Technology and manufacturing in the Seventh District

Alenka S. Giese and William A. Testa

State and local policymakers in the Midwest have eased up in their pursuit of the so-called "high-tech" industries, such as telecommunications, semiconductors, computing equipment, aerospace, and instruments. In part, this change of emphasis reflects the fact that high-tech industry growth has leveled off following the spurt of the late 1970s and early 1980s. In addition, because most such industries have remained highly concentrated in their region of origin, it has become clear that high-tech industries are not equally suited to all regions.

With the let-up in high-tech industry-chasing, the more general role of technology in regional growth has become more important to policymakers. They have recognized that technology can be an important feature of many of those industries that are not recognized for their technology intensity. Accordingly, development programs have been established to encourage technology transfer to older manufacturing industries and to encourage those activities of the manufacturing process such as product research and development (R&D) that can potentially revitalize the more traditional industries. And in recognition of the strong locational ties between existing high-tech industries and their home regions, economic development programs have begun to encourage local entrepreneurs to carry scientific findings from the lab to the marketplace in hopes of establishing the next generation of high-tech industries.

This article reviews two aspects of technology relating to economic performance in the Seventh District. First, prospects and performance of the so-called "high-tech" industries are reviewed. Secondly, the technology intensity of the District's traditional industries is assessed as a possible indicator of the District economy's relative strengths.

What are high-tech industries?

High-tech industries are, by now, widely familiar in developed economies. In the United States, these industries gained great renown during the latter 1970s and early 1980s because their growth in output and employment exceeded national averages and was not severely interrupted by the national economic downturns of 1980 and 1981-82. Their role in the revival of the once-depressed New England economy led other traditional manufacturing regions, including the Midwest, to believe that high-tech industries offer a solution to their employment problems also.

Analysts have considered several industry characteristics in formally defining and identifying high-tech industries. One approach has included those industries that produce technologically sophisticated products. Sophisticated products, however, may eventually come to be produced by standard production methods. And, technologically advanced products and standardized products may be grouped under the same product heading under the Standard Industrial Code.

An approach which partly circumvents these difficulties distinguishes industries by the extent that their activities are technology-oriented. Such activities include industrial processes that incorporate emerging technology or that are characterized by significant product research and development (R&D). Following this approach, one practice has been to define high-tech by measuring the percent of an industry's sales or value added that is composed of research and development expenditures. This approach measures directly an industry's most obvious and pervasive technology activity, product innovation.

However, such an approach overlooks the application of emerging technologies to the production process of standardized products. For example, such a definition could conceivably overlook traditional metal-bending industries which may be producing with increasingly automated operations such as Computer Assisted Design/Computer Assisted

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Table 1

Concentration of top twenty high-tech manufacturing industries in Seventh District states

Industry	Percent of labor force scientists, engineers, and technicians	Index of employment concentration relative to U.S.—1985					
		District	Illinois	Indiana	Iowa	Michigan	Wisconsin
Guided missiles, space vehicles, and parts	35.4	.03	n.a.	n.a.	n.a.	.03	n.a.
Electronic computing equipment	26.4	.11	.05	.01	.34	.09	.28
Aircrafts and parts	17.3	.38	.23	1.29	n.a.	.34	.02
Radio, T.V., and communication equipment	16.2	1.01	1.46	2.00	1.17	.13	.32
Drugs	16.1	1.58	1.30	3.90	.53	1.63	.19
Industrial and miscellaneous chemicals	15.4	.85	1.13	.49	.28	1.14	.34
Photographic equipment and supplies	15.3	.38	.80	.17	–	.05	.41
Scientific and controlling instruments	14.3	.96	1.11	.92	.79	.82	.96
Not specified electrical machinery	14.1	1.98	.58	5.12	1.05	1.39	3.50
Office and accounting machines	13.5	1.05	1.40	.16	n.a.	1.85	.28
Petroleum refining	12.6	.58	.97	.95	n.a.	.32	n.a.
Electrical machinery equipment n.e.c.	11.9	1.03	1.30	1.43	.40	.43	1.34
Paints, varnishes, and related products	11.3	1.74	2.37	1.20	.93	1.95	.95
Ordnance	10.7	.44	n.a.	1.12	1.79	.05	.71
Agricultural chemicals	10.7	.86	.78	1.45	2.87	.18	.48
Plastics, synthetics, and resins	9.6	.44	.38	.40	.46	.67	.22
Engines and turbines	8.8	2.90	1.54	3.40	.44	2.60	7.68
Optical and health services supplies	8.7	.74	1.08	1.00	.18	.43	.47
Soaps and cosmetics	8.0	1.16	1.66	.84	.42	.77	1.38
Construction and material handling equipment	6.3	2.16	2.99	.75	4.52	1.09	2.30

*A concentration index greater than 1 indicates that the state has a greater percentage of employment in that industry than the U.S. average.

n.a. = not available or not disclosed.

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

Manufacturing (CAD/CAM) or Flexible Manufacturing Systems (FMS) but which otherwise perform very little internal R&D.

To avoid these problems, defining high-tech industries as those employing high proportions of scientific, engineering, and technical personnel has become a popular method, and the one used here. This occupational criterion is applied by measuring the percent of an industry's workforce employed as scientists, engineers, and technicians (SET) or sometimes scientists and engineers alone (SE). The presence of significant R&D activities within an industry will still be accounted for through this measure by the employment of scientists and engineers who perform such activities. In addition, the occupational criterion is more inclusive of those industries that adopt emerging technologies rather than undertake their own R&D because these industries presumably employ engineering and technical personnel to purchase and operate sophisticated equipment.

In arraying major manufacturing industries by their SET intensity, it is seen that the propensity to employ such personnel is highly skewed towards a few industries including the guided missiles and aerospace, computing equipment, aircraft, communications equipment, and pharmaceuticals industries (Table 1). Even within this industry subgroup, SET intensity falls off quickly. The number one ranked industry—aerospace—employs over one-third of its labor force in these professions while the third-ranked aircraft industry employs approximately 17 percent. Following the highest echelon, SET intensity falls off in a fairly con-

Table 2

High-tech manufacturing employment: Levels and growth

	Employment		Cumulative percent of total manufacturing employment		Percent growth 1978 to 1985	
	District	U.S.	District	U.S.	District	U.S.
Guided missilies, space vehicles, and parts	649	173,826	.02	.9	n.a.	100.7
Electronic computing equipment	6,817	277,433	.22	2.3	81.0	63.5
Aircrafts and parts	32,955	636,566	1.22	5.6	7.6	19.4
Radio, T.V., and communication equipment	89,766	652,883	3.92	9.0	-27.3	32.4
Drugs	44,337	206,323	5.22	10.1	- 5.0	11.3
Industrial and miscellaneous chemicals	46,062	397,070	6.62	12.2	-10.8	- 7.1
Photographic equipment and supplies	6,383	122,525	6.82	12.8	-38.9	- 7.5
Scientific and controlling instruments	43,529	333,830	8.12	14.5	- 8.7	17.2
Not specified electrical machinery	41,785	154,443	9.42	15.3	-34.5	-10.2
Office and accounting machines	8,963	62,810	9.72	15.6	-33.8	-14.2
Petroleum refining	11,124	141,060	10.02	16.3	-34.8	-14.4
Electrical machinery equipment n.e.c.	148,264	1,057,745	14.52	21.8	-12.6	15.4
Paints, varnishes, and related products	14,880	63,500*	14.92	22.1	- 7.5	- 7.6
Ordnance	4,655	78,094	15.02	22.5	.4	30.4
Agricultural chemicals	7,143	58,800*	15.22	22.8	-13.6	-12.8
Plastics, synthetics, and resins	10,373	172,664	15.52	23.7	- 6.0	-18.4
Engines and turbines	49,976	125,238	17.02	24.3	-32.1	- 8.9
Optical and health services supplies	24,895	247,873	17.82	25.6	27.6	19.9
Soaps and cosmetics	22,933	145,179	18.52	26.4	16.1	6.9
Construction and material handling equipment	74,335	252,581	21.72	27.7	-43.8	-32.2

*Estimates
SOURCE: U.S. Department of Labor, (E.S. 202).

tinuous fashion. Accordingly, there is no natural cutoff point at which to define the high-tech industries. Any grouping becomes somewhat arbitrary.

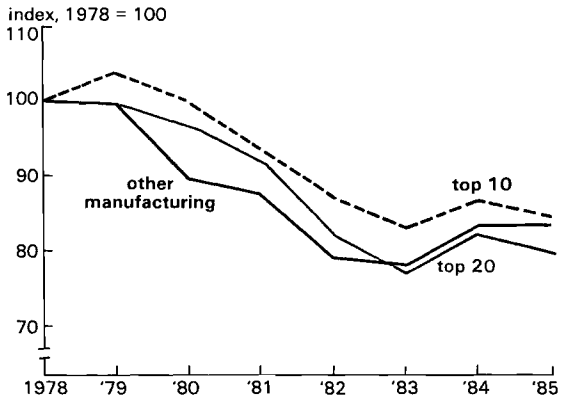
It is perhaps because of this arbitrary quality in defining high-tech industry that the findings of many studies are in conflict. Definitions that include a greater number of industries tend not to display the spectacular employment growth rates that are found using less inclusive high-tech groupings.[1] Differences in definition are equally important in comparing the technological orientation of the Midwest to the nation as a whole. Studies using a broader group of industries tend to find the Midwest's high-tech industry concentration to be close to the nation's average while others find Midwest concentration below average.[2]

High-tech industry in the Seventh District

Comparing industry concentration in the District with the nation reveals a reason why studies using a more narrow definition often show the Midwest's economy to be less oriented toward high-tech industries (Table 1). Relatively few District workers are employed in the most technology-intensive industries—aerospace computing equipment, and aircraft. The absence of these industries is also widely evident across individual states in the District, with the exception of a sizable presence of the aircraft industry in Indiana.

When the definition of a high-tech industry is further broadened, the District economy records a significant presence in the communications equipment and the pharmaceuticals industries. The states of Indiana and Illinois strongly contribute to employment in both of these industry sectors, while Iowa is strong in communications equipment and Michigan in pharmaceuticals. Further down the high-tech scale, the District displays above-average employment concentration in the production of electrical machinery and office and computing machinery. However, such high-tech main-

Figure 1
Employment growth in high tech industries vs. other manufacturing industries in the Seventh District



stays as scientific and controlling instruments, photographic equipment, ordnance, optical and health supplies, plastics, and industrial chemicals are only moderately represented. Towards the bottom of the high-tech scale, District employment concentration is heavy in industries typically thought of as traditional or mainstay to the Midwest, including the engines and turbine industry and the construction and materials handling industry.

The District's light concentration at the top of the high-tech spectrum and its heavy concentration at the bottom results in major fluctuations in the District's concentration of high-tech industries depending on the industries included. For example, in using the top half of industries as defined by SET concentration, the District's employment concentration lies 26 percent below the nation. However, using the 20 industries shown in Table 1, the District lies only 6 percent below the national average.

Overall, the District economy is best characterized as composed of only a moderate number of high-tech industries, varying with the particular industry definition that is used. Nevertheless, as the eight above-average industry concentration indexes indicate, the District economy maintains significant high-tech industry strengths.

Growth performance

The record of employment growth among the nation's high-tech industries reveals the elusive nature of the relation between technology intensity and employment growth (Table 2). First, it is quite common to find that employment has declined among individual high-tech industries. This is apparent among both top tier and bottom tier industries. And while overall employment growth is quite robust among the top 10 high-tech industries, the bulk of this employment growth derives from the top 5 industries—aerospace, computing equipment, aircraft, communications, and drugs.

This concentration of growth in the very top cluster of industries, along with the tenuous relation between growth and tech intensity among individual industries, suggests that there is no inherent growth potential in an industry's technology intensity. The 1978-1985 surge in a single subgroup of tech-intensive industries may have more to do with other factors. Some analysts suggest that strong federal government support, especially from the Department of Defense, is a common denominator behind the remarkable growth of these industries.[3] The growth rate of U.S. defense outlays has outstripped overall GNP growth in every year since 1978. At the same time, the nation's defensive systems have become increasingly reliant on sophisticated equipment produced by U.S. manufacturers.

The District's high-tech industries have performed dismally in relation to the national average. Among individual industries, only the electronic computing equipment, the optical-health care supplies and the soaps-cosmetics industries display superior employment growth in the District over the nation. Lagging District growth is especially evident for the upper echelon of high-tech industries (Table 2). Over the period of study, national employment in the top 10 grew by slightly under 20 percent while the District experienced a decline of 18 percent. The growth record improves in examining the entire top 20 high-tech industries. But within the second tier of industries, it is not that Seventh District performance improves but, rather, that similar rates of decline are exhibited between District industries and their national counterparts.

In perspective, the geography and performance of high-tech industry growth has not favored the Seventh District. The District's high tech manufacturing industries have performed very similarly to the remainder of its manufacturing base (Figure 1). This suggests

Table 3

Top twenty Seventh District manufacturing industries as ranked by employment concentration—1985

	Scientists and engineers			Scientists, engineers and technicians			1985
	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	3.32
Metal forgings and stamps	1.71	1.79	− .09	2.58	2.61	− .02	3.17
Farm machinery and equipment	4.94	4.00	+ .94	6.01	4.89	+1.12	2.81
Metalworking machinery	3.38	3.19	+ .19	4.27	4.27	0	2.66
Screw machine products	1.42	1.70	− .28	2.11	2.49	− .37	2.58
Iron and steel foundries	2.27	2.15	+ .12	3.57	3.39	+ .18	2.34
Grain mill products	2.39	2.00	+ .39	4.88	4.00	+ .88	2.20
Railroad locomotives and equipment	3.95	3.65	+ .30	4.71	4.53	+ .18	2.19
Household appliances	3.75	3.24	+ .51	5.13	4.43	+ .10	2.18
Construction and material handling equipment	5.81	5.01	+ .81	7.10	6.32	+ .77	2.16
Blast furnaces, steelworks, rolling and finishing mills	2.44	2.49	− .06	3.85	3.93	− .07	2.15
Machinery except electrical n.e.c.	4.08	3.80	+ .28	5.20	4.94	+ .26	1.98
Cutlery, handtools, and hardware	2.44	2.14	+ .30	3.34	2.85	+ .49	1.85
Paints, varnishes, and related products	5.83	5.26	+ .58	12.34	11.30	+1.04	1.72
Miscellaneous fabricated metal products	2.56	2.51	+ .06	3.50	3.57	− .07	1.69
Dairy products	1.26	.93	+ .33	3.95	3.05	+ .90	1.65
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
Cycles and miscellaneous trans. equipment	4.97	3.00	+1.97	6.36	3.83	+2.52	1.47

*Excludes tires and inner tubes

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

that fast-growing high-tech industries have not been isolated from the competitive problems that have affected the region. Although there are a few high-tech industries in which the District economy has excelled, the majority continue to fall behind the nation. Moreover, those industries that have exhibited the strongest growth at the national level are those in which District is not heavily involved.

Technology and mainstay industries

All the attention surrounding high-tech industries has highlighted the importance of the technology input to manufacturing. This importance extends not only to the high-tech firms but also to many industries in which technological activities comprise much smaller shares of total costs.

It has been recognized that each individual industry encompasses a string of activities, each with a varying degree of technological orientation. The "product cycle" theory suggests that an industry evolves through several distinct phases.[4] At its inception, a typical product will tend to be produced with a greater proportion of innovative personnel. This is partly because background research and product development will initially require more scientists, engineers, and technicians. And, preceding the period when mass production can be brought to bear, market demand may be thin so that production occurs in small customized batches requiring skilled personnel. Eventually, as product demand grows and the production process of familiar products becomes routinized, the need for more innovative activities will subside.

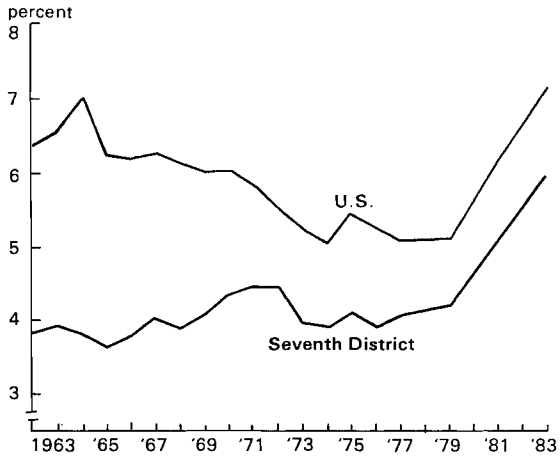
The product cycle model of industrial evolution can help to explain regional growth and also help to shape a region's development policies. It is possible that different activities within the same industry are attracted to different locales depending on features such as low labor costs, available labor skills, and access to government and university research institutions. To the extent that these features are clustered within particular regions, identifiable activities (e.g., R&D or routinized branch plant production) within the same industry may be concentrated in different regions. For example, a recent study of the semiconductor, medical instruments, computer programming, and computing equipment industries found that firms headquartered in other regions tended to establish relatively few branch plants in the North Central and Northeast regions. In contrast, both the South and West displayed much higher ratios of branch plants to headquarters.[5] These findings, when generalized across a region's economic base, suggest that a region's comparative advantage can be identified by *type of activity,* rather than by industry.

What types of activities characterize the Seventh District economy? Could the region be thought of as a seedbed of industrial product innovation, specializing in the more innovative activities of industry product cycles? We have already seen that for upper echelon high-tech industries the District does not appear to be such a seedbed.[6] But, it is possible that the District economy specializes in the technological activities of its more traditional manufacturing industries.

One way to go about answering this question is to array the District's mainstay industries alongside region-specific measures of each industry's tech intensity.

The District's top 20 industries as ranked by their employment concentration relative to the U.S. are chosen to represent the District's mainstay manufacturing sector (Table 3). In characterizing their tech intensity, these industries are not found among the highest tier in SET personnel, but neither are they in the lowest. With a few exceptions such as the dairy products and screw machine products industries, the SE and SET labor force share within the District's mainstay industries fall within one standard deviation of the U.S. mean of all manufacturing industries. Moreover, using either the SE or SET measure, a clear majority

Figure 2
Research and development expenditure as a percent of value added in manufacturing



of these industries can be counted as above the U.S. average. A comparison of the tech intensity of these industries with the tech intensity of their national counterparts reveals that the District tends to specialize in the tech-oriented activities of manufacturing.

That the District's mainstay industries tend to employ greater shares of SET personnel than their national counterparts suggests that these industries have retained their technology-intensive activities in the District. Such facilities are typified by R&D laboratories and early stage developmental production for which a skilled labor force is often crucial. This further suggests that the District maintains a technological edge in many of the industries in which it has a historical and present comparative advantage, perhaps serving as a seedbed for new products from these industries before spinning off routinized production to lower cost locales.

Additional support for the hypothesis that the District's manufacturing economy has become increasingly specialized in technology-oriented activities can be provided by evidence of recent trends in indicators of tech intensity. While trends based on SET personnel cannot be constructed, trends in industrial R&D expenditures within the District provide a very good alternative. Such data are examined against the backdrop of total manufacturing activity which is measured by value added, (the sum of payments for labor, R&D, capital, land, and profits that accrue in the process of

producing manufactured goods within the District). As such, value added is the best available measure of the region's overall manufacturing production activity.

Over the past two and one-half decades, the District's manufacturing sector has gained in R&D intensity relative to the nation (Figure 2). Throughout most of the 1960s and 1970s, the ratio of R&D to value added climbed in the District while the long-term national trend can best be characterized as stagnant or declining. This supports the notion that the District has retained its R&D activities to a greater extent than production activities.

From a policy perspective, the preceding evidence implies that economic development efforts in the District could well consider supporting the infrastructure necessary to attract and retain technologically advanced types of operations which generate product innovations. This is especially so for the District's traditional industries for which there is already a confluence of locational advantages to be found in the region. The region's traditional manufacturing sector displays some evidence of specialization in technology intensive activities, while the overall R&D intensity of the District's manufacturing sector has increased both in absolute terms and relative to the nation's manufacturing base.

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[1] For example see Richard W. Riche, Daniel Hecker, and John U. Burgan, "High technology today and tomorrow: a small slice of the employment pie," *Monthly Labor Review,* November, 1983.

[2] For example, one study using broad definitions of technology intensive manufacturing reported above average concentrations for the Great Lakes region. See Federal Reserve Bank of Chicago in conjunction with The Great Lakes Commission, *The Great Lakes Economy: A Resource and Industry Profile of the Great Lakes States,* Harbor House Publishers, Boyne City, Michigan, 1985. In studying high-tech employment concentration using several definitions, another study finds Great Lakes employment concentration to be growing as the definition is broadened. See Lynn E. Browne, "Can High-Tech Save the Great Lakes States?," *New England Economic Review,* November/December 1983.

[3] Empirical evidence to this effect is reported by Ann Markusen, Peter Hall, and Amy Glasmeier, *High-Tech America*, Allen & Unwin, Boston, 1986.

[4] One early discussion of the product cycle concept can be found in Raymond Vernon, "International Investment and International Trade in the Product Cycle," *Quarterly Journal of Economics,* vol. 80, pps. 190-207. For a discussion of the regional application of the product cycle concept see John Rees and Howard Stafford, "Theories of Regional Growth and Industrial Location: Their Relevance for Understanding High-Tech Complexes," in John Rees ed., *Technology, Regions, and Policy,* Rowman and Littlefield Publishers, Totowa, New Jersey, 1986, pps. 23-50.

[5] Edward J. Malecki, "Industrial Location and Corporate Organization in High Technology Industries," *Economic Geography,* Vol. 61, no. 4, October, 1985.

[6] This topic is further addressed by Alenka S. Giese and William A. Testa, *Measuring Regional High Tech Activity with Occupational Data,* Federal Reserve Bank of Chicago, Regional Working Paper 1987/1.