peak to Trough

	Tech-Pole	Percent Decline, Peak to Trough	Percent Decline, Cycle Relative to Trend
1	Rochester, MN	-11.61	-20.85
2	Eau Claire, WI	-9.78	-17.74
3	South Bend, IN	-8.86	-13.93
4	Wichita, KS	-8.74	-13.33
5	Killeen-Temple, TX	-8.24	-15.34
6	Williamsport, PA	-8.03	-12.39
7	Tucson, AZ	-7.84	-13.44
8	La Crosse, WI-MN	-6.57	-14.39
9	Sheboygan, WI	-6.27	-8.11
10	Jamestown, NY	-6.20	-12.35
11	Benton Harbr, MI	-6.02	-10.88
12	Dutchess County, NY	-5.73	-15.66
13	West Palm Beach-Boca Raton, FL	-5.72	-11.41
14	Rockford, IL	-5.60	-10.07
15	Lexington, KY	-5.30	-10.67
16	Fort Collins-Loveland, CO	-5.27	-13.40
17	Greeley, CO	-5.20	-12.36
18	Yakima, WA	-5.18	-8.46
19	Fayetteville, NC	-4.95	-7.97
20	Beaumont-Port Arthur, TX	-4.93	-9.26
21	Utica-Rome, NY	-4.85	-10.48
22	Fayetteville-Springdale-Rogers, AR	-4.83	-8.17
23	Baton Rouge, LA	-4.80	-7.35
24	Boise City, ID	-4.73	-15.31
25	Savannah, GA	-4.72	-8.30
26	Knoxville, TN	-4.70	-9.48
27	Mansfield, OH	-4.69	-7.43
28	Amarillo, TX	-4.59	-8.62
29	Raleigh-Durham-Chapel Hill, NC	-4.54	-12.18
30	Brownsville-Harlingen-San Benito, TX	-4.51	-9.52
31	Erie, PA	-4.41	-8.28
32	Lake Charles, LA	-4.38	-6.80
33	Parkerburg-Marietta, WV-OH	-4.28	-7.55
34	Lakeland-Winter Haven, FL	-4.22	-7.00
35	Hamilton-Middletown, OH	-4.16	-8.73
36	Binghamton, NY	-4.15	-11.22
37	Sacramento, CA	-4.13	-10.74
38	Greenville-Spartanburg-Anderson, SC	-4.13	-8.05
39	Altoona, PA	-4.11	-7.24
40	Mobile, AL	-4.10	-7.90
41	Bellingham, WA	-4.09	-8.66
42	Green Bay, WI	-4.08	-7.33
43	Toledo, OH	-4.03	-10.01
44	Houston, TX	-3.96	-8.85
45	Lewiston-Auburn, ME	-3.83	-7.73
46	Roanoke, VA	-3.81	-8.60
47	Abilene, TX	-3.77	-8.57
48	Santa Fe, NM	-3.77	-8.76
49	Dayton-Springfield, OH	-3.77	-9.99
50	Punta Gorda, FL	-3.75	-6.38

** Each metro must contain either a place with a minimum population of 50,000 or a Census Bureau defined urbanized area and total population of a least 100,000 (75,000 in New England). Ametro compromises one or more counties.*
Sources: Milken Institute, RFA

SECTION 5

Key Economic Development and Business Planning Implications

In previous sections, we demonstrated the potential and actual benefits of high-tech clustering to regional economic growth in metropolitan areas. The success of many metropolitan areas in the 1990s is contingent upon either their ability to attract and nurture high-tech-oriented industries, or, in other cases, historical endowment that enables them to promote expansion of their high-tech industry base. In either case, the result of such high-tech-driven growth — or endogenous economic growth — has been substantial. As a result of this remarkable economic performance, Tech-Pole regions such as San Jose and Boston have been the subjects of various economic studies. Serious attempts have also been made across the country, and even around the world, to duplicate "the San Jose experience," e.g., Austin and Dallas in Texas, Boise in Idaho, Hsinchu in Taiwan, and Kyushu in Japan. Many regions have at least to some degree made great strides in high tech developments, but none has been as dynamic and as broadly developed as San Jose (Silicon Valley).

High-tech-driven economic growth is the success story of the 1990s.

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In the Section 4 of this study, a detailed analysis of high-tech industries and economic risk suggested that a number of regional technology clusters will face greater uncertainty in the future, in contrast to the euphoric past assessments of the industry's resiliency during economic downturns. The muted cyclical or business cycle neutrality characteristics of high-tech industries will likely disappear in the future as technology and technological applications are more widely adapted and defused in the "new" economic system. A more "commercialized" technology industry will inevitably entangle with the national economy and economic cycle. Furthermore, the geographic and physical constraints of a regional economy could also impose limitations on future high-tech industry growth.

The benefit of high-tech growth is well publicized, but the risk that comes with it is not addressed nor understood.

In light of this tremendous opportunity for employment gain and income growth, as well as the potential risks in regional and national economic

While the economic benefit of high-technology-driven growth is very similar to that of other means of economic expansion, the factors that constitute such growth are completely different.

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High-tech growth brings economic vitality to a region but comes with certain costs.

downturns, a proper form of public policy and economic development strategy that can lead to the rapid development of a technology-based economy has to be carefully formulated. However, before we can assess what types or orientation of policy can be applied, we first need to define and describe the characteristics of high-tech industries and how they operate. High-technology industries can be characterized as:

- Industries that hunger for new ideas and concepts rather than a piece of hardware or machine; knowledge is valued far more highly than physical inputs.
- Industries with global content and linkages, not solely about serving the local community or bound by geography.
- Industries that emphasize innovation over mass production and entrepreneurial spirit over the risk of failure.
- Industries that have a highly mobile and skilled labor force operating in a fiercely competitive environment.
- Industries that, whether heterogeneous or homogeneous in size, in capability, or in specialization, require intensive and expensive basic research and development, as the accumulation of the basic research embodies and fosters entrepreneurial growth.

What advantages do these characteristics provide for a regional economy? What kind of economic environment helps create and foster superior development? High-tech economic growth brings rapid accumulation of wealth and employment opportunity to a region. High-tech—based growth transforms and elevates the requirements for the skill-set of the local labor force, drastically alters regional income distribution, and changes the existing demographic mix and business culture in the region. Along with these positive externalities induced by the tech-based economic growth, negative impacts manifest themselves. A high influx of skilled labor from other regions, as well as out-migration of existing households, disrupts local ways of life. Long-existing local culture is diluted if not displaced; rapid growth in population as well as wealth brings congestion and rising housing costs. High mobility, however, is the nature of high-tech industries and their work forces. It is almost impossible to predict when and to where high-tech workers and industries will migrate. These are the issues and difficulties that regional planners and economic development officials have to anticipate and for which they must plan.

About 50 years ago, economic development in different regions inside and outside the United States took center stage. Various theories and policies were adopted, only later to be rejected on the basis of being overly simplistic or difficult to administrate (Higgins and Savoie 1995). In the

1970s and 1980s, with compounding problems of urban decay and the rapid deterioration of many once U.S.–dominated industries, regional economic development became critically important as a policy tool; it represented a remedy for state and local governments — an opportunity to revitalize their local economies. Despite proactive federal, state, and local governmental policy and funding (EDC / SBA / EPA), economic development that depends on a "home grown" or endogenous growth had mixed results. Most of the larger and older urban areas in the United States channeled their revitalization efforts into introducing "exogenous" growth measures.

Government can play an important role in developing a high-tech economy.

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Economic Policy and High Tech Clustering

The vitality of high-tech industries and the economic benefits derived from them are well documented and analyzed in this study and in other publications. A more important and relevant question, however, remains. Can the economic achievements of San Jose, Boise, Austin, and Albuquerque be duplicated? More precisely, can economic policy induce high-tech industry formation and augment high-tech clustering in a region? Those metropolitan areas exemplify how technology and technological applications can promote regional economic development. If they can be duplicated, what kind of public policy and economic development strategy can expedite and fortify development in the future?

However, public policy and government intervention may be inadequate to guide development in the rapidly changing technology environment.

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We list a set of variables that matters to the development of regional high-tech industries in Table 5.1. State and local governments, public policies, and the interaction between private and public sectors are crucial for the genesis, the expansion, and the fortification phases of high-tech development. Nonetheless, due to the unique characteristics of high-tech industries, government's role is also limited. Overly active government intervention and public policy may be counterproductive and harmful to the long-term development of high-tech industries. In the table, we divide those factors into three groups: public policy, comparative location benchmarking, and social infrastructure development. We rated each factor based upon its importance in different stages of regional economic development and its effectiveness in helping the establishment of a regional high-tech cluster. All factors in the table are interrelated. Because of this, the role of local government is critical to the development process.

Establishing and nurturing research centers and promoting education are among the basic and most effective public policies.

Long before high-tech industries' significant contribution to regional economic growth and prosperity was recognized, government played an important role in fortifying regional high-tech formation and clustering (Sternberg 1996). However, research centers and institutions are undisputedly the most important factor in incubating high-tech industries. Furthermore, the technical capability and scientific research activities therein train and educate the labor that will be critical in expanding and reinforcing regional high-tech industries. A form of public and private venture that aims to establish and maintain leading-edge regional research

Table 5.1
High-Tech Sensitivity to Recession
Ranked by Peak to Trough

	Inception	Growth	Fortification
Public Policy			
Tax Incentives	• • •	•	
Public Investment	•		• •
Commercialization of Ideas	•	• •	• •
Comparative Location Benchmarking			
Cost Factors	• • •		
Research Institutions	• • •	• • •	• • •
Skilled or Educated Labor Force	• •	• • •	• • •
Transportation Center	•		
Proximity to Supplies & Markets	• •	•	•
Social Infrastructure Developments			
Attending Changing Needs		• •	• • •
Re-education & Training Facilities		• • •	•
Establishing Trade Groups, & Affiliations		• • •	• • •
Housing, Zoning, & Quality of Life	• •	• •	• • •

• • • *Critical*
• • *Very Important*
• *Important*

• • •

Reputable research institutes are the most important factors in determining where the leading technology is created — the genesis of the high-tech base economy.

centers and educational institutes is a critical long-term economic growth strategy. The success story of Raleigh-Durham-Chapel Hill, NC, represents a fine combination of public and private venture.

Federal Science and Technology grants and defense-related expenditures were never intended to make San Jose prosper in making semiconductors. They did establish San Jose as a leading location in advanced material research and production. Federal and state governments played silent yet effective roles in sowing the seeds for high-tech centers that would later spring up throughout the country. The Federal Science and Technology grants fortified the technological superiority of Boston, Philadelphia, Middlesex-Somerset-Hunterdon, Washington, St. Louis, Austin, Los Angeles, and San Jose metro areas. Additionally, over the past half-century, Federal defense expenditures promoted and built highly specialized labor forces in various regions to produce high-tech weaponry — a totally unintended benefit of the Cold War. However, it would be a mischaracterization to overly emphasize the role of the federal government in establishing high-tech centers in those regions.

Pre-existing technology research centers and institutions and the pool of highly talented researchers played a more instrumental role than the government in the formation of regional technology production centers. Hence, radar and signal processing research grants were channeled to New Jersey (Bell Labs) and San Diego (Naval base). Semiconductor research grants went to the San Francisco Bay Area where Berkeley and Stanford were located. Systems integration grants went to the Greater Boston area where MIT, Wang Computer, and DEC were located. In other words, government plays a significant, yet limited role in high-tech formation and clustering in regions. Nonetheless, this limited yet very important function assumed by government established the landscape of high-technology regions across the country. Through its seemingly unintended policy over the past 50 years, the federal government has reinforced the position of those regions' eminent role in leading-edge research and production.

If the formation of high-tech clusters is a "random" event, as many regional economists and economic geographers tend to believe (Krugman 1997), then the expansion of high-technology clusters is the result of an indeterminate dynamic interaction among firms, industry, and government. A proper venue of public policy or development strategy that is intended to strengthen the development of high-tech industries is an important endeavor. Providing a readily available labor pool is probably the best investment that state and local governments can make. The highly successful experiences in metropolitan areas such as Boise, ID, Austin, TX, and others all show one significant common characteristic. These metropolitan areas' rankings on the percentage of college graduates in the labor force are within the top 20 percent of all metros in the country. Boise, for example, ranked 61 of 319 metropolitan areas on this measure. The building up of Austin's high-tech research complex by the state and local governments, in conjunction with the recruitment of new technology firms into its existing technology base in late the 1980s and 1990s, proved to be a highly effective policy. Public investments in basic research established competitive advantages that benefited both Austin and Dallas in the 1990s.

Enhancing and reinforcing high-tech research capability both in basic research and in applied research (commercializing ideas and technology) can be a fruitful and effective public policy, especially during the growth stage of the high-tech industries. Promoting and marketing the region's industrial capability and research results serve to link the region's intellectual power to practical applications. This policy does more than turn ideas and knowledge into tangible products. More critically, the process attracts investments, venture capital, and other talented workers to the region, thus enhancing economic performance of the region thereafter.

A leading research center also attracts investment and fosters the buildup of regional production facilities.

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In a dynamic high-tech economy, skilled labor and quality education are the key ingredients of success.

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Selling and promoting the local high-tech research capability can help reinforce local industries' linkages to and dominance in the outside world.

Favorable location factors do not guarantee a long-term successful high-tech development.

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High costs of doing business can be a positive factor in reinforcing the dominance of a Tech-Pole.

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Low cost and a supportive local government can help in establishing a high-tech manufacturing base.

One important distinction of high-tech development is its dynamic and constantly evolving content and orientation. Location factors, a favorable term that development economists emphasize relentlessly, are a set of variables that remain significantly important, yet no longer sufficient in guaranteeing the long-term prosperity of regional high-tech industries. Costs of doing business, proximity to both suppliers and markets, and the attributes of quality and amenity of life that have traditionally weighed heavily are no longer sufficient to explain the gravitational force of the San Jose, Boston and Washington metros. The importance of these attributes changes in the course of development. For instance, a high cost of doing business is an unfavorable factor in locating business.

The San Francisco Bay Area is the most expensive location in the country, yet the Bay Area remains the most concentrated Tech-Pole in the country (Table 3.8). One cannot rule out the possibility that the success of such high-profile metropolitan areas is based at least partially on the high cost of doing business in those regions. High costs can become the catalyst for existing firms in the region to pursue higher revenues through inventing new concepts and products. High costs also force out marginal or older products, an evolutionary step that is both necessary and essential for the high-tech cluster to remain at the leading edge of technology innovation. It helps create an absolutely dynamic high-tech cluster base that prevents any high tech firm or industry from "lock in." In the later stage of a high-tech development, the importance of cost factors and proximity to suppliers and markets is diminished.

Unfavorable costs may not be a significant deterrent to expanding high-tech economies in Boston and San Jose, but they might prove critical to emerging locations. When other factors are equal, low-cost regions do attract high-tech manufacturing. The location factors in Boise, ID, are near ideal. Abundant labor supply and relatively low labor wages and local taxes enable the region to specialize in semiconductors and related accessories, producing low-end products where cost efficiency is critical. Besides having an adequately educated labor force, falling shipping costs and a favorable local business environment enhance the region's capability as a manufacturing and processing center.

Some other very similar success stories can be told about Sioux Falls, SD, and Rochester, MN. These cases are inarguably the success stories in building and nurturing high-tech industry. In fact, at the current stage of high-tech development, the rapid dispersion of high-tech manufacturing and processing from a Tech-Pole region such as San Jose has intensified. As technology application is broadly adapted, more standardized forms of high-tech manufacturing can be moved to locations such as Sioux Falls, where cost factors are substantially lower than San Jose or Portland, OR. Proximity to suppliers and markets is becoming less relevant today as communication and shipping costs fall, as many people have already discovered. Many of the components that are assembled into our computers in Sioux Falls' Gateway 2000 plants or Austin's Dell Computer plants actually are produced and shipped from Taiwan. Contacting customers and sensing the pulse of the market in today's economy are one fingertip away. The success in utilizing communication technology has shrunk the importance of being close to markets.

In the realm of economic development, tax incentives and public finance are the instruments that state and local governments applied the most. Can they be decisive and effective policy tools in aiding high-tech development? Tax incentives and public policy may have helped lure firms and industry to the locality, but the success of high-tech firms relies more heavily on their ability to create value and new concepts. Tax rebates and incentives hence can be a good tool in laying the foundation for development, particularly by helping smaller entrepreneurs to set up basic operational bases. Government entities should be cautious in distinguishing and recognizing the orientation of such policy, however. Government's function should be only to jump-start the process at the most, not to baby-sit the expansion and growth of high-tech industry. In the early stage of development, when capital is the most critical component of starting an enterprise, government and public entities' subsidies in the form of tax incentives and rebates provide invaluable assistance. Overly favorable public investment and tax instruments may create distortions and provide a static environment that will not foster the high-tech development intended. Furthermore, public finance most often caters to larger companies and institutions, while the most dynamic part of the high-tech base — the smaller entrepreneurial enterprises — are left out.

Financial aid and tax incentives are good policy instruments to jump-start development.

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Overemphasis on such public investments can work to a metro's detriment.

Rapidly changing high-tech industries mean shorter and shorter product cycles and shelf lives for their products. Huge public investment may not produce a long enough period of economic benefit. Since the new high-tech economy is a globally based system whose operations are highly mobile, a high-tech company can move from one region or country to another in a relatively short period of time. Low costs of production in a region can rarely be a long-term advantage. Public finance in a highly volatile, rapidly changing, and evolving industry artificially reduces the premium of such risks. A good example of that is the memory chip plants in Austin, TX. The excessive supply of and weak demand for memory chips in 1996 caused memory chip prices in the world market to fall. Many producers, including Intel, had to cut back production. In that year, Austin's economy slowed noticeably because of weakening construction of chip plants and production of memory chips.

Many of the newly emerging high-tech regions have shown the importance of high-tech industries to local economic development. Many people rarely associate Pocatello, ID, Harrisburg-Lebanon-Carlisle, PA, or Rochester, MN, with the catchy phrase of " high-tech." Those metros' achievements are fine examples which other state and local governments should try to emulate. This successful story, however, is still a one-dimensional high-tech development. What Rochester, MN, and Sioux Falls, SD, have in common on high-tech development is their reliance on personal computer and accessory manufacturing. This is a form of industry concentration and agglomeration based on forward and backward linkage. These industrial structures are limited compared to the complex high-tech clustering of networking and capital venture present in San Jose, Dallas, or Boston. Rochester and Sioux Falls are not yet the sophisticated high-tech clusters and Tech-Poles that ultimately demonstrate the high-tech prowess and resilience in its present form.

A successful high-tech economy has to be multi-dimensional.

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High-Tech manufacturing and processing alone will not sustain high-tech growth in a regional economy.

Economic development such as Boise or Sioux Falls pursued may face eminent threats in the future. These regional economies may face competition from overseas as the American high-tech gospel migrates and is assimilated around the globe. Malaysia, Korea, and China may be even more effective in manufacturing and assembling personal computers and other electronic accessories than the United States has been. We are not suggesting that this development model is inappropriate for either Boise or Sioux Falls but merely that they should be cognizant of potential risks. The second threat stems from the fact that their economies are concentrated in a single dimension of the high-tech development, and one that future downturns in the national economy may severely impact (Tables 4.4 and 4.5).

To a certain degree, the scope of recent high-tech development policy and its success in attracting firms and industries have been limited. Metropolitan areas such as Rochester, MN, Harrisburg, PA, and Merced, CA, showed tremendous growth in high-tech-related production. But they remain cost-effective production centers, rather than dynamic high-tech clustering regions such as Austin or Raleigh-Durham-Chapel Hill. Dispersion of high tech is a natural path of technology evolution. Establishing a production or assembly plant in a region is very much a standard economic development practice (the effect of spillover). Utilizing public policy and the interaction between local high-tech companies and government to form research centers can be important in long-term high-tech development.

The New Economy revolutionizes the utilization of technologies, which simultaneously creates the insurgency of technology whereby the old economy adapts to technology changes. As Michael Porter profoundly stated about high-tech clustering, "the most important agglomeration economies are dynamic rather than static efficiency and revolve around the rate of learning and the capacity for innovation" (Porter 1996). High-tech development is an eclectic experience. The process of establishing a high-tech economy is complex and multifaceted. Its evolution is totally dynamic and, in many aspects, self-guiding. Developing a regional culture that is amenable to change and growth and building a society that is open to new ideas are probably the best strategies and principles government can have in both attracting and expanding high-tech industries.

Just as we have changed our view about the contents of technology from the relatively pure form of product to a more complex combination of ideas, creativity, and entrepreneurial activities, economic development policy should adjust to being about the building of cultural and social environment as well as physical infrastructure. Establishing local public and private trade groups and affiliations is a sound policy that promotes the exchange of ideas, trade information, and public awareness of the development. Attending to the needs of local firms and newcomers alike will help the region to attract the desired skilled labor.

Promoting the exchange of ideas and an open social environment us the most important step.

From its inception of one or two high-tech firms, to the totally heterogeneous structures of today, took only a quarter of a century for San Jose's electronic sector. However, the alteration in the region's landscape that resulted is beyond description. The explosive transformation turned farmland into laboratories and factories. The booming economy attracted immigrants that changed the faces in the once quiet, fairly homogenous area to a multicultural neighborhood. Substantial pay differences based upon educational level deepen income disparity among the "haves" and "have nots." Congestion and limited living space present insurmountable challenges to the local government and housing development agency. These are less desirable changes that a promising high-tech economy will bring.

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During San Jose's economic transformation from 1970 to 1995, the population mix changed drastically. The Asian population increased from a miniscule 42,000 in 1970 to 338,000 in 1995, almost an eight-fold increase, while the general population increased by only 50 percent in the same period (Woods and Poole Economics 1998). This truly was a culture shock. The "modernization" of the once-tranquil farmland in Santa Clara County displaced thousands of farmers and unskilled laborers. Those were changes public officials could not accurately foresee; hence, they could not provide effective public policy at the outset of development.

Drastic changes that impose on a society are a very serious concern.

Expanding local infrastructure, housing, and educational systems are issues that local governments should anticipate and attempt to solve. Although San Jose might be an extreme case, proper public policies should address those "pressure points" during the cultural and technological transformations. Promoting life-long learning, and re-educating the existing labor force and population, may be critical in retaining local population and culture. More up-to-date skill-sets passed on to the local population can soften the trepidation local residents may feel when faced with newcomers. Proper and responsive housing policy can lighten the burden of rising housing costs on both the existing and new populations.

Implications for Business Planning

What does the high-tech revolution bring to regional economies? More precisely, how important is it for firms to seek out the next technology frontier? First and foremost, the new economy is about innovation and new ideas. Knowledge and information are placed in higher esteem than ever before. The very beginning of the new economy, namely, the electronic information revolution, will inevitably impact the way we think and the way we conduct our daily business. It opens a totally new avenue of possibility for business organizations and individuals alike. The speed of transmitting information and the seemingly unlimited computing power on our desktops have profound impacts, ranging from how companies shall organize to where an individual should live.

Changes in demographic composition alter housing demand.

The most profound impact of new and cheaper technology is on smaller firms and entrepreneurial-minded individuals. In the past, when computer equipment was expensive and communication was so costly, economic efficiency and creativity largely rested on the operation of only larger firms; without expensive and sophisticated computers, ideas cannot be tested and communicated. The majority of individuals had only limited access to information and the ability to utilize it. The rules of the game have changed in the 1990s. A marketing researcher can build a large set of databases on his or her computer to compete with a large company. This competition is about ideas and is not handicapped by a piece of technology. This change is leveling the playing field of competition between larger and smaller firms. It cultivates an environment that encourages small business growth.

The ability of growth-oriented firms and business to tap into the next rising tech-cluster regions, where the customer base is widening and their needs are customized, represents a tremendous opportunity. More important, operating in a high-tech region among firms that gain the first experience and knowledge on the next wave of change is a supreme competitive advantage.

There is nothing more dramatic than the impacts of the high-tech service boom upon the commercial and office construction markets. Mushrooming Internet Web-service firms and graphic design studios are changing the concept of space planning, building and office construction, and remodeling. These highly entrepreneurial-spirited companies tend to start with a limited amount of capital and few staff. Their office space requirements and demands are usually small at the beginning. They are among the least-recognized clients to commercial builders. However, the surging high-tech service demand offers great opportunity to these companies. The expansion of these enterprises, often through public listing of their stocks, creates escalating demand for commercial and office space. High-tech regions such as Boston, Atlanta, Austin, and Dallas have exhibited this growth trend in the past several years. The next high-tech frontier will follow a similar pattern in the commercial construction markets.

A growing high-tech region rapidly transforms the local community. New tech clustering and rapid accumulation of wealth in a regional market creates business opportunity ranging from home building to retail. Housing markets are among the first to witness the impacts. A high influx of immigrants and domestic migrants is common among high-growth, high-tech clusters. Population increases in a growing high-tech region tend to be biased toward the 25 to 44 age cohort. The development experience in San Jose, Dallas, Atlanta, Washington, DC, and others has demonstrated this to be the case. Residential housing catering to this growing age group is an exceptional challenge and opportunity.

With a greater proportion of this age cohort in the 25 to 34 subgroup, development officials must pay attention to factors such as mobility and lack of equity when considering metro housing needs. Multi-unit housing that addresses the sense of community and also affordability is more appropriate than single-family homes. Another segment of the housing industry that offers great potential is the renovation market. Contemporary living in an urban center is major trend shift in 1990s. Home renovation will help generate greater demand for interior design services, architects, and home improvement stores. Spotting the expansion of the high-tech industries in a region is vitally important to home improvement companies such as Home Depot and Hechinger.

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Just like other smaller high-growth firms, high-tech enterprises demand various types of professional services.

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Professional service providers should be equally vigilant about high-tech frontier development. These new and relatively smaller high-tech enterprises tend to utilize their limited and precious capital to create new ideas and products. A new start-up will have to rely heavily on outside service providers, such as financial planners, financial consultants, accountants, and human resources agencies. Service providers can expand their operations in the growing high-tech region. Specialty service providers, such as Kinko's, can capitalize on the rapid growth. Another significant change to the business environment caused by high technology is in the retail sector, and in eating and drinking establishments. Rapidly rising income and the wealth buildup in the region tend to put further demands on local amenities. Finally, the influx of younger age cohorts, in time, will create great demand for babysitting and for preschool education services.

APPENDIX
High-Tech Industry Profiles

The pharmaceutical industry has been highly profitable, but price controls and health-care reform threaten.

SIC 283 - Drugs

The drug and pharmaceuticals industry is the fastest-growing segment of the chemical group and has undergone structural change in the past decade. The threat of government-imposed price controls and potential health-care reform has resulted in pricing restraint and consolidation within the industry. The broad drug industry includes firms involved in manufacturing, fabricating, and processing pharmaceutical products, medicinal chemicals, diagnostic products, and botanical preparations. The drug and pharmaceutical industry has displayed a high degree of profitability, encouraged and aided by the 17-year patent protection for its discoveries. The discovery and commercial development of many life-saving medications from company-funded research labs have created enormous demand for pharmaceuticals. The high research and development and marketing costs have contributed to a concentrated industry structure. Many attribute the success of American pharmaceuticals firms to the absence of stringent price controls that have been imposed in other industrialized nations.

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The drug sector is at the forefront of research and development investment among U.S. industries. Drug companies plowed 9 percent of sales back into R&D during the 1980s, and between 10 and 12 percent in the 1990s. This commitment to R&D spending has been a key competitive advantage for the industry. These investments yielded a whole new batch of drug products, includingtreatments for hypertension, cholesterol, blood clots in victims of heart attack, prostate abnormalities, cardiovascular disease, Alzheimer's disease, cancer, and AIDS. Approximately 20 percent of the industry's 260,000 employees are full-time R&D scientists and engineers, as opposed to 4 percent for manufacturing overall (Trumbull 1997).

Biotechnology is an important investment area.

Biotechnology has been an important investment area. Knowledge of specific protein functions in the body — whether to stimulate infection-fighting cells or block a destructive internal process — allows physicians to inject biotechnology-produced proteins into the body to induce desired reactions in patients. Bioengineered treatments have had limited commercial success but, because of the potential to provide "break-through" treatments, offer much hope for the future.

The export market accounts for approximately 10 percent of drug industry output, with Western Europe receiving over half of all exports. The U.S. Department of Commerce has estimated that American pharmaceutical companies produce approximately half of worldwide pharmaceutical sales. Expanding international sales, especially in China and other Asian countries, offers great long-range opportunities for growth. Over the past 30 years, real output growth in the drug industry was a compound annual rate of 4.6 percent, matching the average of the high-tech sector as a whole. Industry output in real 1992 dollars totaled $77.9 billion in 1997. Output per man-hour in the drug industry in 1996 was $136, the largest among the high-tech sectors.

The aging of the baby boomers provides great opportunity for growth in industry sales, not only in the United States but in Japan and Western Europe as well. Senior citizens purchase one-third of all prescription medication dispensed in the United States and will account for 30 percent of the total population within 10 years. Future growth prospects are favorable for the drug industry, with high profit margins.

SIC 357 - Computers and Office Equipment

Computers and peripheral equipment are at the core of the information technology revolution. Along with electronic components and accessories, computers and peripheral equipment has been at the top of industry growth rankings over the past three decades. When adjusted for price declines and performance improvements, output growth has accelerated in the 1990s. Technological advancements within the industry have been remarkable. The computer-equipment sector includes firms engaged in the production of electronic computers, storage devices, computer terminals, computer peripheral equipment (including communication interfaces), and electronic-imaging equipment. During each evolutionary phase, the price of computing power has fallen, and the market has broadened. The computer hardware industry is generally subdivided into three segments: personal computers, systems and servers, and workstations.

The business sector was responsible for generating most of the growth in computer hardware over the past 30 years, but the importance of the consumer sector has grown over the past decade. During the 1970s, businesses invested in computer hardware primarily to automate back-office operations, such as accounting. Competition within the industry intensified as technological advances permitted the production of cheaper and smaller devices. By the 1980s, computers were small enough to sit on a desktop, and the personal computer was introduced. Although largely a

U.S. pharmaceutical companies produce half of worldwide sales.

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Demographic change will keep the industry growing in the years to come.

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The computer industry has been near the top of U.S. growth rankings for three decades.

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Prices are down, speeds are faster, and the market has broadened.

personal-productivity tool for tasks such as word processing, the PC created a massive consumer market for computers. The most recent stage in the computer revolution has been in network computing. Networked computers draw in a growing base of smaller firms and consumer users. Today's servers provide users with a technology that is lower priced than but almost as powerful as large mainframes and minicomputers. The introduction of the Internet has promoted strong demand for network computers and equipment. The Internet promises to expand the "network" globally, connecting individuals and businesses in hundreds of nations.

The Internet has played an important role.

Research and development expenditures are critical for American firms to maintain technological leadership. The industry has generally spent between 7 and 9 percent of sales on R&D, ranking it among industry leaders. During the 1990s, the U.S. computer industry invested more funds in R&D than any other U.S. industry. Electrical engineers, programmers, and technicians represent around 30 percent of industry employment of 365,000. Restructuring and rapid productivity growth within the industry have resulted in a decline in employment since it peaked at 516,000 in 1984. Output per man-hour has increased at a compound annual rate of 9.2 percent over the past 30 years, faster than any other major U.S. industry. Gross industry output in real 1992 dollars totaled $188.9 billion in 1997. Computers and office equipment averaged compound annual output growth of 9.6 percent over the past 30 years, and in real terms, growth was substantially greater.

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Exports account for a large market share, but foreign competition is strong.

International trade in computer equipment plays a major role in the United States. Exports account for over 30 percent of industry output and imports represent about 50 percent of industry sales. The United States runs a large deficit in computer peripherals and parts, as Asian firms are highly efficient and formidable competitors. U.S. firms have moved production into foreign countries, helping to give them access to global markets, lowering component costs in the United States, and promoting manufacturing flexibility to meet customer needs.

Rapid technology improvements in processing capabilities in the computer industry promise to sustain a high rate of growth. Business investment in computers and related equipment will be driven by a number of factors: strong Internet growth, declining prices, and intense competitive pressure to boost efficiency and productivity. The tremendous expansion in the area of communication interfaces (fax modems, Ethernet cards, and PCMCIA cards) due to networking will be an important area of growth.

SIC 366 — Communications Equipment

The communications equipment industry is undergoing a virtual explosion in demand for its products, led by massive investment in communications networking gear. Due to the advent of satellite communications, wireless services, digital technology, and fiber optics, the communications equipment industry has undergone a dramatic transformation over the past 20 years. The technology innovations were driven by the telecommunications companies' desire to increase the capacity of the communications systems and improve the quality and breadth of their service offerings (Cavallone 1998). Concurrent innovation in computing, microprocessors, and miniaturization also played an important role. Communication equipment is generally broken down into two major categories: telephone and telegraph apparatus, and radio and television broadcasting equipment.

The communications equipment industry has been a major beneficiary of the high tech revolution.

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The global communications equipment industry is dominated by an oligopoly of American and international manufacturers, whose structure has been influenced by relations with major communications companies, economies of scale, and R&D. Several important equipment categories dominate the industry. Wireless is the fastest growing segment of the communications equipment market, with shipments valued at $40 billion in 1997. This includes both wireless network equipment infrastructure and handsets. About 64 million Americans subscribed to wireless service in 1998, up from 28 million in 1995. In addition to wireless, shipments of wireline, or traditional network equipment, have also been strong and were valued at $170 billion in 1997 (Cavallone 1998, 8, 12).

Wireless is the fastest growing industry segment.

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Several factors help to explain this trend, including the boom in private and commercial construction, corporate expenditures on voice and data communications upgrades, installation of the latest fiber optic and high-speed digital access systems, and increased phone line demand for fax, voice mail, and Internet service (Trumbull 1997, 19-8). Indeed, much of the growth in communications equipment in recent years has been parallel with the spread of the Internet. If computers are the vehicles by which we travel the information superhighway, communications equipment is the pavement that links the system together. Internet volume is increasing dramatically, leading to demand for greater bandwidth supplied by a number of competing systems from telephone and cable companies. Today, the communications equipment industry is characterized by deregulation, intense competition, and high rates of technological change that have benefited consumers with lower costs while simultaneously tightening profit margins for equipment manufacturers.

The Internet is creating additional demand.

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Few markets have grown as quickly in recent years as communications equipment. Between 1991 and 1997, gross industry output increased a staggering 88.2 percent and grew 24.4 percent in the three years from 1995 to 1997. The industry has maintained this level of growth with a workforce of 272,300 persons, which is up 13.6 percent from a 1992 recession low, but nowhere near the 307,500 employed in 1985. Output per man-hour was $108 in 1996, ranking it among industry leaders.

Deregulation will aid foreign markets.

Wireless may offer developing nations significant cost savings over traditional wireline infrastructure.

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Semiconductors are finding their way into a myriad of products and devices.

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Continued development drives the entire high tech sector.

The United States leads the world in communications equipment exports, although foreign manufacturers produce a great deal of products for the consumer market. Exports grew 17 percent annually over the past decade, with exports to Japan, China, other Asian countries, and Canada growing 11 percent annually. The industry has not been immune to recent global economic turmoil, but with 60 countries planning to privatize their communication service industries in the next five years, long-term industry prospects remain strong. Developed countries will continue to follow America's lead by expanding and modernizing voice and data communications systems, while new technologies, such as wireless, promise developing nations significant cost savings over the conventional wireline communications infrastructure.

The communications equipment industry is projected to grow at about 6.5 percent annually over the next decade (Trumbull 1997). Most growth will occur in the wireless, satellite, and broadband fields, but even sales to the few industry sectors that have performed poorly in recent years, such as defense, commercial aerospace, and air traffic control, are expected to increase as systems are modernized. Competition between firms will remain intense, with industry deregulation a continuing trend. Technically, digital, fiber optic, and wireless conversion will continue, and efficiencies will be sought through the convergence of voice and data transmission by means of packet-based switching.

SIC 367 - Electronic Components and Accessories

The electronic components and accessories industry provides the technical base that drives the entire high-technology sector. This industry is responsible for the production of electrical and electronic devices, including semiconductors, printed circuit boards, electron tubes, capacitors, resistors, coils, transformers, and connectors (Trumbull 1997). These devices comprise the vital components in computer, telecommunications, instrumentation, medical, and transportation equipment. Like the computer and office equipment industry, electronic components have placed near the top of industry growth rankings over the past three decades. Between 1990 and 1997 the value of shipments for semiconductors alone grew nearly 300 percent. Indeed, semiconductors and related devices (SIC 3674) account for the largest portion of the electronic components and accessories industry, with 43 percent of employment and 56 percent of value of shipments in 1997.

With developmental forces shaped by defense and industrial concerns, the electronic components industry has experienced most of its growth in the consumer sector in the past two decades. This will continue, as personal computing and telecommunication devices move beyond the business sector and into the home, and as these devices become increasingly technology-laden. The forces of innovation drive the electronic components industry. Each subsequent generation of devices realizes gains in efficiency, productivity, and speed, with simultaneous reductions in size. The very nature of this innovation produces high rates of obsolescence and subsequent product turnover. This is particularly true in the semiconductor industry, where innovation (fostered by the premise of Moore's Law) produces a demand cycle for processor-intensive applications and a subsequent need for faster speeds. The requirements of Internet-capable devices have only accelerated this process. Nevertheless, the electronic components industry is currently in a period of slow growth after a phenomenal mid-decade. Global economic turmoil, industry overcapacity, lower pricing, and the emergence of a strong low-end personal computer market are to blame (McGovern 1998).

The industry has cooled off in recent years...

Employment prospects for electronic components remain strong. Productivity gains and industry consolidation lowered employment from a peak of 683,000 in 1984, but with strong demand in the 1990s, employment has rebounded and approached historical highs in 1998. Over the last 30 years, nominal industry output growth averaged 9.8 percent annually, and totaled $585.6 billion in 1997. Semiconductor industry figures are even more striking: between 1959 and 1997 the market grew at an average of 17 percent per year (Scalise 1998). Semiconductors now rank first in the generation of added value in the manufacturing sector. Research and development is vital to growth. U.S. companies spend an average of 14 percent of annual revenue on R&D.

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...and faces stiff competition from foreign manufacturers.

International trade accounts for a large part of the electronic components business. Exports, for example, comprise about 25 percent of industry output, while imports account for about 30 percent of sales. The Asia / Pacific region is America's largest trading partner for electronic components. Favorable exchange rates, competitive prices, and low production costs (particularly for less-sophisticated components), makes Asia the chief growth market for both supply and demand. Most major U.S. manufacturers now operate production facilities in the region. Asia appears to have bottomed out of its recent economic crisis, and with many reform-minded governments in power, industry deregulation seems likely, although the U.S. market remains vulnerable to low-cost dumping practices.

The computer and telecommunications sectors will continue to be an important market for devices produced by the electronic components industry. Prospects for continued expansion remain bright, although the industry will mature, and growth rates will likely moderate as technology diffuses into the economy. International competition, particularly from the Asia / Pacific Rim region, is expected to remain strong. Finally, the importance of technological development and innovation should not be underestimated as a driving force for the continued success and productivity of the industry as well as the entire high-tech sector.

SICs 372 and 376 - Aerospace

The aerospace industry is one of the oldest high-technology sectors in the U.S. economy. Barriers to entry are great, including a high ratio of research and development expenditures to sales. Aerospace consists of a few broadly defined product groups for both civilian and military use. For the purposes of this study, these include SIC 372 aircraft and parts, as well as SIC 376 (guided missiles, space vehicles, and parts). For nearly half a century aerospace was the largest recipient of the national defense expenditures. During the Cold War, the industry typically received more revenues from its military production than from civilian projects at about a two-to-one ratio. At its height, the American aircraft industry received more than $41 billion from the Department of Defense. With the collapse of the Soviet Union, however, lucrative government contracts eroded, and the period of prolonged high growth came to an end. In 1998, aerospace received only $30 billion from military contracts (Napier 1998).

Although back orders remain, the current round of aircraft purchases seems to have ended.

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The Asia Crisis has hurt foreign sales...

With the end of the Cold War, the American aerospace industry faced a rapidly integrating global economic structure, robust demand for its products from South East Asian markets, and the transformation of its customer mix from military to civilian purchases. The requirements of civilian aviation have affected American aerospace in a number of ways. Industry R&D — which makes up more than 25 percent of global aerospace R&D — now emphasizes fuel efficiency and passenger comfort over the tactical characteristics of military aircraft (Friedman 1998). Rocket and missile R&D has also focused on the needs of the lucrative civilian satellite market, with an emphasis on new, larger boosters that enhance cost efficiency and increase payload capacity. Consolidation has also taken place in the aerospace industry. Indeed, the merger of Boeing and McDonnell Douglas attest to the industry's ability to transform itself by adapting to the new operating environment. The merger will further reinforce the global dominance of the Boeing Co. against fierce competition from European manufacturers, who have been steadily gaining world market share. Boeing's ability to maintain its North American market and exploit rapidly expanding demand in Asia will no doubt determine its future as industry leader.

The U.S. aircraft industry is a leader in the global marketplace, accounting for more than 60 percent of the world aircraft market. The industry sold $47 billion worth of aircraft and parts to civilian air carriers in 1998 (Napier 1999). Superiority in research, development, and production has allowed the U.S. aircraft industry to position itself as the major exporter of both commercial and military aircraft for the past 50 years. Aircraft, aircraft engines, and parts comprise one of the leading net exports in the U.S. economy, with exports valued at $59 billion in 1998 against $22 billion in imports (Napier 1999). Booming economies in Asia over the past 15 years have boosted the industry's bottom line as well as its contribution to U.S. export activities, but the Asian economic downturn has slowed orders since mid-1997. Asia accounts for about one-fifth of global aircraft sales, and the downturn has led some regional airlines to cancel or defer orders, particularly on profitable widebody aircraft. This may curtail the recent global boom in aircraft construction, despite a continuing backlog of orders (Friedman 1998).

...but long-term prospects remains strong...

The Boeing Co. estimates that from 1998 to 2007, worldwide passenger air travel will increase at an annual rate of 5 percent. If true, this will mandate the construction of more than 7,000 commercial aircraft over the next decade, worth an estimated $520 billion in 1997 dollars (Friedman 1998). Although the current order cycle for commercial aircraft appears to have peaked, Asian economies seem to have bottomed out, and sales will increase in the coming years. Future demand trends for commercial aircraft will move toward longer ranges and greater seating capacities. Like commercial air travel, the aerospace industry will continue to experience growing demand for commercial satellite launch vehicles, although the American manufacturers have recently been slowed by a number of well-publicized booster failures, which highlight the technical complexity, difficulty, and risk of rocket launching.

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...and new contracts will stimulate defense aerospace.

Finally, spending for defense aerospace appears to be bottoming out after more than a decade of cutbacks and consolidation. Several important contracts are now gearing up for production, including the F-22 Raptor and Joint Strike Fighter. Missile production is also expected to increase upon reports of shortages after military actions in Iraq, Afghanistan, Africa, and the Balkans.

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SIC 381 - Search and Navigation Equipment

Producing radar, navigation, and instruments, the search and navigation equipment industry is considered a "niche segment" of aerospace...

The search and navigation equipment industry produces devices used for the guidance and detection of military and civilian aircraft and ships. These devices include radar and sonar systems, control equipment for aircraft and missiles, flight and navigation products, gyroscopes, and instruments. Many of these devices employ the latest in computer and electronic hardware and software, and as such, the industry earns the moniker of high tech.

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...and often shares its fate.

Although search and navigation equipment manufacturers produce devices for nautical use, most equipment sales are to the aerospace sector. As a result, many consider the industry to be a "niche segment" of aerospace, and the two share similar fates in the marketplace. Both industries boomed in the early 1980s under Reagan-era defense spending, but less than a decade later each was weathering recession, defense cutbacks, canceled orders from commercial markets, and increased global competition. Since that time, each also has undergone a period of restructuring and consolidation. By nature, the search and navigation equipment industry is cyclical, relying on extended contracts with long lead times from traditional commercial and government customers. High rates of development characterize the devices produced by this industry. This burdens manufacturers with product obsolescence, employee retraining, and retooling costs, and cost overruns from untried technologies.

Employment is down over 50 percent from a historical high of 360,000 employees in 1985. Gross industry output was $30.4 billion in 1997, which was down nearly 30 percent from a decade earlier. Despite dramatic reductions in employment and output, the industry has grown at a compound annual rate of 3.8 percent over the past 30 years. Output per man-hour was a respectable $80 in 1996. R&D funds for the search and navigation equipment industry from both public and private sources have decreased in recent years.

Systems upgrades and new defense contracts should pull the industry out of its current lull.

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Measuring and controlling devices move, manipulate, and measure fluids or energy.

Despite increasing competition in the global marketplace, the United States leads the world in the production and export of search and navigation equipment. Although the industry has suffered setbacks from global financial turmoil (particularly in Asia), prospects for continued export growth remain strong. There are several reasons for this assertion. First, the growing market for air travel around the world will result in improved demand for on-board flight systems in commercial aircraft as well as the modernization of air traffic and ground control networks. Second, the end of the Cold War has hastened the need to upgrade military aircraft, avionics, and control systems in many countries, particularly those in Eastern Europe, Asia, and the Middle East.

The American search and navigation equipment industry is expected to soon awaken from a decade of dormancy. In addition to a rebounding international market, demand for commercial aircraft for domestic use remains strong, and the modernization of the U.S. air traffic control systems continues. In defense-related markets, the U.S. aerospace industry will soon be gearing up for the production of the F-22 Raptor and Joint Strike Fighter projects, which are among the largest defense contracts in history. Industry shipments are expected to increase 4–5 percent per year over the next 10 years. Technically, industry trends are moving toward interactive and virtual systems, increased reliability, and "fault-tolerance" (or the ability to operate through system failures). Efficiencies in size, weight, cost, and power consumption are also being pursued. Finally, defense conversion is on the minds of many search and navigation equipment manufacturers, as the industry tries to branch out from traditional markets. The growing use of global positions systems (GPS) in automobiles and other consumer products is merely one example of a recent conversion success story (Trumbull 1997).

SIC 382 - Measuring and Controlling Devices

"Measuring and controlling devices" is a general term that describes a myriad of technologies employed in industrial, commercial, consumer, and research settings. Broadly speaking, these devices move, manipulate, and measure fluids or energy. The type of equipment and the industries that use these devices run the gamut from high to low tech, but most are increasingly technical in nature and can be classified into a few broad groups: (1) laboratory, scientific, and optical apparatus used for medical and biotechnology research, environmental testing, and telecommunications; (2) automatic control devices that regulate environments, industrial processes, and appliances for commercial, residential, and industrial use; and (3) devices for measuring electricity, such as semiconductor, circuit board, and communications test equipment (U.S. Department of Commerce 1994).

The strong US manufacturing and construction sectors should keep the industry growing at a moderate pace.

With the exception of equipment sold to defense-related markets, the measuring and controlling device industry is expected to grow at a moderate pace. Several trends support this assertion. Sales of automatic control devices such as thermostats and appliance systems have been up along with the strong construction market, which is expected to remain stable in the coming years. The strong American economy has also led manufacturers to pursue efficiency and productivity gains through the purchase of high-tech industrial process controls and instruments. The continued growth of the computer, biomedical, pharmaceutical, and environmental industries will hasten demand for laboratory equipment and measuring devices (Trumbull 1997).

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The measuring and controlling device industry employs roughly 300,000 people, which is down 11.8 percent from a high of 336,800 in 1981. Gross industry output increased 69.2 percent during that same period, however, and was $45.3 billion in 1997. Over the last 30 years, gross industry output grew 4.4 percent annually. Output per man-hour was $68 in 1996.

Manufacturers of measuring and controlling devices have been hit by recent global economic turmoil, yet demand for control systems, appliances, and measuring equipment in developing nations will be strong over the next decade. U.S. sales will continue to grow as well. Industry shipments to domestic and foreign customers are expected to expand by 5.5 percent per year over the next decade (Trumbull 1997).

Information technology is now in many of the devices that keep us alive and in good health.

SIC 384 - Medical Instruments and Supplies

In addition to being a force behind growth in industries as diverse as computer equipment, aerospace, and even motion pictures, information technology is also playing an increasingly important role in keeping us alive and in good health. Medical devices, used to perform diagnoses, complex and delicate surgeries, and, increasingly, "minimally invasive" procedures employ many of the same technologies found in personal computers, aircraft, and high-resolution graphics displays. The medical instruments and supplies industry is part of a market that in the United

Profits for medical equipment manufacturers have slowed, but new innovation is likely.

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Two forces will shape the industry in the years to come: Demographics and managed care.

States alone that amounted to $46.2 billion in 1996, and includes those establishments involved in the manufacture of surgical and medical devices, dental equipment, orthopedic and prosthetic appliances, as well as X-ray, electromedical, and electrotherapeutic apparatus.

The medical instruments and supplies industry has undergone dramatic change in recent years. The industry is currently experiencing a round of consolidation, with the value of mergers reaching $10 billion in 1997 and an estimated $15 billion in 1998. Several factors have been cited for this recent trend, including greater industry competition, price discounting, constrained Medicare reimbursement, and the growing influence of managed-care companies, which, for purposes of economies of scale, prefer to deal with a few large suppliers of medical equipment. Also cited is the growing cost of government regulation and, in particular, the barriers to and high costs involved in FDAapproval of medical equipment. The medical instrument industry has also matured in recent years, as the market for minimally invasive surgical instruments and angioplasty catheters has peaked. Industry profits have slowed, but this new and promising sphere is ripe for further development (Saftlas 1998).

Firms producing medical instruments and supplies employed over 270,000 in 1998. More than 20,000 companies are licensed to produce medical devices in the United States, but fewer than 1,500 firms are primarily engaged in the endeavor. The industry spends a large portion of its revenues on R&D — near 6.5 percent in the 1990s. Additional funding comes from government sources. Gross industry output for the medical instruments industry in real 1992 dollars was $181 billion in 1997, and has increased at a staggering 6.5 percent annual rate over the past 30 years. Relative to the high tech-sectors ranked in this study, this rate of growth was outpaced only by those of computer-related fields.

The United States controls about 42 percent of the production market for medical equipment and supplies worldwide, with Europe accounting for 27 percent, Japan 14 percent, and other areas 17 percent (Saftlas 1998, 7). International markets for U.S.–produced medical equipment will continue to grow. The value of U.S. exports to Asian emerging markets was nearly $1 billion in 1997. Exports to Asia were hurt in 1998 but are estimated to have increased slightly, despite recession and currency devaluation. Long-term sales prospects for the region are strong, as rising standards of living and government emphasis on public health lead to export growth. In Europe, the introduction of the euro is expected to have a positive impact on the medical equipment industry, as business practices and prices become standardized across national boundaries and the regulatory approval process is streamlined (Saftlas 1998).

Two primary forces will shape the medical instruments and supplies industry, as well as the entire healthcare industry, in the years to come. First is the enormous demographic change that will occur in the United

States and worldwide in the coming decades. According to the World Health Organization, the number of individuals 65 years and older is expected to increase from 390 million in 1997 to 800 million in 2025. In the United States, the over-65 population will double between 1995 and 2030. This will have an enormous effect on the demand for medical instruments. The second force is the continued influence of the cost-conscious managed-care industry on equipment sales and prices. More than 60 percent of all medical device purchases in the United States are made by managed-care systems, and the industry exerts strong pressures that encourage lower cost devices, pharmaceutical treatments, and outpatient procedures (Saftlas 1998, 8–9).

Telephone communications services include local and long distance networks.

SIC 481 - Telephone Communications

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The telephone communications, or telecommunications, industry provides services to 94 million households and 25 million businesses nationwide. The industry is divided into two distinct segments. The first of these segments is wireline, which provides telephone voice and data communications services over land-based wire networks. The wireline industry can be divided further into local networks (about 70 percent of which are serviced by regional Bell operating companies) and long-distance carriers (of which 80 percent of the market is controlled by four companies: AT&T, MCI, Sprint, and WorldCom) (Wohl 1998a). The second segment of the telecommunications industry is wireless, which provides two-way radiotelephone communications, such as cellular telephone, pager, and beeper services.

Long distance remains very profitable...

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The breakup of AT&T in 1984 into regional “Baby Bells” came on the cusp of a technological revolution that would soon sweep the telecommunications industry. Competition fostered by the breakup led to investment in new technology to improve service quality (fiber optic networks and call waiting) and create new markets (wireless and pager services). The industry stalled in the early 1990s as the result of recession and lower profits from a competitive environment, but since that time it has grown at phenomenal rates.

...wireless service is exploding...

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Several factors can explain this growth. For many years long distance service has been the mainstay of the telecommunications industry, and still is. The four main long-distance operators saw an average revenue growth increase of over 12 percent in 1998; even so, over the decade, technology has lowered prices and cut margins (Wohl 1998b). Competition is fierce. This has led many companies to seek new opportunities for growth in markets such as wireless, which has grown exponentially. The industry's subscriber base has been growing at about 20 percent annually in recent years, and for many consumers mobile phones are now a necessity. Subscribers are expected to top 75 million by the end of 1999 (Wohl 1998b). Telecommunication companies have also sought new revenue

...but competition is fierce.

Deregulation and international trade agreements will keep the global market growing despite recent setbacks.

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The global wireless market may eventually surpass wireline.

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Consolidation, continued deregulation, and fierce competition will characterize the industry.

opportunities in the fast-growing Internet-service-provider market. Companies now offer high-speed Internet connections through existing telephone networks, but competing systems have not been standardized and service areas are restricted.

Gross industry output in the communications industry (which includes radio, television, and cable broadcasting in addition to telecommunications) has grown an average of 4.8 percent annually over the past three decades, and stood at $320 billion in 1997. The industry employs 1.4 million people, an increase of over 6 percent since 1986. This rate seems small when considering that gross industry output increased 29.3 percent during the same period. This has been possible through the adoption of labor-saving technologies, which continue to promise cost reductions without a loss of service, particularly in the wireline segment of the industry. Technology has allowed the communications industry to maintain a highly productive workforce, with an output per man-hour of $105 in 1996.

U.S. telecommunications service providers are the most competitive in the world. They currently dominate global markets with their technological expertise and market know-how. Despite recent global economic turmoil, markets continue to expand around the world. In 1998, 72 member nations of the World Trade Organization signed an agreement that allows companies to acquire interests in foreign telephone operations that previously had been state-owned. This, along with the planned privatization of over 60 telecommunications systems in countries around the world, will open markets to U.S. exports. Similar to the United States, countries around the globe, particularly in Latin America and China, represent a strong growth market for wireless services. These systems offer developing economies the opportunity to meet their telecommunications needs without investment in expensive wireline networks. The global wireless market is estimated to be a $200 billion segment of the $900 billion worldwide telecommunications market, and may eventually surpass wireline (Wohl 1998b).

Several trends characterize the telecommunications industry as it prepares to enter a new century. The industry has been consolidating, with merger talks that may reassemble a number of Baby Bells if resistance from Federal regulators can be overcome. These larger companies wish to "bundle" long distance, cellular, and Internet services to consumers for a single flat rate in markets nationwide. Recent legislation and deregulation will also affect the industry. The Telecom Act of 1996, for example, enables local telephone companies, long-distance carriers, and cable television operators to enter one another's markets. This will increase competition in local networks, and continue to blur the distinction between communication and transmission companies. Other trends in the telecommunications industry include continued deregulation, blinding competition, overlapping markets and revenue streams, globalization, greater consumer choice, lower prices, and a technical emphasis on data communication and on fiber optic and digital conversion.

SIC 737 - Computer and Data Processing Services

The computer and data processing services sector is responsible for the production of most computer applications used by business, government, and consumers. Like the computer hardware sector, computer services are among the fastest-growing industries in the U.S. economy, with annual growth rates in the 1990s reaching double digits. The computer and data processing services sector includes a variety of establishments engaged in programming services (specialized programming on a contract or fee basis), data preparation and processing services, information retrieval, computer systems design, computer maintenance and repair, and the largest industry in the sector — prepackaged software.

Software sales and the Internet will keep computer and data processing services among the fastest growing sectors of the US economy.

The origins of the computer and data processing services sector stretch back to the early years of computing in the 1950s. At that time, tailor-made programs and systems were created for expensive mainframe computers to automate mundane, time-consuming, and expensive back-office tasks for large businesses and government, who often shared machines on a rental or lease basis. Growth in the computer programming industry skyrocketed in the 1980s with the introduction of the personal computer and the demand for business applications for these machines. By the early 1990s, however, growth in the computer programming industry had been quelled somewhat by the increased sales of prepackaged software.

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The Internet's true potential is only now being realized...

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...but labor shortages will continue to be a drag on the industry.

Several factors can explain this transition. Rapid advances in the speed and memory capabilities of personal computers convinced all but the largest firms that the high cost of retaining a full-time programming staff could not be justified. Also, the growing use of networks and client/server systems required software products that operated in many environments and network configurations — conditions that prepackaged software could provide (Trumbull 1997). This has become even more of a necessity with the spread of the Internet, which has become an enormous new area of growth for computer and systems programmers. Since its emergence, software vendors have tried to integrate Internet features into their products and develop business-ready E-commerce applications such as online banking and payment systems, financial and travel services, and navigation tools (Goodstadt 1998, 2). Perhaps the Internet's most promising feature, in terms of commerce, is its potential to automate front-office duties, including sales, customer service, and supply-chain management functions (Goodstadt 1998). The phenomenal growth of this new medium has led to an enormous demand for information system programmers to manage the daily needs of business client/server systems, e-mail, Internet, and software applications.

The US is the global leader in software and Internet products and services.

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Innovation, diffusion, high rates of obsolescence, and stiff competition are industry norms.

The computer and data processing services sector employed 1.75 million individuals in April 1999. The industry has experienced 140 percent employment growth in the past decade. The three fastest-growing professions in the U.S. economy: database administrators–computer support specialists, computer engineers, and systems analysts can all be found in the computer and data processing services sector. While demand for these positions grew at enormous rates, labor supply actually has declined. Since 1986, the number of computer science and mathematics graduates entering the U.S. workforce has declined 42 percent (Goodstadt 1998). With strong demand, salaries have increased 7–10 percent annually for several years, but output per man-hour stood at a flat $63 in 1996 — low for a high-tech industry due to the many data-entry positions. Gross industry output for the computer and data processing services sector was $190 billion in 1997, which is an increase of over 12 percent over 1996. Industry output has increased an average of 9.4 percent over the past three decades, which ranks third, behind only electronic components and accessories, and computer and office equipment. It has been estimated that on a value-added basis, computer software is the third-largest manufacturing business in the United States, exceeded only by automobiles and electronics (Goodstadt 1998), and is soon expected to surpass the automobile industry as the largest contributor to the economy (Business Software Alliance 1999).

While the United States has lost market share to international competition in high-tech sectors such as computer hardware and microprocessors, it has retained its lead as the primary global exporter of software. U.S. companies produce an estimated 57 percent of the world's software, and the United States has the largest domestic market. Globally, Japan has the second-largest. Japan also is a major U.S. competitor for global software sales, even though the United States controls about 50 percent of the Japanese domestic market. Western European markets were collectively valued at three times Japan's, while Pacific Basin economies registered one-half Japan's. The enormous demand for IT workers in the United States, and the comparatively higher salaries offered here (although lower than for domestic employees), has led many foreign workers to emigrate to the United States or seek temporary employment status under H1-B visa provisions.

The computer and data processing services sector is expected to maintain double-digit annual growth in the near future. New technology drives the industry, and as hardware prices have fallen dramatically in recent years, competition in the software market has intensified. Software has been penetrating markets quickly, and growth will slow as the market matures if technological change sits still long enough to allow it (Trumbull 1997, 297). The Internet will continue to be the driving force in the industry. Today, about 80 million Americans, or about 30 percent of the population, have access to the Internet (U.S. Internet Council, 1999). Competition in the Internet sector will remain intense. Since the output produced by this industry is knowledge and, as such, requires a relatively small outlay of capital equipment, few barriers exist for new companies to enter the market. High failure rates, buyouts, and consolidation will be the norm, however.

SIC 781 - Motion Picture Production and Services

On the surface, one might not believe motion picture production and services to be a high-technology industry, yet from its inception over a century ago filmmaking has been a very technical art form. Like other technical professions, film has increasingly become the beneficiary of high-technology inputs for production, post-production, and marketing. The motion picture production and services industry (SIC 781) includes firms involved in the production of theatrical and nontheatrical motion pictures and videotapes for exhibition or sale, as well as educational, industrial, and religious films. Also included are establishments involved in high-tech services vital to motion picture production, such as film processing, editing, titling, and videotape reproduction.

High tech is playing an increasingly important role in motion picture production, post-production, and marketing.

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The film industry has played an important role in the Southern California economy for most of the 20th century. Lured to the area by its open spaces and sunny weather, the film industry helped establish the California "persona" during the golden age of Hollywood. The industry suffered in the postwar years with the emergence of television, and it was not until the mid-1970s, with special effects–laden blockbusters such as *Jaws* and *Star Wars*, did the industry begin to display its enormous profit-making potential. Despite a slow start due to recession in the early 1990s, films such as these continue to be Hollywood's mainstay, with a handful of movies often determining a make-or-break year for many studios. Technology drives the motion picture industry both in terms of production (special effects, digital photography, sound effects, editing) and by offering new venues for film marketing (multimedia such as video and computer games, DVD, satellite, pay-per-view, toys, and theme park rides). Heavily technical and heavily marketed films are very expensive, however, and emphasize what is the biggest problem for the film industry: the high initial outlay of funds necessary to produce a film (Trumbull 1997). Indeed, the film industry is in many ways an oligopolistic market, in which five large companies (Columbia, Disney, Fox, Universal, and Warner) account for about 75 percent of revenues (Trumbull 1997). This has changed a bit in the 1990s, with the success of several small, inexpensive, independently produced films.

Technology is blurring the line between motion pictures and other forms of entertainment.

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Exports are a significant share of the market...

Employment in the motion picture production and services industry stands near an all-time high of 246,000 nationwide in early 1999. In Los Angeles alone, 152,000 individuals are employed in the motion picture industry. Nationwide, employment in motion picture production and services has grown 85 percent since 1990. This is a testament to the

...but intellectual property rights and piracy are becoming important issues.

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Technology is lowering production costs and barriers to entry.

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The end of the Cold War led to restructuring in the engineering and architectural services industry.

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International competition is

International competition is taking a greater market share...

booming number of technology positions available in the industry, as well as the increased demand for the industry's products in an expanding number of marketable forms. Gross industry output averaged an annual growth rate of 3.9 percent over the last three decades.

Foreign markets have long been an important source of income for the American motion picture industry, accounting for about half of total sales over the last 30 years. In an industry where only a few films earn more at the box office than they cost to make, foreign distribution often determines the difference between success and failure. Perhaps the most salient issue affecting export earnings for the American motion picture industry is the issue of intellectual property rights and the unauthorized presentation, theft, or piracy of films in international markets. According to the International Intellectual Property Alliance, worldwide piracy costs the American film industry $15 billion to $17 billion each year.

Technological change will continue to drive the motion picture production and services industry in the coming years. Like the music industry before it, motion picture production and marketing is expected to become increasingly digital in form. The use of digital cameras and projectors will continue to blur the lines between what are motion pictures and other forms of multimedia. Technology also is expected to reduce production costs (including film stock, editing, and special effects) and subsequently lower the entry level for filmmakers with stories to tell, but limited budgets to tell them with.

SIC 871 - Engineering and Architectural Services, and SIC 873 - Research and Testing Services

This relatively small segment of the high-tech sector includes establishments employing a varied array of technologies used to provide design, construction, testing, measuring, and research services. Two industries comprise this segment. The first is engineering, architectural, and surveying services (SIC 871), which provides professional engineering and architectural contracting and consulting, as well as land, water, and aerial surveying. Second is research, development, and testing services (SIC 873), which includes nonmedical laboratory services and organizations involved in commercial and noncommercial research in the applied, natural, and social sciences.

Establishments in the engineering and architectural, and research and testing industries are generally involved in longer-term, contract-type projects with long lead times. These projects include commercial buildings, industrial processing plants and factories, naval and aeronautical systems, public and institutional facilities (such as hospitals and schools), and large infrastructure projects including power generating facilities, water supply and sanitation systems, highways, roads, and bridges. Both industries experienced downturns during the recession of the early 1990s. This led to layoffs, downsizing, and restructuring. The engineering services industry was burdened further by the end of the Cold War and the political change that cut funding for defense technologies. Today, civilian projects are the primary source of industry income, and with them come a more interdisciplinary approach to problem solving.

Many foreign professionals are trained in the U.S.

International markets also have become a major growth area, and demand for services is often tied to conditions in other countries. U.S. companies are, however, experiencing increased competition from foreign firms, and a small but growing number of international firms are winnnning contracts for projects in the United States. Competition has forced U.S. companies to expand productivity and reduce costs. Many nations also turn to the United States to train their engineers, architects, scientists, and researchers. In 1994—95, for example, 58 percent of the engineering Ph.D.s awarded by American universities went to foreign-born students (National Center for Education Statistics 1997).

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The strong U.S. economy should keep the industry growing at a moderate pace.

Gross industry output for the engineering and architectural, and research past 30 years, and was $94 billion and $62 billion, respectively in 1997. These figures are each near all-time industry highs, as are employment levels. Engineering and architectural services firms employ over 900,000 individuals, while research and testing services have a workforce of slightly less that 600,000. Output per man-hour for both industries, however, hovered at $50 in 1996 — at the bottom of the high-tech sector. Each industry is of spillover). Utilizing public policy and the interaction between local high-tech companies and government to form research centers can be important in long-term high-tech development.

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