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Measuring Regional High Tech Activity with Occupational Data

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Introduction and summary

Rapid growth of technology-intensive industries has been a striking feature of the U.S. economic landscape in the 1970s and 1980s.[1] National and state policymakers are concerned with the growth and promotion of these broadly defined high tech industries because they are viewed as being crucial components of national economic growth and an increasingly important part of our international export base.[2] At the regional level, high tech industries have been targeted as a source of economic development.[3] This has been especially the case in the Midwest where high tech, whether in the form of rising new industries (e.g. semiconductors) or application of technological advances to traditional industries (e.g. robotics in the auto industry), has been touted as a possible solution to the region's economic decline.

Numerous studies have tried to define exactly what industries comprise the high tech sector so as to measure their actual contribution to the economy and employment. Taking a different point of departure, this paper surveys regional concentration of those skilled occupations—namely scientists, engineers, and technicians—who are often associated with America's fast growing technology-intensive industries. This approach offers a more comprehensive survey of innovative activity because it is not bound by somewhat arbitrary industry definitions but, rather, it measures innovative activity across all industries. And as a contribution toward regional policy decisions, this approach further gauges the region's development potential for technology-related industry. Highly skilled labor has been found to be an important and necessary condition for high tech industry growth. The talents represented by scientific and engineering occupations are attractive in the firm location decision, and they also provide the pool of entrepreneurs who can initiate highly innovative enterprises.

The paper is organized into three sections. The first section surveys regional concentration of scientists, engineers, and technicians (SET) and highlights the Seventh District (i.e. all of Iowa and major portions of Illinois, Indiana, Michigan, and Wisconsin) in comparison with other regions. Overall, the District's economy was found to support a below average proportion of these technical occupations but there is considerable variation between the states.

The second section takes into consideration the fact that urban areas tend to attract much of the nation's high tech activity because of agglomeration economies arising from a highly specialized labor force, highly organized networks of information, varied business consulting services, and specialized capital markets which can be found in many large cities and metro areas. Several metropolitan areas in the Seventh District are shown to support high concentrations of scientists, engineers, and technicians. These include very large metro areas such as Detroit, Chicago, and Indianapolis along with smaller metro areas such as Rockford, Ann Arbor, and Champaign-Urbana. More finely detailed occupational profiles for these areas help to focus on specific labor market strengths in local areas.

Data in the first two sections suggest that the District's occupational strengths are closely tied to its traditional industrial base of durable manufacturing industries. For example, the Seventh District economy supports a sizable engineering labor pool—especially metal, industrial, and mechanical engineers. This reflects the District's specialization in capital goods, metal fabrication and automotive products.

The final section analyzes the finding that the District's economy tends to support fewer SET personnel by examining employment across broad industry sectors—those being private industry, education, and federal government employers of scientists and engineers (SE). Interestingly enough, employment concentration of SE personnel in the District's private industry sector is very close but slightly below the national average. The near parity can be attributed to the strong continued presence of the Midwest's durable goods industries, especially capital goods and autos. However, the presence of these industries is not enough to offset weaker SE employment by the federal government and educational sectors. In the case of education, evidence suggests that Seventh District SE employment related to teaching is strong while research-related employment at the region's universities remains below par.

Private industry employment of SET personnel is further disaggregated into specific industries so as to throw light on the role of technology in the District's industrial economy. It is found that those private industries that are concentrated in the Seventh District tend to fall below the very highest echelons of technology intensity as measured by the proportion of scientists and engineeers comprising an industry's labor force. The top three technology intensive manufacturing industries—the aircraft, computer, and space vehicle-guided missile industries—are very poorly represented in the Seventh District.

This pattern is repeated for high tech services in the District including the computer and data processing industry along with commercial research, development, and testing labs. The District's under-representation in these high tech leaders is partly compensated for by strong District representation in the pharmaceutical and communication industries which are *bona fide* high tech by all definitions. Moreover, second tier technology-intensive industries, (i.e. those below the top ten), are well represented in the District. These industries include engines and turbines, construction and material handling machinery, paints and varnishes, office and accounting machines, soaps and cosmetics, and electrical machinery.

In viewing only those manufacturing industries that comprise the District's dominant industries—be they high tech or not, it was found that these industries are *more* technology intensive than their counterpart industries in the rest of the nation. In characterizing the District's economy, this suggests that the District concentrates on the upstream production activities of the "product cycle," specializing in highly skilled, R&D intensive manufacturing activities as opposed to routinized production operations. This finding is consistent with several research studies that have concluded that the Midwest does not tend to attract branch plants of manufacturing firms headquartered here or branch plants headquartered in other regions.[4] Instead, standardized production operations of the region's basic industries tend to be farmed out to lower cost regions of unskilled labor or overseas.

This finding raises an important policy implication for the Midwest. Unlike regions such as the South that are able to realize economic growth through the establishment of branch plants engaging in routinized production, the Midwest region will need to maintain and develop a technological edge in key industries in order to retain its traditional economic base. With regard to economic development, the policy implications point to the need for the District to promote a technology-oriented infrastructure that can aid its manufacturing industries in producing innovative products, in implementing technologically advanced processes, and in taking advantage of its highly skilled labor pool.

While this study finds that the District economy is oriented toward technology and skilled processes the District cannot, however, rely solely on its mainstay industries for robust economic growth. In many instances, demand for the region's traditional products will be insufficient to restore past economic prowess. Nor can the District focus solely on those regional policies that attempt to capture future national growth in those industries in the highest echelon of tech intensity. Those industries identified today as high tech, high growth in other regions—computers, aircraft, and advanced electronics—are by now firmly entrenched in their home regions so that Midwest growth will be limited by the agglomerative forces pulling these industries toward their region of origination, although subcenter growth in the Midwest can be significant. For these reasons, the District's development policy must also focus on fostering the much-touted entrepreneurial climate in the hopes that new or rejuvenated industries will arise to sustain the regional economy.

Regional concentration of SET personnel

To what extent are skilled occupations—namely scientists, engineers, and technicians (SET) who are associated with America's fast growing technology intensive industries—located in the District? A focus on occupational data has several advantages over the more commonly-used industrial employment data. Firstly, direct measurement of such industries themselves is difficult because the standard industrial classification system is often ill-suited to monitoring emerging industries. Assignment of a new product to a classification of industries created years ago can end up erroneously combining highly innovative industries with those mature industries producing standardized products. One recent study, for example, noted that the two largest robotics manufacturers were listed under different Department of Commerce Standard Industrial Classifications (Armington et al 1982). Because of such inevitable errors, measuring the extent of high tech activity in a region by summing up employment across selected industries that are deemed to be *high tech* can easily be misleading. Indeed, research and development are pursued to some degree across a wide spectrum of industries so that examination of only the *high tech* industry can easily misrepresent a region's innovative capacity. Occupational data can circumvent these problems by measuring high tech activity across all industries within a region. Those workers associated with innovative industrial activity will be measured and counted regardless of their firm's industrial classification. And while there are alternative measures, such as patent data (also hindered by data problems) to measure innovative activity, the skills of a region's labor force offer the further advantage in reflecting the predisposition of the region for further development of tech-related industry. Large and varied pools of scientists, engineers, and technicians serve specialized needs of tech-related industries both in innovation and in applying technological advances to industrial processes in mature industries. In addition, they also represent potential entrepreneurs who can spin off new industries and regenerate the economic base. Existing statistical evidence on the locational determinants of high tech activity suggests that skilled labor supply is an important and necessary condition for high tech growth (and one that can be influenced by public policy). In recent studies using establishment-level data, the rate of formation of new firms in high tech industries has been associated with these skilled labor attributes (Malecki 1985) (Armington et al 1982). Availability of skilled labor has also been cited as a dominant concern in the high tech firm's location decision (Joint Economic Committee 1982) (Rees and Stafford 1983).

The availability of engineering, scientific, and technical workers has been found to be especially important to those establishments that actually perform R&D and create prototypes in contrast to branch plants that engage in routinized production of innovative products (Howells 1984). Here, the product cycle model, as first suggested by Raymond Vernon (1966), becomes important in understanding the regional dispersion of those facilities and establishments that are often classified as *high tech*. Corporate headquarters establishments, branch manufacturing plants, and research facilities of high tech firms often differ in locational preferences. Furthermore, production facilities themselves differ in location preference by their stage of production as set forth in the product cycle model. Under this framework, products are first developed by highly skilled labor and produced in small volumes for a limited and often customized market. At these initial stages, production and development tend to locate near marketing offices, R&D laboratories, and corporate headquarters of multi-establishment corporations because close communication links from market to production site are crucial to successful product development and market introduction. In later stages, as the product market expands and the production method becomes routine, the firm has greater latitude to relocate the production site in search of lower operating costs. In the firm's location decision for production, then, the stage of production determines the type of facility required which, in turn, will be drawn to different types of labor force. In the context of location of facilities, branch plants tend to seek out locations where there is an abundancy of low wage and low skilled labor whereas those establishments housing the more recently-developed products and processes will gravitate toward locations of skilled labor and corporate headquarters.

These relationships have important implications for regional economic development policy. The Midwest, with its reputation for high wages and unionized skilled labor, would not prove to be attractive for branch plant location. In fact, recent empirical studies have shown that the Midwest retains relatively few branch plants in high tech industries, especially in relation to low cost, low skill regions such as the South (Armington et al) (Malecki 1985). In contrast, there seems to be little, if any, locational aversion on the part of both initial stage production facilities and R&D laboratories to areas of high wages and unionization because, for these facilities, routinized labor costs are secondary in importance to skilled labor availability and its related environment. (One recent study on high tech industries' spatial tendencies found that trade union organization and wage rate differences did not affect location; see Glasmeier et al). For this reason, it is more likely that the Midwest region's skilled labor pool imparts a comparative advantage in attracting, creating, and retaining those high tech facilities and industries concentrating in R&D and prototypes. If so, policies directed toward promoting research oriented products such as pharmaceuticals along with implementing technological advancements in traditional industries will merit much attention.

The importance of having a high-skilled labor pool to promote high tech industry has also focused attention on public policies to promote higher education in key technical areas. Here, the activities of both Stanford University and MIT in the 1940s and 1950s have furnished community development models that combine the buildup of an academic department's excellence (e.g. electrical engineering) and industry outreach programs (e.g; Stanford Industrial Park and Stanford Research Institute or SRI) in order to stimulate high tech economic growth. In the Stanford-Silicon Valley example, the venture capital community and heavy government defense spending were undoubtedly critical in stimulating the semiconductor industry in that area. However, the excellence of the electrical engineering department at Stanford in combination with the SRI was crucial in the beginnings of that region's high tech industry concentrations (Saxenian 1985). Universities such as Stanford and U.C.-Berkeley, as well as local technical schools in that region, have provided both skilled labor to existing firms and a stream of entrepreneurs who have founded new companies and even new industries.

While several Midwest universities such as the University of Michigan-Ann Arbor have maintained long-established programs of technology transfer, many public and private universities of research caliber face the daunting task of establishing similar industry-research programs some 30 or more years behind today's success stories. While their late start raises something of a hurdle, the large potential payoff has convinced many regions to make further investment in higher education as a development strategy. While the prospects for duplication of the Route 128 and Silicon Valley success in microelectronics, semiconductors, and computers are dim because of their head start, industrial development in the Midwest has left a legacy of renowned research programs that offer foundations on which to build other high tech industries such as robotics, pharmaceuticals, and telecommunications. Moreover, prospects for future growth of technology intensive industries in the U.S. are highly regarded so that the capture of only a small share of the high technology pie may be worth pursuing.

Scientific and engineering occupations by region

The National Science Foundation (NSF) surveys employed scientists and engineers by state and region on a biennial basis. While the NSF surveys include social scientists, these are excluded in the following tables because it is believed that large proportions of these professions are outside of relevant research fields. The NSF bases its survey on type and field of degree earned at college and graduate levels by employees and self-employed persons who work in administrative, teaching, quality control, product development, and pure research endeavors. Two categories are reported in the following tables, one being employed persons with doctoral degrees and the second being the more inclusive category of all employed scientists and engineers.

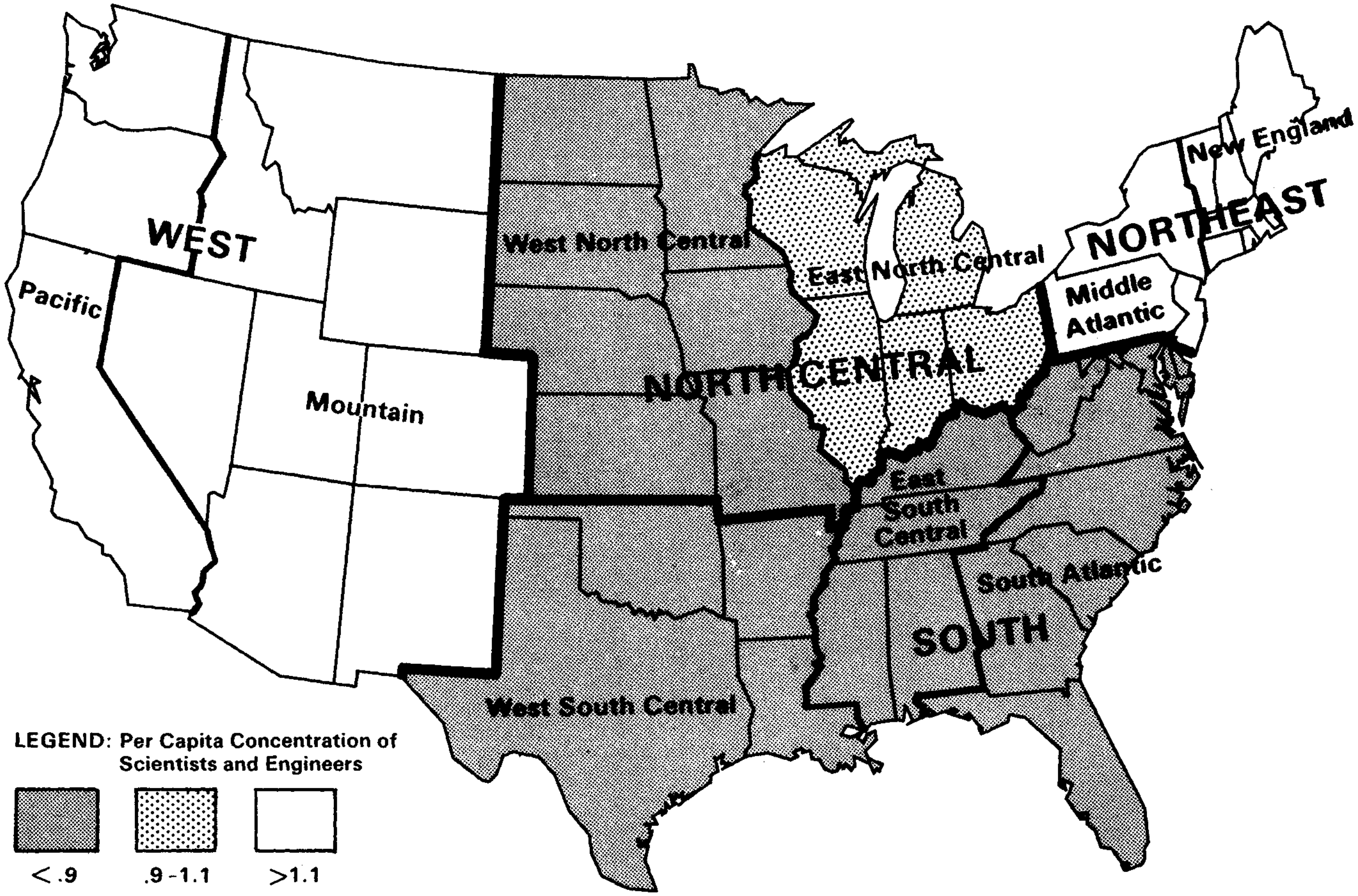
Throughout this study, reported concentrations of scientific, engineering, and technical personnel are summarized according to geographic area by taking employed persons per capita or employed persons per total labor force in the geographic area and dividing this measure by the identical measure for the U.S. as a whole. Such a measure, commonly known as a *location quotient,* will index to a value of one equality between a region and the nation in shares of SE per capita or total employment. The division of the nation into areas follows that of the Bureau of the Census with four large regions which are divided into a total of nine divisions. The Seventh District of the Federal Reserve System is added.

Employed scientists and engineers are distinctly concentrated (on a per capita basis) in the Northeast and West regions of the U.S. according to 1982 information from the National Science Foundation (Figure 1). Within the Northeast region, both the New England and Mid Atlantic divisions are strong, with the New England states dominating both the Northeast and the entire nation in concentration of all scientists and engineers as well as in doctoral scientists and engineers. New England ranks lower than only one of the nation's regions, the West, in any one category—that being doctoral engineers (Table 1). The Mid Atlantic states rank high relative to the nation in the overall SE category and especially high for doctoral engineers.

The West region's labor force employs an above average proportion of overall scientists and engineers and doctoral SE as well. Of the two divisions comprising the West Region, the Pacific Division in the West displays the greater concentration of overall SE while the Mountain division tends toward greater employment of SE at the doctoral level. Indeed, the latter has the highest concentration of doctoral engineers in the nation.

Among the remaining regions, only a division of the South region, the South Atlantic states, shows signs of significantly high strength by any of these measures, and here only among doctoral scientists and engineers. In this division, the large concentration of research labs in and around Washington D.C. helps to push the number of employed scientists and engineers above the nation's norm. Despite rapid employment growth in the remainder of the South in recent years, the overall region has not yet reached parity with the nation in SE personnel.

**Concentration of Employed Scientists and Engineers
Per Capita by Census Divisions**



NOTE: Alaska and Hawaii are also included in the Pacific Division.

Table 1
Concentration of Employed Scientists and Engineers by Region
(index based on population)

Region	All scientists and engineers 1982 Scientists	Engineers	Total	Doctoral scientists and engineers 1983 Scientists	Engineers	Total
Northeast						
-New England	1.49	1.40	1.44	1.43	1.26	1.39
-Mid Atlantic	1.20	1.06	1.12	.85	1.24	.94
Central						
-East North Central	.86	1.02	.96	.85	.80	.83
-Seventh District	**.78**	**.98**	**.91**	**.85**	**.69**	**.82**
-West North Central	.91	.80	.84	.90	.58	.83
South						
-South Atlantic	.93	.80	.87	1.10	.92	1.06
-East South Central	.65	.63	.64	.67	.57	.65
-West South Central	.84	.90	.87	.74	.82	.76
West						
-Mountain	1.14	1.03	1.08	1.22	1.45	1.27
-Pacific	1.16	1.38	1.29	1.07	1.37	1.14

NOTE: Concentration indices are measuring employed scientists and engineers per capita in relation to the U.S. so that, for example, a value of one indicates equal scientists and engineers per capita in both the region and the nation while a value of 1.10 indicates 10 percent greater scientists and engineers per capita in the region.

SOURCE: National Science Foundation.

Table 2
Concentration of Employed Scientists and Engineers
in Seventh District States
(index based on population)

	All levels of education 1982 Engineers	Scientists	Scientists and Engineers	Doctoral scientists and engineers 1983 Engineers	Scientists	Scientists and Engineers
Illinois	.95	.97	.96	.84	.89	.88
Indiana	.79	.72	.76	.63	.84	.80
Iowa	.68	.74	.71	.38	.85	.74
Michigan	1.17	.76	1.00	.74	.82	.80
Wisconsin	.91	.85	.89	.52	.82	.76
Seventh District	.95	.84	.91	.69	.85	.82

SOURCE: National Science Foundation.

Within the Central region, occupational concentration is near but below the national average for overall SE but it is slightly above average for overall engineers in the East North Central Division. In contrast, the region is markedly below average in employment of both doctoral scientists and engineers. The above average engineering employment concentration in the East North Central division can be attributed to the area's specialization in mature durable goods manufacturing industries such as autos, steel, capital goods, and metal fabrication.

The Seventh District

The labor force occupational structure of the Seventh District follows a similar pattern to the Central region; overall scientists and engineers in the District comprise a lesser share of total population than they do in the nation with doctoral categories especially below average. Overall engineering employment approaches the national average and it is clearly more concentrated than scientific occupations (Table 2). The State of Michigan employs a 17 percent greater share of engineers than the national average while Illinois and Wisconsin fall less than 10 percent below the nation on a population-weighted basis. Illinois leads among Seventh District states in concentration of employed scientists at 97 percent of the national average in 1982 and also in doctoral scientists with 89 percent. Illinois and Michigan concentrations lie close to the national average in overall SE concentration, Wisconsin is close to the 90 percent mark, and Indiana and Iowa lie closer to three-quarters of the national average.

Urban areas and SET personnel

Urban areas are attractive locales for both high tech industries and for high tech activities such as research and development. Many notable high tech locations in the U.S. such as the Route 128, The Research Triangle, and the Silicon Valley areas are found near top universities and are encompassed by metropolitan areas (although high tech activity itself is usually far-removed from central city areas of metro areas e.g., Boston, San Jose, Chicago, Raleigh-Durham, and New York City). This metro area locational tendency rings true for R&D lab activity. In a study of the trends in industrial R&D lab location in the U.S., Edward Malecki found that the top ten SMSAs contained 52.4 percent and the top twenty accounted for 64.9 percent of the nation's industrial R&D labs in 1975. These locations respectively accounted for only 28.7 and 38.4 percent of U.S. population. In addition, one recent tabulation reported that only 10 percent of *high growth high technology* firms were located in nonmetro areas (O'Connor 1986).

The tendency of high tech firms and research activities to locate in urban areas reflects two broad sets of location factors. These factors are often referred to as *economies of agglomeration* such that some dimension relating to either greater industry concentration or to larger city size tends to lower firm costs over a wide range. One set of these factors associated with large city size—such as access to specialized business and legal services—is often referred to as *urbanization economies*. In large cities, the product demands for specialized legal and business services reach a sufficient size where they can be supplied at reasonable prices. Several industries may rely on such a particular service as air transport shipping or temporary clerical help services which are widely available in urban areas.

Urbanization economies also arise from the spillover benefits of proximity to other industries or activities. R&D facilities of multi-plant firms are often located near corporate headquarters which themselves tend to locate in large urban areas. In addition, major research universities in urban areas often provide needed skilled laborers for established firms and they can also be a source of entrepreneurs—either professors or students—to start up new companies.

A second set of economies giving rise to the concentrated presence of high tech activity in particular urban areas can be attributed to the concept of *localization economies* through which high tech firms benefit from proximity to each other (Malecki 1981)(Oakey 1984). Localization economies are scale economies that are realized external to the firm but internal to the industry when similarly engaged firms and activities locate in close proximity (Mills 1980). A classic example is the clustering of retail firms (such as restaurants or apparel stores) in order to capture customer convenience in the shopping selection process. Of closer relevance to manufacturing, firms may tend to locate close to suppliers to economize on transportation costs of intermediate inputs or to facilitate *just in time* delivery. In addition, the clustering of firms can better sustain a labor force of specialized labor skill when individual firm needs are cyclical, seasonal, or highly variable. Under such conditions of variable labor demand by single firms, overall labor demand will be smoothed out over large numbers of firms so that wages paid for specialized skills can be lower than wages required to employ laborers on a seasonal basis or to bring in occasional labor from outside the immediate area.

The agglomeration theory as it relates to high tech activity deviates somewhat from its more familiar applications to manufacturing in that supplier linkages and proximity to customers are not as critical. What is critical is access to organized skilled labor pools and information networks between colleagues that spawn new ideas. Availability of a skilled and specialized labor force is important to both traditional and *high tech* manufacturing, but to many high tech industries, it is paramount. One reason for its importance in forming an agglomeration economy is that large pools of skilled labor allow for the cross fertilization of ideas and innovative ventures that spur economic growth (Thompson 1965). A firm in a highly competitive and technologically changing industry can hardly afford to locate outside such a locus of activity. Perhaps on a very large scale even a single large facility or dominant firm (e.g. IBM) may achieve similar results, making the latter situation more significant for emerging firms and those smaller firms in industries where internal scale economies are quickly exhausted.

Agglomeration economies can also be achieved by firms looking to serve their highly specialized and rapidly fluctuating labor needs from very large and organized labor pools (Oakey 1981). With a few exceptions, such labor pools can only be sustained in large concentrations. With access to a large labor pool, firms can expand their work force rapidly when necessary and cheaply search out specialized skills. From the skilled worker's perspective, agglomeration is beneficial because relocation may not be necessary over long distances if the worker is terminated or wishes to change companies.

Empirical studies on the location of high tech firms have shown that urban areas tend to be seedbeds of high tech activity, especially for those firms at the nascent stage who benefit from accessibility to needed factors of production arising from agglomeration economies. These advantages allow the small firm to contract for small bundles of skilled labor, to cheaply gather information from the presence of other high tech firms which can also serve as models in entrepreneurship, and to access specialized business support and consulting services. The importance of proximity to other firms and to critical local resources was underscored by a study done by Raymond Oakey, (1984). In studying the growth of small firms in England, the author found that small firm employment growth was linked to higher levels of product innovation which, in turn, was found to be stronger in prosperous regions as opposed to peripheral development regions which suffered from a poorer local resource environment (i.e. the absence of agglomeration economies).

Other studies of location have focused on R&D facilities themselves rather than establishments of firms included under *high tech* industry definitions. These studies are important because they remind us that *high tech* industries are not alone in engaging in innovation and R&D. High tech industry can be defined by type of activity rather than by grouping all establishments into an industry engaged in a single product line. Studies focusing on only a top ranking of industries by tech intensity overlook the fact that many cities are concentrations of R&D facilities that serve traditional and mature industries. For example, in studying R&D lab locations in private industry Edward Malecki (1981) has observed that Detroit and Cleveland concentrate in R&D laboratories in the automotive industry, Boston and San Francisco specialize in electronics, and Chicago leads the nation in the food industry. To a large extent, these R&D lab specializations reflect regional industry specialization and the close linkages between production activities and R&D labs, and between corporate headquarters and their R&D auxiliary facilities. Studies in both the U.K (Howells 1984) and in the U.S. (Malecki 1979) have cited the attraction of locating R&D laboratory sites at or in close proximity to corporate headquarters. For many industries, communication links between corporate marketing and planning operations lead many large multi-establishment corporations to locate R&D labs at or within close proximity to corporate headquarters while headquarters, in turn, concentrate in urban areas for many of the same reasons as high tech firms—availability of skilled labor and access to specialized services.

A few large metropolitan areas have also been cited as more general centers of R&D lab location (Malecki 1979, 1981). Of the ten industries associated with the labs under study, at least three of them tended to be concentrated in the Los Angeles, New York, Chicago, Philadelphia, and San Francisco metropolitan areas. Los Angeles and New York were considered as domiciles of more than five industries including such high tech notables as aerospace, electronics, and scientific instruments.

Concentration of high tech activities in urban areas has been, in many instances, reinforced and propelled by spin-offs from university research and especially large high tech firms; the Silicon Valley area is archetypical of the latter. Government research centers have, so far, proven to be attractive for subcontracting firms but they have not been generally observed to stimulate private high tech industries of comparable importance, at least in the U.S. (Sirbu 1976) (Malecki 1982). However, in some studies, government labs linked with universities have been found to generate substantial spin-off activity. One study reports that 50 firms or more evolved from technology development at MIT's Lincoln Lab (Roberts and Wainer 1968). Spin-off success has also been reported from The University of Michigan's Willow Run Laboratories which were set up in 1946 to conduct defense-related research. Seventeen companies are reported to have spun off of its activities (Evaldson 1970) (Krzyzowski et al 1982). In the United Kingdom, the reverse finding has been reported. Government research centers have been reported as important catalysts to high tech growth while university-industry relations are reported to be quite rare in comparison (Oakey 1984).

SET personnel in Seventh District metro areas

The Seventh District population resides in SMSAs in similar proportion to the U.S.—with 76.7 percent of District population in SMSAs in comparison to 76.0 percent in the U.S. for 1983. The cities of Chicago and Detroit comprise two of the ten largest U.S. cities and, with Milwaukee and Indianapolis, four of the top twenty.

Occupational data on the SMSAs in the District are available from the 1980 Census of Population for those SMSAs over 250,000 residents.[5] In contrast to the NSF survey, the Census labor force measure, SET, includes such technical workers as computer programers, engineering, and science technicians. These occupational data cover scientific, engineering, and technical professions without discerning individuals' level of formal education. Occupational data from the Census also differ from the NSF data in that they tend to exclude those scientists and engineers in teaching professions.[6] While this feature helps to focus on concentrations of research and innovative activity *per se,* at the same time, it neglects the activity and potential activity of teaching scientists in research and consulting.

It is found that no state in the Seventh District is without a major location of labor concentration in SET fields and most states contain several such metro areas (Table 3).[7] The District's largest metro areas, Chicago and Detroit, both had above average concentrations of SET occupations in 1980. Chicago's SET labor force concentration was above average in both science and engineering, and Detroit's strength is its 25 percent greater concentration in engineering. Many of these engineers work in the auto industry's corporate headquarters and product design facilities in Southeastern Michigan which have remained there despite the geographical dispersion of auto production facilities in recent years.

Several smaller SMSAs in the District can also claim an above average engineering labor force which can be traced to the region's dominance in machinery, consumer durables, and metal fabrication. Peoria, Rockford, Flint, Davenport, the Quad Cities area, and Fort Wayne fit the pattern of strong engineering concentration and weaker scientific labor force. Among mid-sized cities, Milwaukee's labor force also fits this pattern. Indianapolis diverges from the pattern as it is strong in both engineers and in scientists—the latter being principally life scientists associated with the pharmaceutical industry.

Table 3
Concentration of Scientific, Engineering and Technical Occupations in Seventh District SMSAs—1980 (index based on total employment)

	Scientists, Engineers and Technicians	Engineers	Scientists	Technicians
Illinois	.93	.97	.90	.91
-Chicago	1.06	1.08	1.07	1.02
-Peoria	1.11	1.48	.94	.81
-Rockford	1.10	1.67	.34	.92
Indiana	.85	.94	.67	.87
-Fort Wayne	1.06	1.36	.67	.94
-Gary/Hammond	.86	.92	.63	.94
-Indianapolis	1.10	1.07	1.18	1.08
-South Bend	.84	.90	.72	.84
Iowa	.64	.62	.56	.71
-Davenport/Rock Island Moline(IA-IL)	.96	1.14	.94	.78
-Des Moines	.72	.46	.99	.85
Michigan	1.03	1.29	.85	.85
-Ann Arbor	1.87	1.89	2.22	1.66
-Detroit	1.24	1.68	.93	.92
-Flint	.73	1.09	.42	.52
-Grand Rapids	.74	.98	.45	.66
-Kalamazoo/Portage	.93	.67	1.03	1.15
-Lansing/E. Lansing	.95	.72	1.17	1.07
Wisconsin	.78	.77	.67	.87
-Appleton/Oshkosh	.79	.75	.55	.99
-Madison	1.34	.70	1.95	1.69
-Milwaukee	.98	1.12	.75	.95
Benchmark SMSAs				
-Boston, MA	1.51	1.51	1.65	1.42
-Raleigh/Durham NC	1.73	1.39	2.07	1.91
-San Jose, CA	3.15	3.79	2.18	3.03

NOTE: Engineers excludes civil engineers; technicians excludes draftsmen.
SOURCE: U.S. Bureau of Census, *1980 Census of Population.*

Table 4
Detailed SET Occupations In Selected Seventh District SMSAs—1980
(index based on total employment)

	Chicago	Detroit	Ann Arbor	India-napolis	Des Moines	Milwaukee	Madison
Engineers	1.06	1.54	1.86	1.03	.52	1.07	.81
-Aerospace	.06	.15	.35	.71	0	.05	.07
-Metal	1.17	2.24	2.42	1.24	0	1.65	.29
-Mining	.16	.11	0	.26	0	.17	0
-Petroleum	.15	.05	.07	.07	0	0	0
-Chemical	1.21	.85	.97	.82	.54	.31	.32
-Nuclear	.71	.35	2.23	.16	0	0	0
-Civil	.95	.70	1.65	.77	.86	.70	1.41
-Agricultural	2.21	1.62	1.86	.77	5.94	3.57	1.80
-Electrical	1.20	.70	1.31	1.07	.47	1.00	.70
-Industrial	1.14	1.59	1.23	1.28	.52	2.00	.76
-Mechanical	1.32	5.32	4.63	1.53	.46	1.55	.65
-Marine	.17	.60	.57	.21	0	.05	.22
-NEC	1.20	1.16	2.03	.93	.60	1.02	1.20
Math & Computer Science	1.23	1.28	2.18	1.17	1.40	.99	1.26
-Computer Systems	1.28	1.26	2.44	1.12	1.47	1.10	1.45
-Operations & Systems	1.06	1.58	.57	1.13	.70	.85	.85
-Actuaries	2.13	.66	1.86	2.63	4.09	1.47	1.47
-Statisticians	1.31	1.14	5.03	1.21	2.21	.65	.72
-NEC	.17	.04	1.32	.75	0	.31	2.46
Natural Scientists	.90	.57	2.20	1.18	.55	.50	2.69
-Physicists & Astronomers	1.14	.28	3.85	.60	0	.13	2.04
-Chemists	1.47	1.02	2.42	1.74	.62	.64	1.64
-Atmospheric, Space	.97	.61	.64	.49	1.40	.56	5.02
-Geologists	.19	.06	.62	.32	.24	.08	1.07
-Physical NEC	.85	.54	4.02	.92	1.29	.26	2.57
-Agriclutural & Food	.61	.28	.89	.68	.95	.74	4.77
-Biological & Life	.86	.57	3.56	1.63	.77	.51	6.62
-Forestry & Conservation	.16	.18	.81	.32	.28	.37	.81
-Medical Science	1.00	.88	3.65	2.40	.38	1.09	3.79
Electric and Electronic Technicians	.92	.71	1.06	1.04	.60	1.01	.91
Industrial Engineer Technicians	.73	1.09	.59	1.06	1.46	.88	0
Mechanical Technicians	.55	4.87	3.41	2.70	.11	1.25	.61
Eng. Technicians (NEC)	.89	1.05	1.32	.92	.75	.86	2.19
Science Technicians	.91	.61	1.63	1.54	.68	.83	1.54
-Biology	1.03	.46	1.51	4.17	1.56	1.23	2.60
-Chemical	1.02	.74	1.32	.86	.10	.45	1.18
-Science NEC	.73	.56	2.01	.60	.73	.97	1.26
Computer Programmers	1.30	.97	2.40	.90	1.26	1.03	2.11

SOURCE: Bureau of the Census, *1980 Census of Population.*

Some smaller SMSAs in the District that host major research universities have high proportions of scientists and engineers. (Again, postsecondary teachers in these fields are excluded.) Ann Arbor's share of both scientists and engineers surpassed such high tech meccas as Boston and Raleigh-Durham in 1980 while its proportion of scientists even surpassed the San Jose- "Silicon Valley" SMSA. Similarly, the high tech labor force in Madison was very strong in scientific fields—especially the natural sciences (although engineering was not so strong). Occupational information on Champaign-Urbana SMSA, home of Illinois' major public university, was not available because of its smaller size. This is unfortunate because of its long-standing role and recent rise as a world center in computer sciences.[8] Many technology intensive industries are reported to have located there.

Despite their technology intensive economies, it must be noted that these university-related District communities make up only 3.5 percent of their state's population and, except for Ann Arbor, they are geographically isolated from major population centers. This geographic separation reduces agglomeration economies and hinders the university's ability to act as a catalyst to emerging industries and to spinning off new ventures from faculty, student, and faculty-student initiatives.

While the occupational data from the 1980 Census are becoming out of date, their fine level of detail is unsurpassed in identifying labor force concentrations at the metropolitan area level (Table 4). These data are no more than suggestive but they throw some light on the region's areas of comparative advantage and often contradict some common perceptions about a specific area. For example, despite the Chicago area's reputed concentration in medical research and pharmaceuticals, labor force concentration in the natural sciences—especially the life sciences of biology and medicine—was not particularly evident in 1980. Computer programming and math sciences, however, were surprisingly strong in Chicago and in many other of the District's urban areas. The finding that Chicago supports a large computer science labor force is consistent with a recent study by Edward Malecki who reports that Illinois is a seedbed for computer programming firms (1985). Detroit, as well, has a strong computer-related labor force along with its strength in mechanical and metal engineering. The Des Moines economy can be characterized by its dearth of employed engineers and by its strength in mathematical scientists. Many of the latter were reported to work in the insurance industry in 1980.

Urban concentration and Midwest development policy

The fact that the Seventh District region contains several large metro areas and many other medium sized metro areas with visible concentrations of scientific and/or engineering personnel would seem to augur well for the region's future economic outlook. However, optimism in this regard should be tempered by the fact that many of the industries supporting research related activities in Midwestern cities—such as autos, farm machinery, and machine tools—have been declining in recent years. As demand for these industry products decline, agglomeration economies involving related innovative activities will be of limited help in preserving jobs and income. Moreover, nothing in the economic literature suggests that the labor pool legacy of these declining industries, both skilled or otherwise, can be easily converted to suit the needs of the nation's emerging industries.

In fact, given the extent to which agglomeration is important to emerging high tech industries such as biotechnology and microcomputers, some analysts feel that existing high tech locales will continue to flourish in their established fields of industry specialization (Hall, Markusen 1986), and thus it is unlikely that older manufacturing cities will garner much activity. Industry studies of renowned high tech industries often reveal region-specific and area-specific agglomerations of firms. In studying the emerging biotechnology industry, Marshall Feldman reports that 50 percent of these firms have located in California and Massachusetts. And within California, 50 percent of biotech firms are located in the San-Francisco-Oakland area (1985). Similarly, the semiconductor and microcomputer industries have continued to concentrate in the Northeast and in California. Even though the computer software industry is becoming decentralized, the decentralization is reported to largely involve sales and service branches while product development remains in established areas (Hall et al 1985). If the attractions of established locales are so strong, like the agglomerative forces of Detroit to the auto industry in years past, can older cities in the Midwest hope to replicate the experience of Route 128 and Silicon Valley?

Positive prospects arise from the fact that new industries continue to emerge under the definitions of high tech. Even though many Midwestern urban areas were bypassed by the recent wave of high tech growth, they may yet become the future location of some budding industries such as robotics. Currently, the East North Central Division is at the forefront of robotics production with 40 percent of the firms reported there (Delphi Study 1985). An evolutionary perspective on high tech development suggests that Midwest policymakers begin to position the region for a transition to new industries.

In considering any development policy, high tech or otherwise, benefits must be weighed by probabilities of payoff and also be compared to costs. Observations to date suggest that it is unlikely that existing focal points of identifiable high tech industries can easily be diverted. Public policies to do so have been a dismal failure in the U.K., and the odds are against such a policy in the U.S. Still, some past experience in the U.S. can suggest conditions where nascent high tech development is more likely to flourish. First, a strong university research institution (and possibly a government research institute) along with an industry outreach program or research park have been shown to be successful models for development in the U.S. Especially for those regions or metro areas that already contain strong research universities, the incremental costs of industry outreach are not large, although the gestation period for such ventures are often very long—at least five years and frequently much longer.

Second, high tech agglomerations require a skilled labor force. In this case, those large urban areas with existing scientific and engineering labor force concentrations have a leg up on other areas. Such areas frequently have already established an amenable environment in which to recruit and maintain innovative personnel. The incremental costs of policies to promote entrepreneurship, to ease access to business-educational services, and to ease information and capital flows would not be insurmountable for such areas.

Policies focusing on entrepreneurship and capital markets are probably most important for such promising urban areas because of agglomerative forces favoring established tech oriented locales. Long before the recent wave of high tech notoriety, some urban analysts asserted that the viability of urban areas sprang from their ability to continually regenerate their economic base through entrepreneurship rather than from inherent factor cost or locational advantages:

> "The economic base of the larger metropolitan area is, then, the creativity of its universities and research parks, the sophistication of its engineering firms and financial institutions, the persuasiveness of its public relations and advertising agencies, the flexibility of its transportation networks, and all other dimensions of infrastructure that facilitate the quick and orderly transfer from old dying bases to new growing ones.
>
> Whatever may be the prime source of national economic development, entrepreneurship must be the heart of comparative regional growth in any system of open regions. The large urban area would seem to have a great advantage in the critical functions of invention, innovation, promotion, and rationalization of the new."[9]

Finally, given agglomeration economies already possessed by Midwestern metro areas, they can expect to create or capture those high tech firms who eventually find it desirable to locate close to the Midwest as their markets and industries mature. Several prominent theories of U.S. regional growth have depicted the long term growth process of the West and Southwest as resulting from these regions first serving as a hinterland to the Midwest and Northeast, supplying agriculture and raw materials to an industrial heartland in exchange for manufactured goods (Norton, Rees 1979)(Mieszkowski 1980). Gradually, as hinterland areas grew and reached a critical mass or density, scale economies were reached so that imports of manufactured goods could be increasingly replaced with local products. Through this process, these regions could support their own manufacturing base. From this base industries in these regions were able to bring about and eventually overtake the Midwest in some areas of innovative industrialization. In a parallel fashion, while the West and New England have come to capture the lead in industrialization through this process, much of their market remains in the Midwest. As the markets for high tech products originating in home areas expand, some production can be expected to spill over to Midwestern markets to facilitate transport cost savings, to facilitate face-to-face contact with customers, and to lower industry production costs as own-region factor costs rise with congestion. For example, software related to airlines reservation systems has reportedly stimulated a fledgling software industry in the Dallas metro area. Similar opportunities may arise from biotech applications to Midwest agriculture.[10] As similar events unfold in other industries, the Midwest economy should be ready to establish regional centers from these expansion opportunities.

Accounting for District occupational profile: a sectoral approach

Compared to the nation, the Seventh District's share of labor force employed in science and engineering is approximately 9 percent below average, and it is 18 percent below average in corresponding doctoral scientists and engineers. While this does not characterize the District as second-rate in high-skill labor force, the differences are substantial enough to provoke interest in the characteristics of a region that maintains above-average per capita incomes apparently without today's much-touted technological edge.

The District's ability to employ scientists, engineers, and technicians can be understood by viewing the major employment sectors of scientific and engineering occupations. In total, the private industry, education, and federal government sectors employed 89 percent of total scientists and engineers in 1983 (Table 5). Private industry alone accounted for over two-thirds of all scientists and engineers. For doctoral scientists and engineers, education commanded the majority with a 50 percent share in 1983.

Table 5
Employed Scientists and Engineers in U.S. by Industry*
(and percent of total)—1983

	Total Scientists and Engineers				
	Total	Business/ Industry	Educational Institutions	Federal Government	Other
Scientists	1,135.2 (100.0)	626.8 (55.2)	240.7 (21.2)	140.4 (12.4)	127.3 (11.2)
Engineers	1,940.0 (100.0)	1,548.1 (79.8)	53.0 (2.7)	138.7 (7.1)	200.2 (10.3)
Scientists and Engineers	3,075.2 (100.0)	2,174.9 (70.7)	293.7 (9.6)	279.1 (9.1)	327.5 (10.6)

	Doctoral Scientists and Engineers				
	Total	Business/ Industry	Educational Institutions	Federal Government	Other
Scientists	201.9 (100.0)	59.2 (29.3)	110.7 (54.8)	19.1 (9.5)	25.6 (12.7)
Engineers	61.5 (100.0)	34.5 (56.1)	20.3 (33.0)	3.8 (6.2)	2.9 (4.7)
Scientists and Engineers	263.4 (100.0)	93.7 (35.6)	131.0 (49.7)	22.9 (8.7)	28.5 (10.8)

*Excludes social scientists and psychologists.
SOURCE: NSF 85-302.

Table 6
Concentration of Employed Scientists and Engineers in the private industry sector* in the Seventh District States—1980
(index based on population)

	Engineers		Scientists		Engineers & Scientists	
	Business/ Industry	Manufac- turing	Business/ Industry	Manufac- turing	Business/ Industry	Manufac- turing
Illinois	1.02	1.03	1.02	1.04	1.02	1.04
Indiana	.89	1.19	.73	1.04	.87	1.14
Iowa	.66	.78	.51	.44	.62	.73
Michigan	.78	1.53	.79	1.18	1.10	1.51
Wisconsin	.78	1.0	.68	.74	.76	.96
Seventh District	.98	1.12	.85	1.04	.95	1.12

*Excludes hospitals, education, and government.

SOURCE: U.S. Bureau of the Census, *1980 Census of Population.*

The slightly subpar record of the Seventh District can be explained by the strength or weakness of these three sectors in employing scientists and engineers. Employment in the education sector is slightly weak in the District, owing not to education itself but more to lower levels of university related research activities. The private industry sector is generally strong due to the many durable goods industries centered in the Midwest even though it is weak in the smaller set of manufacturing industries that comprises the highest echelon of technology industries. Finally, the District's federal government employment of scientists and engineers is notably weak, consistent with the region's record of receiving a low federal funds return in relation to its federal tax originations.

Industry employment of SET

The private industry sector of the Seventh District, which excludes education, government, and not-for-profit establishments, holds its own in supporting scientific and engineering personnel. Although, on average, the District's industries are less skill intensive than their national counterparts, the greater relative size of the District's private industry economy—especially durable goods manufacturing—lifts per capita private industry SE personnel to approximately par with the nation. As Table 6 shows, the Seventh Districts's SE concentration in private industry is .95, only 5 percent below the national average. This near parity with the nation is attributable to the District's SE strength in manufacturing. Its manufacturing sector employs 12 percent more engineers and 4 percent more scientists than the nation's manufacturing sector. All Seventh District states, except Iowa, have a near or above average SE concentration in manufacturing, especially with regards to engineers.

A more disaggregated account of SE personnel intensity by individual industry reveals much about the District's economy. Table 7 provides a list of the top 20 high tech manufacturing industries in the U.S. (as measured by intensity of SE and SET employment) along with corresponding District regional concentration indexes.[11] This table identifies industries that are nationally dominant in SE and SET employment and whether or not these industries are concentrated in the District in comparison to the nation. Among the noteworthy industries on the list are several that are not often associated with high tech industries but are usually categorized under "traditional" or "mature" industry labels. These include the engines and turbines industry and the construction and material handling machines industry. This finding suggests that the separation between high tech and traditional industries is blurred and that traditional industries should not be discounted from those contributing to high tech activity.

Table 7
The Top Twenty High Tech Manufacturing Industries in the U.S. and the Seventh District SET Labor Force Content and Employment Concentration

Industry	Percent of Labor Force Scientists and Engineers U.S.	District	Difference District minus U.S.	Regional Concentration Index 1984
Guided Missiles, Space Vehicles, and Parts	29.2	12.7	-16.5	.03
Electronics Computing Equip.	15.4	14.6	- .8	.10
Aircraft and Parts	14.1	9.2	- 4.8	.40
Radio, T.V. and Communication Equipment	10.5	8.3	- 2.1	1.16
Photograhic Equipment and Supplies	10.2	4.9	- 5.3	.40
Industrial and Miscellaneous Chemicals	9.3	8.9	- .4	.84
Scientific and Controlling Instruments	9.2	7.0	- 2.2	.94
Drugs	9.1	10.5	+ 1.4	1.58
Office and Accounting Machines	9.0	3.0	- 6.0	1.08
Ordnance	8.0	4.7	- 3.4	.29
Not Specified Elec. Machinery & Supplies	8.0	7.0	- .9	n.a.
Petroleum Refining	7.9	8.3	+ .4	.57
Electrical Machinery, Equip., Supplies n.e.c.	7.4	5.5	- 1.9	1.08
Engines and Turbines	7.0	5.4	- 1.6	3.55
Agricultural Chemicals	6.3	4.2	- 2.1	.92
Paints, Varnishes, and Related Products	5.3	5.8	+ .6	1.69
Plastics, Synthetics, and Resins	5.1	3.6	- 1.5	.42
Optical and Health Services Supplies	5.0	5.6	+ .6	.69
Construction and Material Handling Machines	5.0	5.8	+ .8	2.29
Soaps and Cosmetics	4.9	4.0	- .9	1.15

Industry	Percent of Labor Force Scientists, Engineers and Technicans U.S.	District	Difference District minus U.S.	Regional Concentration Index* 1984
Guided Missiles, Space Vehicles, and Parts	35.4	17.8	-17.6	.03
Electronics Computing Equip.	26.4	23.3	- 3.1	.10
Aircraft and Parts	17.3	12.3	- 5.0	.40
Radio, T.V. and Communication Equipment	16.2	12.9	- 3.3	1.16
Drugs	16.1	19.7	+ 3.5	1.58
Industrial and Miscellaneous Chemicals	15.4	14.5	- .9	.84
Photographic Equipment and Supplies	15.3	7.6	- 7.7	.40
Scientific and Controlling Instruments	14.3	10.6	- 3.7	.94
Not Specified Elec. Machinery & Supplies	14.1	11.0	- 3.1	n.a.
Office Accounting Machines	13.5	3.9	- 9.6	1.08
Petroleum Refining	12.6	12.8	+ .2	.57
Electrical Machinery, Equip., Supplies n.e.c.	11.9	8.2	- 3.7	1.08
Paints, Varnishes, and Related Products	11.3	12.3	+ 1.0	1.69
Ordnance	10.7	6.3	- 4.5	.29
Agricultural Chemicals	10.7	8.1	- 2.6	.99
Plastics, Synthetics, and Resins	9.6	7.2	- 2.4	.42
Engines and Turbines	8.8	6.8	- 2.0	3.55
Optical and Health Services Supplies	8.7	9.2	+ .5	.69
Soaps and Cosmetics	8.0	6.8	- 1.2	1.15
Construction and Material Handling Machines	6.3	7.1	+ .8	2.29

*Concentration indices are measuring area industry employment as a percent of total area employment relative to the U.S. Thus a value of 1 indicates that industry employment as a percent of total employment in the area and the nation are equal.

SOURCE: U.S. Bureau of the Census, *1980 Census of Population; and* Bureau of Labor Statistics, (E.S. 202).

District employment concentration in those national manufacturing industries that are the major employers of SET personnel is notably weak at the top end of the spectrum where a tight grouping of industries displays pronounced concentrations of SET personnel (Table 7). Among those are the guided missile and space industry, electronic computing equipment, and the aircraft industry. The reason for their weak representation in the District is that these industries have tended to cluster outside the District in such regions as New England, the West Coast, and the Southwest. Only three of the top ten employers of SET personnel—drugs, communication equipment, and office-accounting machines—are relatively concentrated in the Seventh District, using employment as a measure.

Examination of high tech activity at the overall regional level can hide specific strengths in individual locations below the regional scale. For example, even though overall employment in the Seventh District is not highly concentrated in those aforementioned industries that employ the highest percentage of SET, there are states within the District with an established industrial base in several high tech industries (Table 8). Indiana and Illinois stand out with particular strengths in eight of the top twenty high tech industries listed so that these states greatly contribute, for example, to the District's above average concentration in the radio, T.V., and communication equipment industry and the pharmaceuticals industry. These latter two industries rank fourth and fifth on the national scale by SET employment intensity. In the pharmaceuticals industry, Michigan also greatly contributes to the region's high employment concentration. There are other state-specific high tech strengths that belie the District averages. For example, Indiana is particularly concentrated in the aircraft and related parts industry.

Although manufacturing employs most of the SET employed by private industry in the District, the services sector also has several industries such as computer data processing and R&D labs that employ a significant proportion of SET. In examining high tech services (similarly identified by SET employment), the District overall does not display notably high employment concentrations and neither do most of the individual District states (Table 9). There are, however, two exceptions: Illinois is quite strong in R&D lab employment with a concentration index of 1.2. The Chicago area was reported to contain 88 percent of industrial R&D labs in Illinois in 1985 (Giese and Testa 1986). Meanwhile, Michigan has a strong engineering, architecture, and surveying service sector.

Within the second tier of manufacturing industries that intensively employ SET personnel, District employment concentration is somewhat higher. Several prominent industries in the District require extensive research, development, and design functions performed by skilled professionals. These

Table 8
Concentration of Top Twenty High Tech Manufacturing Industries in Seventh District States

Industry	Percent of Labor Force Scientists, Engineers and Technicans	Index of Employment Concentration Relative to the U.S.—1984					
		District	Illinois	Indiana	Iowa	Michigan	Wisconsin
Guided Missiles, Space Vehicles, and Parts	35.4	.03					
Electronics Computing Equipment	26.4	.10					
Aircraft and Parts	17.3	.40		1.4			
Radio, T.V. and Communication Equipment	16.2	1.16	1.7	2.2	1.1		
Drugs	16.1	1.58	1.3	4.0		2.8	
Industrial and Miscellaneous Chemicals	15.4	.84					
Photographic Equipment and Supplies	15.3	.40					
Scientific and Controlling	14.3	.94	1.1			1.2	
Not Specified Elec. Machinery & Supplies	14.1	n.a.**					
Office Accounting Machines	13.5	1.08	1.5			1.9	
Petroleum Refining	12.6	.57					
Electrical Machinery, Equip., Supplies n.e.c.	11.9	1.08		1.9			1.6
Paints, Varnishes, and Related Products	11.3	1.69	2.4	1.2		1.7	
Ordnance	10.7	.29		1.1			
Agricultural Chemicals	10.7	.99		1.5	2.9		
Plastics, Synthetics, and Resins	9.6	.42					
Engines and Turbines	8.8	3.55	2.0	4.2		3.2	9.0
Optical and Health Services Supplies	8.7	.69					
Soaps and Cosmetics	8.0	1.15	1.6				1.3
Construction and Material Handling Machines	6.3	2.29	3.0		4.6	1.1	2.3

*A concentration index of greater than 1 indicates that the state has a greater percentage of employment in that industry than the U.S. average. Only those industry concentrations that are greater than the U.S. in District states are shown.

**These figures are unavailable.

SOURCE: U.S. Bureau of the Census, *1980 Census of Population;* and Bureau of Labor Statistics, (E.S. 202).

Table 9
SET Labor Force Content In Selected Service Industries in the U.S. and the Seventh District—SET Labor Force Content and Employment Concentration

Industry	Percent of Labor force Scientists and Engineers		Difference District minus	Percent of Labor Force Scientists, Engineers and Technicians		Difference District minus	1984 Regional Concentration
	U.S.	District	U.S.	U.S.	District	U.S.	Index
Radio and Television Broadcasting	4.36	4.70	+ .35	6.53	6.25	- .29	.82
Telegraph and Misc. Communication Service	4.71	4.22	- .49	9.18	8.01	-1.17	.62
Commercial Research, Development, and Testing Labs	22.85	21.54	-1.30	38.21	37.24	- .97	.73
Computer and Data Processing Services	13.98	11.10	-2.88	30.51	26.36	-4.16	.90
Engineering, Architectural and Surveying Services	26.90	26.27	- .63	29.70	28.60	-1.10	.76
Noncommercial Educational and Scientific Reserch	21.24	11.95	-9.30	30.09	19.34	-10.75	.68

SOURCE: U.S. Bureau of the Census, *1980 Census of Population; and* and Bureau of Labor Statistics (ES-202).

industries include engines and turbines, electrical machinery, construction-material handling machinery, and soap and cosmetics. The District's relatively high concentration in such industries partly offsets its lesser presence at the top end of the technology spectrum. This observation can explain why some studies of high tech industries indicate the Midwest Region's strong high tech presence (FRB—Chicago) while others suggest the opposite (Browne). The broader, more inclusive industry definitions of the high tech sector are more favorable to both the District and the largely overlapping East North Central Division.

In addition to the District's weakness in the first tier of high tech industries, another contributing factor to the District's lower overall proportion of SET professionals in total employment is that the proportion of scientists and engineers within specific industries in the District can be seen to be consistently lower than the proportion in U.S. counterpart industries. Across the sample of all individual manufacturing industries, the mean difference of the U.S. SET proportion of labor from the District's proportion was positive and statistically significant at the 5 percent level in 1980. This pattern is particularly evident for high tech industries and selected high tech services (Tables 7 and 9). Nine of the top ten high tech industries nationally maintain labor forces with a greater composition of SE and SET personnel than the District's industry counterparts. In regards to services, only one of the selected six (i.e. radio and TV broadcasting) displayed a SET percentage that was greater in the District than in the U.S. To cite one industry example from the national high tech industry list, the proportion of scientists and engineers in the nation's aircraft and parts industry registered 14.1 percent of labor force in comparison to 9.2 percent in the District's aircraft industry. Examples can be also cited from those high tech industries which tend to have above average concentrations in the District such as engines and turbines, electrical machinery (n.e.c.), office and accounting machines, and soaps and cosmetics. However, among these industries concentrated in the District, there are notable counter examples such as paints and varnish, construction-material handling machinery, and drugs.

In trying to explain why industry-by-industry SET employment proportions in the District diverge from the nation's, it is insightful to examine theories on regional industrial location. The most useful model is that of the product cycle which provides an explanation of why firms choose to spatially separate across regions their high tech R&D intensive functions from their routine production operations, and thus why certain regions have more technology intensive establishments that employ a high level of SET while others have more branch plants that employ low-skill labor (see previous discussion on page 12).

Reconciling this theory with the observed low proportions of SE personnel in the District's high tech industries would suggest that, within the same industry, high tech firms have chosen to locate the more technology intensive aspects of production outside of the District while locating the lesser tech intensive production, which requires a lower skilled and low cost labor force, within the District.

The latter scenario is clearly at odds with the conventional wisdom and common observations that the North Central Region, and especially the East North Central Division, has a significant labor cost disadvantage *vis a vis* competing regions such as the South. Other things equal, this would encourage the more skill intensive and more capital intensive industries as the region's comparative advantage rather than routinized production facilities characterized by labor intensity of lower skills. Indeed, empirical studies have found, using firm-specific data over samples of multi-branch firms, that the Central Region (containing the Seventh District) has relatively few branch plants (Jusenius and Ledebur 1978). In a recent study of the electronic computing equipment, medical and surgical instruments, semiconductors, and computer programming industries, the author found that the Northeast and Central regions retained and attracted fewer branch plants than the South and West (Malecki 1985). According to the study, the Northeast and North Central regions retain fewer branch plants of firms headquartered there and they also attract fewer branch plants of firms headquartered outside the regions. If this is so, one would expect the District to employ larger and not smaller shares of SET personnel because firms with branch plants employing lesser skilled labor would tend to locate these low tech operations to outlying low cost regions. This assumes that labor costs for unskilled labor and general costs of operation are unfavorable to the District while highly skilled operations are relatively advantaged.

Although observations of the District's weak tech intensity within the nation's highest echelon of high tech industries are at odds with current regional locational theory and evidence, it is hypothesized here that the data are partly misleading. A competing explanation of the tendency of District industries to employ fewer SET personnel within the same industry is that industry definitions are very highly aggregated so that different industry mixes (both high and low tech) across regions are measured under identical SIC classifications. For example, under the classification of office and accounting machines (SIC 357), electronic calculator-electronic cash register products (SIC 3574) are classified, but so too are the office paper stapler and remover products (SIC 3579). This is to suggest, for example, that the District aircraft industry puts out a different (lower tech) product altogether from the U.S. or Seattle aircraft industry. Even for these high tech industries in the District, then, the actual product lines where the region holds a comparative advantage (when properly disaggregated) may tend to lie at the lower to middle tech end of the spectrum as measured by employment of SET personnel. This does not necessarily contradict the theory that, within industries which are finely disaggregated, the District holds a comparative advantage in highly skilled operations and establishments.

The hypothesis concerning the limitations of the data could not be rigorously tested because the regional data on SE personnel by industry could not be disaggregated further into finer industry levels or product lines. However, tech intensity at the finer 4-digit industry level can be defined for some industries using private R&D expenditure to sales ratios from the 1977 Annual Line of Business Survey (ALB) as a proxy for tech intensity.[12] Recognizing that R&D expenditures are only an imperfect proxy for tech intensity, a majority of industry groupings for which sufficient data were available from the ALB suggested that the District's industry concentrations (4 digit level) tended toward the lower tech industries within the more broadly defined high tech industry groupings (3 digit level). This was so for soaps and cosmetics, engines and turbines, office and accounting machines, plastics and synthetics, and optical and health care supplies (SIC 383, 384, and 385). For example, in considering the optical and health care supplies industry in the District, District employment concentration is lower in the research oriented optical lens industry (SIC 383) and strongest in the less research oriented dental equipment and supplies industry (SIC 3843) and in the rest of the orthopedic-medical instruments industry (SIC 384). Likewise, the District specialized in engines and turbines (SIC 351), but more so in the less tech intensive internal combustion engine industry (SIC 3519). Other industries from the top of the high tech echelon were inconclusive in this regard, owing to unavailable data on research expenditures from the ALB survey. In contrast, the scientific and controlling instruments industry group, along with agricultural chemicals, contradicted the hypothesis that the District tends to concentrate in lower tech product areas within high tech industry groupings.

A further accounting of the SET personnel within District industries can be provided by focusing on those District manufacturing industries with *greater* employment concentration relative to the U.S., whether or not they are technology intensive. A ranking of the District's top 20 industries ranked by employment concentration relative to the U.S. yields a set of industry titles that perhaps characterize the Midwest manufacturing-agricultural belt better than any lengthy description. These industries include motor vehicles, engines and turbines, farm machinery, metal forgings and stampings, iron and steel foundries, railroad locomotives and equipment, metalworking equipment (machine tools), household appliances, dairy products, and others (Table 10). While these industries are not in the highest tier in SET personnel, neither are they in the lowest. With a few exceptions, the SE labor force share within the District's mainstay indus-

Table 10
Top Twenty Seventh District Manufacturing Industries as Ranked by Employment Concentration—1984

	Scientists and Engineers			Scientists, Engineers, and Techicians			1984
Industry	Proportion in District	Proportion in U.S.	Difference District -U.S.	Proportion in District	Proportion in U.S.	Difference District -U.S.	Regional Concentration Index
Motor Vehicles and Equipment	5.77	4.19	+1.58	7.08	5.22	+1.86	3.71
Engines and Turbines	5.38	7.01	-1.63	8.77	6.78	-1.98	3.55
Farm Machinery and Equipment	4.94	4.00	+ .94	6.01	4.89	+1.12	3.46
Metal Forgings and Stamplings	1.71	1.79	- .09	2.58	2.61	- .02	3.04
Screw Machine Products	1.42	1.70	- .28	2.11	2.49	- .37	2.57
Metalworking Machinery	3.38	3.19	+ .19	4.27	4.27	0	2.57
Iron and Steel Foundries	2.27	2.15	+ .12	3.57	3.39	+ .18	2.48
Railroad Locomotives and Equipment	3.95	3.65	+ .30	4.71	4.53	+ .18	2.42
Cycles and Miscellaneous Trans Equip.	4.97	3.00	+1.97	6.36	3.83	+2.52	2.34
Grain Mill Products	2.39	2.00	+ .39	4.88	4.00	+ .88	2.23
Construction and Material Handling Equipment	5.81	5.01	+ .81	7.10	6.32	+ .77	2.20
Household Appliances	3.75	3.24	+ .5i	5.13	4.43	+ .10	2.12
Blast Furnaces, Steelworks, Rolling and Finishing Mills	2.44	2.49	- .06	3.85	3.93	- .07	2.10
Cutlery, Handtools, and Hardware	2.44	2.14	+ .30	3.34	2.85	+ .49	1.77
Paints and Varnishes and Related Products	5.83	5.26	+ .58	12.34	11.30	+1.04	1.69
Dairy Products	1.26	93	+ .33	3.95	3.05	+ .90	1.68
Miscellaneous Fabricated							1.62
Metal Products	2.56	2.51	+ .06	3.50	3.57	- .07	1.67
Drugs	10.48	9.10	+1.37	19.65	16.14	+3.51	1.58
Rubber and Miscellaneous Plastics Products*	2.06	2.21	- .15	3.38	3.55	- .17	1.55
Machinery Except Electrical n.e.c	4.08	3.80	+ .28	5.20	4.94	+ .26	1.53

*Excludes tires and inner tubes.

SOURCE: U.S. Bureau of the Census, *1980 Census of Population;* and Bureau of Labor Statistics, (E.S. 202).

tries are within one standard deviation of the U.S. average SE personnel share for manufacturing. Seven out of the top ten District industries are above the U.S. mean share. Using the labor force share definition that includes technicians, 6 out of the top 10 are above the U.S. mean.

It is a telling point that in contrast to the District's industries that are part of the high tech industry tier, the District's mainstay industries tend to employ *greater* shares of SET personnel than their national counterparts. This suggests that the region maintains a technological edge in many of the industries in which it has an historical and present comparative advantage. These observations of above-national tech intensity for the region's mainstay industries *do* tend to support the product cycle model of regional manufacturing location. Assuming that product lines are similar across regions, it would appear that those industries with an apparent comparative advantage in the Midwest (as measured by employment concentration) are tending to locate the technology intensive type of operations within these industries (as evidenced by SE personnel shares) in the District. These facilities are typified by R&D laboratories and early stage developmental production for which a skilled labor force is crucial, and unskilled labor costs are not paramount.

From a policy perspective, the preceding evidence implies that economic development in the Midwest should then focus on supporting the infrastructure necessary to attract and retain technologically advanced types of operations that generate new and changing products. This is especially so for those industry areas of traditional comparative advantage for which there is already a confluence of locational attributes in the region.

Based on the strong SET workforce in the District's private industry, it is also concluded that the District does have the technological base necessary to develop new technological industries and revive the existing ones through technological advances. The region is already trying to capitalize on those strengths through innovations in its indigenous industries. The automotive industry, for example, is aggressively pursuing robotics and automated factory processes while the steel industry continues to push the federal government for help in pursuing *leap frog* technologies in steel production. So too, some bases of truly technology intensive industries such as pharmaceuticals and communications equipment have already found a hospitable environment in the District.

The federal government

The federal government both directly and indirectly supports the nation's R&D. The federal government conducts and manages research—directly employing a significant 8 percent share of the nation's scientific and technical labor force. However, the federal government's indirect role overshadows its direct role in supporting SET personnel employment. It does so by extending federal grants for scientific research to universities, private firms, federally funded research and development centers (FFRDCs), and also through procurement of technology intensive products (mostly defense-related). In 1985, 47 percent of overall U.S. R&D funds could be directly and indirectly traced to the federal government. In addition to *direct* intramural R&D performed by the federal government, these funds include *indirect* contract-related research for the federal government performed by private firms, universities, FFRDCs and non-profits along with federal grants for research purposes. Indirect R&D funding comprised over 73 percent of all federal R&D support in 1985. As a result, the federal government passed along $36.5 billion dollars to other sectors for R&D support. Of these indirect funds, approximately two thirds supported private industry R&D and industry-administered FFRDCs, while 16 percent supported university and college R&D performance.

Similar to the overall flow of federal funds, federal R&D spending largely bypasses the Midwest and the Seventh District region (Erdevig 1985, 1986). On a per capita basis, federal R&D funds flowing to District industries are only 15 percent of that received by all industries in the nation. This largely follows from the region's increasing specialization outside of those private industry groups from which the federal government purchases goods and services (ACIR 1980). In particular, the District's industries receive a below average amount of funds because they have relatively fewer Department of Defense (DOD) contracts than industrial firms in other regions (Erdevig 1986). Those industries performing much of the R&D related to federal defense contracts have tended to situate outside of the Seventh District and the Midwest. These include the ordnance, aircraft and parts, guided missile-space vehicle, and shipbuilding industries (See Table 7). Concentration of federal funds in a small number of such industries influences regional growth and has tended to help Northeast, and West Coast, and several sunbelt areas in the U.S. (Malecki 1982) (ACIR 1980). Federal R&D funding of basic research at colleges and universities has been more evenly dispersed and this has had a moderating influence on the distinct geographic incidence of federal R&D support in the U.S. in recent years.

Intramural and FFRDC federal activity

Because the SE personnel supported by indirect federal funds are already counted in the industry and education sectors of this paper, this section will concentrate on the regional incidence of direct federal government SE employment which is important, as well. In regards to direct R&D obligation categories performed by the government (intramural) or for that R&D performed largely with government proprietary interests (FFRDCs), relatively little federal R&D is located in the District (Table 11).[13] At the regional level the Seventh District share of FFRDC obligations is low in contrast to the New England, Mountain, and Pacific regions which encompass above average proportions of these facilities. Somewhat of an exception among the Seventh District states, Illinois and the Chicago area support a high federally-related SET labor force via the location of two major FFRDCs—Argonne National Laboratory (energy) and Fermi National Laboratory (high energy physics).

Direct employment of scientists and engineers by the federal government was reported to be 8 percent of the nation's total in 1983. Federal employment is generally more technologically intensive than the overall workforce with 15 percent of federal white collar employees being scientists, engineers, and computer specialists (SEC) in comparison to 6 percent of national white collar employment (National Science Foundation 1985). By proportion of workforce, NASA and the EPA greatly concentrate their workforce in technical areas. However, in terms of sheer size, the DOD dominates, employing one-half of all federal scientific, engineering, and computer specialist (SEC) personnel. These include one-fourth of federal scientists, two-thirds of engineers, and three-fifths of computer specialists.

The location of direct federal employment of SET is similar to the location of the federal government itself. The National Science Foundation reports that 36 percent of all federal scientists and engineers were to be found in Washington D.C. and in the States of Virginia and Maryland in 1983. As a result, of all employed scientists and engineers reported in a 1982 survey, 18 percent of the South Atlantic region's SET labor force were employed by the federal government (Table 11). The Mountain and East South Central regions also maintain their SET labor forces with the help of significant federal support. In contrast, only 3 percent of Seventh District scientists and engineers were directly employed by the federal government in 1982.

Universities and colleges

As major employers of scientists and engineers, universities and colleges accounted for 24 percent of all employed scientists and only 3 percent of engineers in 1983 (National Science Board 1985). On a per capita basis, the New England division far and away exceeds all other divisions in university doctoral SE employment (Table 12). There are over 1.8 scientists and engineers per capita in that region for every one in other regions. The Mid Atlantic, Mountain, and West North Central divisions are the only others to exceed the national average in this regard.

Table 11
Federal Intramural and FFRDC Obligations for Research and Development and Direct Federal Employment of Scientists and Engineers By Region and Seventh District States—Fiscal Year 1982

	Federal Intramural Obligations ($ millions)	FFRDC Obligations ($ millions)	Per Capita Obligations Relative to U.S.		Percent of Region's Scientists and Engineers Employed by Federal Government 1982
			Intramural	FFRDCs	
New England	451.7	226.4	.97	1.11	3
Middle Atlantic	645.3	615.5	.47	1.02	3
South Atlantic	4,194.2	143.6	2.92	.23	18
East South Central	503.0	213.9	.90	.88	9
West South Central	322.4	.0	.34	.00	5
East North Central	642.6	239.4	.41	.35	3
Seventh District	174.7	245.8	.14	.45	3
-Illinois	53.5	230.4	.12	1.23	3
-Indiana	44.3	.0	.21	.00	4
-Michigan	44.8	.0	.13	.00	2
-Iowa	13.3	13.8	.12	.29	2
-Wisconsin	18.8	1.6	.11	.02	2
West North Central	106.7	21.6	.16	.07	6
Mountain	567.9	1,009.2	1.25	5.12	11
Pacific	1,313.0	1,336.4	1.06	2.48	5

NOTES: Intramural activities cover costs associated with the administration of intramural and extramural programs by federal personnel in addition to intramural R&D performance.

SOURCE: Table C-106, *Federal Funds for Research and Development Fiscal Years 1982, 83, 84,* National Science Foundation 83-319 and unpublished data from the National Science Foundation.

The Seventh District employs approximately 5 percent fewer doctoral scientists and engineers in the academic system. Engineering employment is somewhat stronger than employment of scientists, actually exceeding the national average in Indiana, Iowa, and Wisconsin. In addition, both Iowa and Wisconsin also employ above-average scientists on a per capita basis.

To arrive at the reason for the regional variation in the SE indices, SE personnel in academics were disaggregated according to primary work activity. Over one-half of the nation's university-college scientists and engineers reported their primary work activity as teaching and over one-quarter reported research, with the remainder in administrative fields or without a reported primary work activity. Although there is no regional data on SE in education by work activity, teaching personnel by region are reflected by degrees awarded in scientific and engineering disciplines (Table 13). Such a proxy will accurately reflect teaching SE by region so long as pupil/teacher ratios are not different across regions. On a per capita basis, the District's colleges and universities are found to award greater numbers of science and engineering degrees at both the undergraduate and graduate levels. The incidence of engineering degrees alone also fit this pattern. Although information concerning science degrees alone is not available at the undergraduate and masters level, doctoral degrees in science awarded in the District were approximately 18 percent higher than the nation on a per capita basis (figures not displayed in table). Together, these figures suggest that below-average university-related employment of SE personnel apparently stems not from lack of teaching personnel but rather from fewer SE in R&D activities domiciled at the District's academic institutions.

A possible explanation for why the District would have fewer college and university employees involved in research activities is that its colleges and universities receive a smaller share of federal R&D funds in comparison to other regions. Information on research and development fund sources to colleges and universities by geographic area is only available for federal government sources. However, almost two-thirds of all college-university R&D dollars derive from the federal government through its agencies (Table 13). Among federal agencies, the National Institutes of Health is the largest source of federal funds for research at colleges and universities while the National Science Foundation and the Department of Defense are also large grantors. In terms of these funds, the District's share compares unfavorably to the nation. The District's per capita federal R&D obligations fell below the national average by over 15 percent in 1981 despite a strong showing by Wisconsin's university system.

Table 12
Concentration of Scientists and Engineers Employed at Doctorate-Granting Universities and Colleges By Region—1984
(index based on population)

	Engineers	Scientists	Scientists and Engineers
New England	1.61	1.87	1.84
Middle Atlantic	.95	1.01	1.00
East North Central	.99	.95	.96
Seventh District	.99	.94	.95
-Illinois	.86	.94	.93
-Indiana	1.28	.94	.99
-Iowa	1.42	1.25	1.27
-Michigan	.89	.78	.80
-Wisconsin	1.06	1.20	1.18
West North Central	1.01	1.07	1.06
South Atlantic	1.05	.93	.95
East South Central	.81	.83	.82
West South Central	.80	.92	.91
Mountain	1.59	.97	1.05
Pacific	.74	.87	.85

NOTE: Index uses resident population estimates of July 1, 1983. Occupational estimates are for January, 1984. Employed persons includes both full and part-time personnel.

SOURCE: National Science Foundation, *Academic Science/Engineering: Scientists and Engineers,* Table B-49, NSF 85-316.

Table 13
Selected Indicators of University and College Employment of SET Personnel in the Seventh District
(concentration indices based on population)

	Degrees Awarded						Federal R&D Obligations
	Engineering: 1984			Science & Engineering: 1983*			to Colleges and
	B.S.	M.S.	Ph.D	B.S.	M.S.	Ph.D.	Universities: 1982
Illinois	.80	.96	2.09	.94	1.05	1.15	.83
Indiana	1.45	.94	1.49	1.11	1.00	1.26	.70
Iowa	1.02	.84	1.23	1.15	.74	1.29	.85
Michigan	1.50	1.23	.97	1.09	1.02	1.14	.70
Wisconsin	1.16	1.04	1.23	1.12	.96	1.21	1.10
District	1.16	1.03	1.50	1.05	1.00	1.18	.82
U.S.	1.00	1.00	1.00	1.00	1.00	1.00	1.00

*Data on science degrees alone not available.

SOURCE: *Engineering Education,* April, 1985; National Science Foundation.

Conclusions

Despite the region's liability in low federal funds flow, the mix of private industry located in the Seventh District favors employment of SET personnel. The region continues to specialize in durable manufacturing industries while durable goods industries tend to intensively employ SET personnel in production. Those durable goods industries that concentrate in the Seventh District region fall largely outside the highest end of the technology spectrum where SET employment is highly skewed. Nevertheless, concentrated regional employment of SET personnel in the second tier of technology intensive industries partly compensates for this tendency. Moreover, the industries in which the region has come to specialize, be they high tech or not, are shown to be more technology oriented than their national counterparts.

These findings indicate that, despite the fact the District is not renowned for high tech industry, one of the District's comparative advantages lies in the technology intensive operations of manufacturing production. And unless the costs of large-scale routinized production operation of general manufacturing can be lowered through wage concessions, less restrictive work rules, or intensive factory automation, the District economy will come to increasingly depend on those industry facilities such as R&D labs and prototype-innovative product assembly for which traditional operating costs are secondary to the availability of skilled labor.

These results suggest that a regional policy focus to encourage technology intensive industries and technological application in the region's mainstay industries is warranted. The District's comparative technological strength in mainstay industries, along with the region's concentration in several *bona fide* high tech industries, suggests that the region promises further development through the regional export of goods with a technological edge.

However, even successful policies to automate the region's traditional industries and to promote technology oriented activities in mainstay industries may not be able to restore the District economy to its former prowess because losses in many traditional tech oriented industries, such as steel and machinery, have been staggering. These job losses cannot be recouped from District growth in those high tech industries that have recently surged in Los Angeles, New England, and the Bay area of California. These industries—such as electronics, aircraft, and computers—are by now firmly entrenched in these areas so that future growth outside of home regions will be somewhat limited. For these reasons, thoughts of strong Midwest revival must also center on creation of new industries. Appropriate policy actions are those that promote and assist entrepreneurs who can generate new industries as many traditional industries go the way of the buffalo.

For example the District's university and college programs to supply new technical labor and encourage technology transfer can be strengthened.

Despite the important findings and the public policy implications derived from occupational data, these data are somewhat limited in what they can tell us of a region's potential in nurturing technology intensive industries. Despite the importance of existing labor pool agglomeration to the future growth of high tech industry, it is a measure only of what is presently located in an area rather than what can be developed. In regards to high tech growth potential, there is a circularity or simultaneity in viewing these snapshots of labor force as indicators of comparative advantage. While future development is partly induced by an area's present endowment of skilled labor, at the same time, an area's future endowment of skilled labor will be determined by the kind of industry that it attracts and propagates. Other factors, including those beyond the control of policy makers, will play a role in future development. To be sure, much more must be understood about the dynamics of high tech industrial growth in U.S. markets.

Even as a simple measure of what kinds of industrial activity are now taking place in the Midwest and elsewhere, labor force profiles must be interpreted with caution. Many occupational activities in the sciences and engineering are not related to new product development or technological leaps in production process, but rather, these activities reflect product testing to assure environmental and quality standards set by the federal government. Thus, they should not be taken as an exhaustive measure of innovative activity.

Despite these caveats, the notable concentrations of scientists and engineers in the District suggest that the Midwest is neither a high tech mecca nor a wasteland. Overall, we are a labor force of production workers and a labor force of innovative entrepreneurs. To the extent that future growth in many tech intensive industries can be strong in urban areas with a skilled labor force, technology intensive industries can be an important part of Midwest economic growth. Of course, this cannot take place without concerted efforts to construct complementary infrastructure, appropriate capital market institutions, information networks (especially between universities and private industries), and the much-touted entrepreneurial climate.

[1] A comparison of high tech industry performance with an average of all industries has repeatedly shown greater employment growth in those industries with high proportions of scientific, engineering, and technical workers. For example, a study by Richard W. Riche and others found that U.S. employment grew by 23.6 percent from 1972 to 1982 in high tech industries defined by the sole criterion that scientific-engineering occupations comprised over 1.5 times the average. High

tech industries defined by a ratio of R&D expenditures to new sales of at least twice the national average, grew by 39.8 percent. At the same time, total employment of wage and salary workers grew by 20.1 percent. See Richard W. Riche et al, "High technology today and tomorrow: a small slice of the employment pie," *Monthly Labor Review*, November, 1983, pps. 50-58.

[2] The U.S. trade balance in high technology manufactured products remained in a surplus position in every year from 1970 to 1984. At the same time, other manufactured goods ran deficit positions in all but a single year and the deficit position has increased by several fold over this period. See National Science Board, *Science Indicators, The 1985 Report*, U.S.G.P.O. 1985, pps. 10-11.

[3] For a state-by-state review of high tech development initiatives in the U.S. see "State and Local Initiatives for High-Technology Development" in *Technology, Innovation, and Regional Development*, U.S. Congress of the United States, Office of Technology Assessment, Washington D.C., July 1984. For a review of state development programs in the Seventh District see David R. Allardice and Alenka S. Giese, "State Development Programs: A Review of the Seventh District," FRB—Chicago, 1985.

[4] While the findings on branch plants in the context of high tech firms are referenced elsewhere in this study, identification of the branch plant phenomena as a source of lagging growth in the East North Central Region occurs across all manufacturing industries; see Carol L. Jusenius and Larry Ledebur, *The Migration of Firms and Workers in Ohio*, Academy For Contemporary Problems, Washington D.C., 1979.

[5] Using data from the U.S. over the period from 1870 to 1950, Jacob Schmookler demonstrated a close correlation between total patent applications (a measure of innovative activity) and the size of the technological workforce. Deviations in trends of both of these individual data series were found to be positively correlated at the five percent level of statistical significance. See Jacob Schmookler, *Invention and Economic Growth*, Harvard University Press, Cambridge, 1966, pps. 41-44.

Occupational association with actual R&D activity is also evident from surveys of employed scientists and engineers. Periodic surveys by the National Science Foundation report that scientists and engineers are widely active in research, product development, and the management of R&D. Scientific and engineering professionals were engaged in R&D in roughly the same proportions in 1983—an average among the two professions of 41.7 percent. Engineers maintained a somewhat greater margin, mostly owing to their active presence in product development as opposed to product research. In contrast, scientists clearly dominated the product and process research area.

At the doctoral level of education, research and development becomes more prevalent with over one-half of those employed primarily active in these areas for science and engineering occupations combined. Still, the greater occupational activity importance at the doctoral level is not dramatic, perhaps owing to the greater importance of teaching at the doctoral level. For data covering all fields save the social sciences, 24.4 percent of employed doctoral scientists and engineers were primarily engaged in teaching in 1983. Among nondoctoral scientists and engineers, only 4.3 percent were most active in teaching. Many doctoral level scientists whose main occupation is teaching are also presumably engaged in research and consulting. (ibid. National Science Board 1985.)

[6] By U.S. Census Bureau procedure, occupations are recorded by self-identification of survey respondent and coded by trained Census staff. To clarify the procedure, for example, a response of "chemistry professor" would be recorded as a postsecondary teacher and not as a research chemist. However, a chemistry professor who identified himself as a "chemist" *would* be included in the scientific occupational category.

[7] In contrast to the data previously presented in this paper, the SMSA occupational concentrations presented here are measured relative to the employed labor force in 1980 rather than to total population so that those differences in labor force participation attributable to demographic and cultural factors can be accounted for. Neither the population-based nor the employment-based measures of occupational concentration are totally acceptable. Population based measures favor those regions with high ratios of employment to population, such as New England. At the same time, the ratio of occupational employment to total employment is not neutral across regions with respect to the business cycle. A cyclically sensitive regional economy may tend to display higher proportions of skilled workers during a downturn because such workers are "hoarded" by firms while low skilled workers are laid off in great numbers.

[8] During 1985, the University of Illinois was chosen by the National Science Foundation to be the site of one of four National Centers for Supercomputing Applications. And, in addition to this and other notable research centers, the University has received a large private bequest to build an interdisciplinary research institute to address questions in the areas of material science, computing, neuroscience, and cognition. There are also plans to establish a Center for Supercomputing Research.

[9] Wilbur R. Thompson, "Internal and External Factors in the Development of Urban Economies" in Harvey S. Perloff and Lowdon Wingo, Jr. eds., *Issues in Urban Economics,* The Johns Hopkins Press, Baltimore, 1968, p. 53.

[10] See David W. South and Lawrence G. Hill, "Can High Technology Stimulate Growth in the Midwest? Examination of Locational Attributes," paper presented at the Midwest Economics Association, March, 1986, for a discussion of Midwest prospects in the field of biotech.

[11] While both SET concentration and research expenditures are commonly used to define high tech industries, the SET measure is used here for two reasons. The obvious reason is our paper's focus on SET personnel as a broad measure of a region's innovative potential. An industry exegesis along these lines will help to explain a region's overall SET concentration. But secondly, several analysts have strongly argued that innovative industries can be either research producers or research product innovators (see Schmookler 1966; Scherer 1982; Davis 1982). Thus, industry's direct R&D expenditures will be a biased toward industries producing innovative products while overlooking those who purchase innovation for application. In contrast, these latter industries would *tend* to be measured using SET-based classifications because their personnel tend to need technical training for purchasing and applying upstream innovative products and processes.

[12] Information regarding indirect federal support of SE personnel by geographic area is now out of date. However, these data confirm low overall federal support

of R&D in Seventh District states. As of 1974, 37 percent of all U.S. SE received some federal support while the proportions of federal support in District states ranged from 18 to 25 percent. See National Science Foundation, *Characteristics of the National Sample of Scientists and Engineers*, 1976.

References

Advisory Commission On Intergovernmental Relations, *Regional Growth: Flow of Federal Funds 1952-76*, Washington, D.C., 1980.

Armington, Catherine, Candee Harris, and Marjorie Odle, "Formation and Growth in High Technology Firms," *Technology, Innovation, and Regional Economic Development*, U.S. Congress, Office of Technology Assessment, U.S.G.P.O., Washington, D.C., 1984.

Browne, Lynn, "Can High Technology Save The Great Lakes?" *New England Economic Review*, November/December, 1983.

Browning, Jon, *How to Select a Business Site*, McGraw-Hill, New York, 1980.

Davis, Lester A., *The Indirect Influence of R&D on Trade Performance*, Staff Report (Project CTR-06-83), Office of Trade and Investment Analysis, U.S. Department of Commerce, Sept., 1983.

Davis, Lester A., *Technology Intensity of U.S. Output and Trade*, Staff Report, Office of Trade and Investment Analysis, International Trade Administration, U.S. Department of Commerce, July, 1982.

Delphi Study, *Industrial Robots Forecasts and Trends*, Society of Manufacturing Engineers, the University of Michigan, 1985.

Erdevig, Eleanor, "The Bucks Stop Elsewhere: The Midwest's Share of Federal R&D," *Economic Perspectives*, F.R.B. Chicago November/December, 1984.

Erdevig, Eleanor, "Federal Funds Flow No Bargain For Midwest," F.R.B. Chicago, *Economic Perspectives*, January/February, 1986.

Evaldson, Rune, "Willow Run Laboratories," unpublished paper, 1970.

Federal Reserve Bank of Chicago and The Great Lakes Commission, *The Great Lakes Economy: An Industry and Resource Profile*, Harbor House Press, Boyne City, Michigan, 1985.

Federal Trade Commission, *Annual Line of Business Report 1977*, Statistical Report of the Bureau of Economics to the F.T.C., May, 1982.

Feldman, Marshall M.A., "Biotechnology and Local Economic Growth," *Silicon Landscapes*, Peter Hall and Ann Markusen eds., Allen and Unwin, Boston, 1985.

Gerstenfeld, Arthur (ed.), *Technological Innovation: Government/Industry Cooperation*, John Wiley & Sons, New York, 1979.

Giese, Alenka S., and William A. Tests, *Research and Development Activity in the Chicago Area*, Regional Working Paper Series, Federal Reserve Bank of Chicago, 1987 (forthcoming).

Glasmeier, Amy K., Peter Hall, and Ann R. Markusen, "Recent Evidence on High Technology Industry: A Preliminary Investigation," *Technology, Innovation, and Regional Economic Development*, U.S. Congress, Office of Technology Assessment, U.S.G.P.O., 1984.

Hall, Peter, and Ann Markusen (eds.), *Silicon Landscapes*, Allen and Unwin, Boston, 1985.

Hall, Peter, et al "The American Computer Software Industry: Economic Development Prospects," *Silicon Landscapes,* Peter Hall and Ann Markusen eds., Allen and Unwin, Boston, 1985.

Hoover, Edgar M., "The Evolving Form and Organization of the Metropolis," in *Issues In Urban Economics,* Harvey S. Perloff and Lowden Wingo eds., The Johns Hopkins Press, Baltimore, 1968.

Howells, J.R.L., "The Location of Research and Development: Some Observations and Evidence from Britain," *Regional Studies,* Vol. 18, No. 1, 1984, pps. 13-29.

Jusenius, Carol L., and Larry Ledebor, *The Migration of Firms and Workers in Ohio, 1970-75,* Academy For Contemporary Problems, Washington D.C., 1978.

Krzyzowski, Marian, B. Michael Conboy, and Jesse Hall, "Developing High Tech Industry," in Harvey E. Brazer and Deborah S. Laren eds., *Michigan's Fiscal and Economic Structure,* The University of Michigan Press, Ann Arbor, 1982.

Malecki, Edward J., "Locational Trends In R&D By Large U.S. Corporations," *Economic Geography,* Vol. 55, No. 4, October, 1979.

Malecki, Edward J., "Corporate Organization of R&D and the Location of Technological Activities," *Regional Studies,* Vol. 14, 1980, pps. 319-334.

Malecki, Edward J., "Recent Trends in the Location of Industrial Research and Development: Regional Development Implications for the United States," *Industrial Location and Regional Systems,* J. Rees et al eds., Bergin, New York, 1981.

Malecki, Edward J., "Science, Technology, and Regional Economic Development: Review and Prospects," *Research Policy,* Vol. 10, 1981, pps. 312-334.

Malecki, Edward J., "Product Cycles, Innovation Cycles, and Regional Economic Change," *Technological Forecasting and Social Change,* Vol. 19, 1981, pps. 291-306.

Malecki, Edward J., "Federal R&D Spending in the United States of America: Some Impacts on Metropolitan Economies," *Regional Studies,* Vol. 16, No. 1, February, 1982, pps. 20-25.

Malecki, Edward J., "Technology and Regional Development: A Survey," *International Regional Science Review,* Vol. 8, No. 2., 1983, pps. 89-125.

Malecki, Edward J., "Industrial Location and Corporate Organization In High Tech Industries," *Economic Geography,* October 1985.

Mieszkowski, Peter, "Recent Trends In Urban and Regional Development," Peter Mieszkowski and William H. Oakland eds., *Issues In Urban Economics,* Johns Hopkins University Press, Baltimore, 1979.

Mills, Edwin, *Urban Economics,* 2nd Edition, Scott, Foresmann Co., Glenview, IL., 1980.

National Science Board, *Science Indicators, The 1985 Report,* U.S.G.P.O., November, 1985.

National Science Foundation, *Federal Scientific and Technical Workers: Numbers and Characteristics, 1973 and 1983,* NSF 85-315, Washington, D.C., 1985.

National Science Foundation, Characteristics of the National Sample of Scientists and Engineers 1974, Part 3. Geographic, U.S.6.P.O., Washington, D.C., 1976.

National Science Foundation, *Academic Science/Engineering:* Scientists and Engineers, January, 1984, NSF 85-316, Washington, D.C. 1985.

National Science Foundation, *Federal Funds For Research and Development: Fiscal Years 1983, 1984, and 1985,* Vol XXXIII, NSF 84-336, Washington, D.C., 1985.

National Science Foundation, *U.S. Scientists and Engineers: 1982,* NSF 84-321, Washington, D.C., 1984.

Norton, R.D., and J. Rees, "The Product Cycle and the Spatial Decentralization of American Manufacturing," *Regional Studies,* Vol. 13, 1979 pps. 141-51.

Oakey, Raymond P., *High Technology Industry and Industrial Location,* Gower-Aldershot, 1981.

Oakey, Raymond P., *High Technology and Small Firms,* Frances Pintner, London, 1984.

O'Connor, Mike, "High-Tech Core Areas Thriving in California and Along the East Coast," *Conway Site Selection Handbook,* 1986, pps. 556-562.

Pascal, Anthony H. and John J. McCall, "Agglomeration Economies, Search Costs, and Industrial Location," *Journal of Urban Economies,* Vol. 8, 1980, pps. 383-88.

Rees, John, "Regional Industrial Shifts in the U.S. and the Internal Generation of Manufacturing in Growth Centers of the Southwest," in *Interregional Movements and Regional Growth,* William C. Wheaton ed., COUPE Vol. 2, The Urban Institute, Washington, D.C., 1980.

Rees, John, "Technological Change and Regional Shifts in Manufacturing," *Professional Geographer,* Vol. 31, 1979, pps. 45-54.

Rees, John, and Howard A. Stafford, "High Technology Location and Regional Development: The Theoretical Base," *Technology, Innovation, and Regional Economic Development,* U.S. Congress, Office of Technology Assessment, Washington, D.C., U.S.G.P.O., 1984, pps. 97-107.

Roberts, E. B. and Wainer, H. A., "New Enterprises on Route 128." *Science Journal,* December, 1968.

Saxenian, Annalee, "The Genesis of Silicon Valley," *Silicon Landscapes,* Peter Hall and Ann Markusen eds., Allen & Unwin, Boston, 1985, pps. 20-34.

Scherer, F. M., "Inter-industry Technology Flows in the United States," *Research Policy* 11(1982), pps. 227-247.

Schmookler, Jacob, *Invention and Economic Growth,* Harvard University Press, Cambridge, 1966.

Sirbu, Jr., M. A., R. Tretel, W. Yorsz, and E. B. Roberts, *The Formation of a Technology Oriented Complex: Lessons from North American and European* *experience*. CPA Report 76-78. Cambridge, Massachusetts: Center for Policy Alternatives, Massachusetts Institute of Technology, 1976.

Storper, Michael and Richard Walker, "The Spatial Division of Labor: Labor and the Location of Industries," in *Sunbelt/Snowbelt: Urban Development and Regional Restructuring*, L. Sawers and W. K. Tabb eds., Oxford University Press, New York, 1984, pps. 19-47.

Thompson, Wilbur R., *A Preface To Urban Economics*, The John Hopkins Press, Baltimore, 1965.

Thompson, Wilbur R., "Internal and External Factors in the Development of Urban Economies," *Issues in Urban Economics*, Harvey S. Perloff and Lowden Wingo eds., The John Hopkins Press, Baltimore, 1968.

Thompson, Wilbur R., and Philip R. Thompson, "High Tech Industry and High Tech Places," *REI Review*, Vol. 1, No. 1, November, 1983, pps. 13-21.

U.S. Congress, Office of Technology Assessment, *Technology, Innovation, and Regional Economic Development*, U.S.G.P.O., Washington, D.C., 1984.

U.S. Department of Commerce, Bureau of the Census, *1980 Census of Population: Part D, Detailed Population Characteristics*, U.S.G.P.O., Washington, D.C., 1983.

U.S. Department of Commerce, Bureau of the Census, *Occupation By Industry: 1980 Census of Population* (data tape).

U.S. Department of Labor, Bureau of Labor Statistics, *Employment and Wages 1978-1984* (data tape).