High Tech Manufacturing: Firm Size, Industry and Population Density

Ernie Goss
George S. Vozikis

ABSTRACT. Location theorists have emphasized the importance of agglomeration economies in explaining the concentration of industrial activity. They have divided these economies into portions that relate to average industry size, firm size, and market size. This study examines these three factors, in the context of value created, and concludes that each is statistically different for high tech industries in comparison to non-high tech industries. This finding adds an important dimension to state industrial development strategies, particularly those focused on high tech.

Introduction

The popular press is replete with accounts of regional development precipitated by the introduction of high tech ventures into the local economy such as those describing the rapid development of California's Silicon Valley and North Carolina's Research Triangle. This publicity, combined with the fact that from 1975 to 1990, high tech manufacturing grew 17.8% while non-high tech manufacturing expanded only 3.3% (Bureau of Labor Statistics, 1975 and 1990), has encouraged local and state policymakers to concentrate on the development of high tech industries, linking thus the issue of location with the concept of "high tech."

The term "high tech," as related to manufacturing, generally connotes manufacturing industries that share common characteristics of substantial technological innovation. The Small Business Administration (SBA) defines "innovation" as a process that begins with an invention, proceeds to development of the invention, and finally results in the introduction of a new product, process or service to the marketplace (Edwards and Gordon, 1984). Innovative output, on the other hand, is the product of knowledge-generating inputs, most notably R&D (Grilliches, 1979). Quantitatively, researchers have classified an industry as innovative, according to the industry's spending on research and development as it relates to total sales, and by the industry's relative employment of scientists, engineers and other technically oriented personnel (Smith and Borowski, 1985). Therefore, manufacturing industries that score relatively high in both these measures can be safely designated as high tech or innovative industries.

Using these two indicators, Smith and Borowski classified the two digit SIC manufacturing industries of Chemicals (SIC 28), Electrical and Electronic Equipment (SIC 36), and Instruments (SIC 38) as high tech, since each of these three industries spent well above the overall industry 3.1% average for research and development (R&D) expenditures as a percentage of revenues, and at the same time employed well above the overall industry 6.3% average of technically trained personnel (Riche, Hecker and Burgan, 1983). Furthermore, in terms of innovation output, Acs and Audretsch (1990), using data from the SBA Small Business Database, also confirmed that these three industries, and additionally SIC 35 (Machinery except Electrical), produced the greatest weighted average number of innovations.

On the other hand, location theorists have also emphasized the importance of agglomeration economies in explaining the concentration of industrial activity and have traditionally divided the agglomeration economies into portions that relate to average industry size (localization econ-

Final version accepted on May 10, 1993

Ernie Goss
Jack A. MacAllister Chairholder
in Regional Economics
Creighton University
Omaha, NE 68178

and

George S. Vozikis
The Alvah H. Chapman, Jr.
Chair in Business Administration
The Citadel
Charleston, SC 29409

Small Business Economics 6: 291—297, 1994.

omies), average plant size (scale/firm size economies), or average market size (urbanization economies) (Carlino, 1980). The objective of this study is to investigate how the innovative input and output environments surrounding the three high tech industries of Chemicals (SIC 28), Electrical and Electronic Equipment (SIC 36), and Instruments (SIC 38) affect agglomeration economies. Whereas past studies have lumped agglomeration economies together, this study will separate the agglomeration economies into those relating to industry size, firm size and market size to determine if they do indeed differ for high tech industries.

High tech industries, agglomeration economies and industrial development strategies

Data and past research studies indicate that high tech firms have tended to cluster together. For example, in terms of the concentration of manufacturing industries according to data from the 1987 Census of Manufacturers, five states, which accounted for only 31.6% of the U.S.'s employment accounted for 40.5% of the U.S. high tech employment. These observations and the publicity surrounding the rapid development of California's Silicon Valley and North Carolina's Research Triangle has prompted state and regional policymakers to attempt to replicate these high tech models in their own locale. More in-depth research examining this issue, however, has concluded that, in many cases, either industry innovation tends to decrease as the level of industry concentration rises (Acs and Audretsch, 1988), or this policy may not be in the best interest of the regional economy (Bezdek, 1975; Browne, 1984; Galbraith, 1985).

Galbraith in particular, found that due to the lack of an adequate supply of technically trained workers, most communities are ill-suited in becoming high tech centers, since high tech firms tend to be "footloose" in the sense that, except for labor skills, these firms were much more mobile in terms of proximity to needed inputs and relevant output markets than previously anticipated. Galbraith concluded that states and communities that have in the past emphasized traditional location benefits such as low taxes, cheap labor, and low unionization to attract industry, will find themselves much less competitive in their recruitment efforts if they shift their focus exclusively to high tech firms.

The Bezdek, Browne, Galbraith, and Acs and Audretsch studies therefore, seem to cast doubt on the policy of community leaders who pursue high tech employment options disregarding other, perhaps more viable industries, in terms of additions to regional income and increases in employment. Furthermore, some other studies (Caves and Riegel, 1980; Acs and Audretsch, 1988) have also found strong relationships between firm size and innovation rates indicating that state and regional high tech development strategies should give additional consideration to firm size. Acs and Audretsch (1988) for example, found that for seven of seventeen industries defined at the two-digit level, the small firm innovation share was significantly larger than the small firm employment share. Three of the seven were high tech industries, as defined earlier, implying that for high tech industries, smaller firms are relatively more innovative.

However, all these studies compound localization economies, firm size, and urbanization economies, and if each of these factors has its own impact on innovation and productivity, they should be disaggregated as this study attempts to do, and their effects discussed separately.

Location economies

According to Scott and Storper (1987, p. 224), "Diverse agglomeration economies flow from the concentration of many workers in one place, and these agglomeration economies help to underpin the overall pattern of localized growth." This concentration is usually attributed to the firm's need for specialized and skilled labor (Galbraith, 1987). Similarly, Browne (1980, p. 16) concludes:

> Industries which are undergoing rapid change and innovation and which produce specialty products tend to cluster together because of the need for specialized resources, particularly skilled labor, not available elsewhere.

Other researchers have found different factors encouraging high tech to locate in close proximity to other innovative firms. According to Markusen *et al.* (1986), information needs of innovative firms compel potential competitors to locate in

close proximity to the pioneering firm, while in a case study, Saxenian (1985) estimated that between 1959 and 1979, Fairchild Semiconductor spawned over fifty new high tech companies in Santa Clara County alone. Additionally, by quantifying the returns from clustering, Hill and Naroff (1984, p. 33), found that for high tech firms there were significantly higher returns and lower risks associated with location in an area in which there already was a concentration of high technology firms. These higher returns are often referred to as "spillover" benefits, since the innovative activity creates research "spillover" effects to a specific location, because of the geographic proximity to the spillover source (Jaffe, 1986 & 1989).

Spillovers can also result from an interaction between the public sector and the private sector. For example, Lund (1986) concluded from his survey of R&D managers that the presence of research universities was a factor in industrial R&D lab locations. Jaffe (1989) found a similar association between industry R&D and university research: In 1981, twenty-nine states with 78% of the U.S. population performed 76% of industry R&D, 81% of university research, and had 85% of patents assigned to corporations within their borders. Jaffe concludes that there is indeed an association between industry R&D and university research within these states, but in terms of causality it is university research that causes industry R&D and not vice versa. Thus, a state or region that decides to improve its university research system will create "spillover" benefits and increase local innovation by attracting industrial R&D work and higher productivity (ibid, p. 968).

Research has also found spillovers between industries located in close geographic proximity. Jaffe (1986) found significant spillovers to one industry from research and development spending in another, because the investment by a firm in R&D reduces not only its own production costs but also, as a result of spillovers, the costs of other firms in the locality. Likewise, Bernstein and Nadiri (1988) found statistically significant inter-industry spillovers among innovative industries which were geographically clustered. Thus, it seems that there are indeed inherent advantages to the geographic concentration of firms in industries in which there are relatively high expenditures on research and development. Acs, Audretsch and Feldman (1991 and 1993) extending Jaffe's study conclude that "spillover" benefits among large firms stem relatively more from corporate R&D, while spillovers among small firms emanate more from university research labs.

In general, it seems that most empirical studies conclude that high tech or innovative industries benefit from locating in areas with a high concentration of innovative industries. Other research, however, has found that agglomeration economies in innovative industries are derived from firm or company size.

Firm size economies

The economies associated with indivisibilities and specialization lead to clustering, not only of the activity in question (internal scale economies), but also of other activities which are vertically related to it. Chinitz (1961) contends that a large corporation is more likely to respond to investment opportunities in its core activity at other locations than to invest at home in unrelated industries. The small firm, on the other hand, according to Chinitz, is more likely to make its surplus resources available for local investment in unrelated industries than for distant opportunities in the same industry. Thus, capital is more likely to be available for new firms and industries in an area where firms are small and many, rather than where firms are large and few (Evans, 1986).

Furthermore, according to Winter (1984), large and small firm innovations are promoted under differing economic and technological conditions, and most empirical studies indicate that, *ceteris paribus*, there are inherent advantages for small firms in high tech industries. Empirical examinations of the relationship between innovation and firm size have generally found, indeed, a strong negative relationship between these two parameters, indicating that strong consideration should be given to firm size in terms of high tech development strategies (Caves and Pugel, 1980; Acs and Audretsch, 1987). In his empirical investigation of SMSAs in the U.S., Carlino (1980), in a test of the Chinitz hypothesis, also found internal scale economies to be negative and statistically significant for three of nineteen industries (two of the three being high tech).

Contrary to Carlino's findings, Markusen *et al.*

(1986) measured a high degree of market power in some high tech industries and presented a case for the emergence of the conglomerate firm in high tech. They concluded that, "market power proves to be considerable in a majority of high tech sectors, challenging the popular image of high tech as a relatively competitive, cutthroat environment" (Markusen *et al.*, 1986, p. 70). On the other hand, Acs and Audretsch (1987) calculated that for three high tech industries, small-firm innovation share was significantly greater than small-firm employment share. In the case of non-high tech, they found that for only four of fourteen non high-tech industries was the small-firm innovation share greater than the small-firm employment share and concluded that small firms indeed tend to have the advantage in generating innovations in innovative industries. They found that the ratio of innovations per employee was 6.64 times greater for small firms than for large firms in innovative industries, while for manufacturing overall, the small firms were only 43 percent more innovative than large firms.

Though not unanimous, most studies conclude that in terms of firm size economies, small firms do indeed possess a differential advantage over large firms in innovative industries.

Urbanization economies

There are large numbers of specialized firms for which their per business demand is so small that large population centers are required to provide the necessary labor input and output demand. In terms of the relationship between high tech manufacturing and population density, data from the 1987 Census of Manufacturing show a positive relationship between these two factors. The median population per square mile in the states with the largest employment in high tech was 208.3, while on the other hand, the median population per square mile in the states with the lowest employment in high tech was 9.3.

Mansfield (1981) provides evidence that the spatial diffusion of innovation begins in the densely populated areas and then is transmitted down to less densely populated areas along a hierarchy of population, and consequently, more innovative industries will be expected to locate in densely populated areas. Since high tech industries are more dependent on skilled labor input than non-high tech industries (Galbraith, 1987), *ceteris paribus*, one would expect to see high tech firms drawn to areas of greater density of population. Miller (1989) found high tech firms, particularly the more innovative, to indeed be drawn to densely populated areas due to the availability of professional and technical workers, seed capital, and close contacts with customers and suppliers. Carlino (1980), however, found support for the existence of urbanization economies for thirteen of nineteen industries, none of which were in high tech. Likewise, Begg and Cameron (1988), found no correlation between the location of high tech manufacturing firms and city size.

Now that the theoretical framework of the impact of industry size, firm size, and population density on innovation has been examined and disaggregated, this study will determine:

1) if there are differentially greater returns to high tech manufacturing venture initiation in locations that possess a relatively large high tech base.
2) if larger average firm size contributes to differentially greater returns to high tech industries than non-high tech industries, and finally,
3) if population density contributes to differentially greater returns to high tech manufacturing than to non-high tech industries.

Methodology

A regression analysis, as presented in Equation (1), will empirically test the disaggregated effects of the impact of industry size, firm size, and population density on productivity of industries defined at the two-digit SIC level as high tech or non-high tech.

$$VALCRT = f(LQ, AVFMSIZE, DENSITY, STVALCR) \quad (1)$$

Where,

VALCRT = *value created per worker.* "Value created" is the total of the firm's ending inventory plus its work-in-process inventory at the end of the period minus its beginning inventory, and includes all direct and indirect labor and capital that are

associated with production. Dividing value created by the number of workers accurately reflects the efficiency of capital, which is hypothesized to be a function of the location variables.

LQ = *the location quotient of the industry.* It is calculated by dividing the state's percent employment in the two-digit manufacturing industry by the nation's percent employment in the same industry. Thus, numbers greater than one indicate that the state's employment is more concentrated in an industry than the U.S. as a whole, and vice versa. As stated earlier, the coefficient for this variable is expected to be more positive for high tech industries than for non-high tech industries.

AVFMSIZE = *average employment size of firms* within the industry. As hypothesized, the coefficient of this variable is expected to be less positive (or more negative) for high tech industries than for non-high tech industries.

DENSITY = *1987 state population per square mile.* As hypothesized, the coefficient of this variable is expected to be more positive (or less negative), for high tech industries than for non-high tech industries, reflecting empirical evidence that high tech industries benefit more from a greater population density.

STVALCR = *total manufacturing value* created in a state for 1987 per worker. This variable is inserted to control for differential manufacturing productivity rates among the states, and the estimated coefficient is expected to possess a positive sign in the regression equation.

One must keep in mind that this study used a cross-sectional approach to test what is in reality a dynamic process. The model is intended to test only whether at a given time, 1987, the differentials across states in terms of value created by industries can be explained by average firm size, industry size, or population density. All data was extracted from the 1987 Census of Manufacturing, except DENSITY which originated from the U.S. Statistical Abstract.

Results

Table I presents the results from empirically estimating Equation (1). Each of the estimated coefficients for high tech industries is statistically significant at the 95% level of confidence and possesses the expected sign.

TABLE I
Regression results of the impact of agglomeration economies on high tech and non-high tech industries

	Coefficient	t-value
Intercept	20.9412*	2.083
Location Quotient (LQ) (Non High Tech)	0.613207	0.761
Location Quotient (LQ) (High Tech)	33.22911*	5.4
AVFMSIZE (Non-High Tech)	193.873	7.906
AVFMSIZE (High Tech)	-333.19*	-6.589
1987 Population DENSITY (Non-High Tech)	-2.33571*	-2.228
1987 Population DENSITY (High Tech)	6.5865*	5.957
Total value created per worker STVALCR	0.0606875*	4.098
R^2 =	0.22	
Number of Observations	765	

"*" indicates that estimated coefficient is statistically different from zero at the 95% level of confidence.

Industry size. In terms of localization economies, results from Table I indicate that there are indeed benefits for the concentration of high tech firms, that is, value created per worker is greater for high tech industries in states with an already high concentration of high tech firms. The results support the general contention that areas with an already high concentration of high tech firms should possess a competitive advantage in their attempts to recruit other high tech firms, *ceteris paribus*, since in areas where there is a concentration of high tech firms, there are more spillover effects reflected in higher value created per worker. On the other hand, the statistically insignificant coefficient for the location quotient (LQ) for non-high tech industries, also indicates that there are no such benefits for the concentration of non-high tech firms. On the practical side, these findings, place doubt upon a high tech development and/or recruitment philosophy for

communities that do not already possess high concentrations of high tech firms.

Firm size. In terms of firm size economies, the results of this study indicate that in high tech industries, smaller firms are indeed more productive than large firms. This finding supports Acs and Audretsch's 1987 study which found that small firms were significantly more innovative than large firms in high tech industries. The results from this study also indicate that this high innovative rate is reflected in higher productivity as measured by value created per worker, and support the Chinitz (1961) hypothesis for high tech industries which proposes that agglomeration economies will be greater in areas with a large number of small high tech firms than in areas with a small number of large high tech firms, *ceteris paribus*. The regression results, however, do not support the same Chinitz hypothesis for non-high tech industries.

Market size. According to the results in Table I, a higher density of population is associated with higher value created per worker in high tech manufacturing industries, and given the importance of labor input to the high tech production process, this finding appears to be consistent with the hypothesized relationship. Thus, areas of high density of population i.e. larger markets, appear to have a competitive advantage in the development of high tech industries, *ceteris paribus*.

Overall, the results of this study indicate that agglomeration economies separated and disaggregated into those relating to industry size, firm size, and market size, do indeed differ according to whether or not the industry is a high tech industry. Table II summarizes the results in terms of the presence or absence of an innovation and productivity advantage for high tech or non-high tech firms as a result of each agglomeration economy factor.

TABLE II
Innovation and productivity advantages from agglomeration economy factors for high tech and non-high tech industries

Agglomeration economy factors	High tech industries	Non-high tech industries
Large Industry Size	Advantage	No Advantage
Large Firm Size	No Advantage	Advantage
Large Market Size	Advantage	No Advantage

Conclusion

This study examined the impact of agglomeration economies disaggregated by industry size, firm size, and market size on value created in manufacturing and found that differences do exist between high tech and non-high tech industries. These findings add an important dimension to state industrial recruitment and development strategies, particularly those focused on economic development based on high tech development. Specifically, in terms of value created by high tech, incremental benefits are achieved by the incubation and continuous recruitment of small high tech firms, *ceteris paribus*. Additionally, the benefits derived by high tech firms are greater for firms located in states with larger high tech location quotients and in more densely populated states. As mentioned earlier however, due to the limitations imposed by the use of cross-sectional data, these results are presented as tentative and form the basis for an expanded study which uses both cross-sectional and dynamic time series data.

References

Acs, Zoltan J. and David B. Audretsch, 1987, 'Innovation, Market Structure and Firm Size', *Review of Economics and Statistics* **69**(4), 567–575.

Acs, Z. J. and David B. Audretsch, 1988, 'Innovation in Large and Small Firms: An Empirical Analysis', *American Economic Review* **78**(4), 678–690.

Acs, Zoltan, David B. Audretsch, and Maryann P. Feldman, 1992, 'Real Effects of Academic Research', *American Economic Review* **82**, 363–367.

Acs, Zoltan, David B. Audretsch, and Maryann P. Feldman, 1993, 'R&D Spillovers and Recipient Firms Size', *Review of Economic and Statistics* **75**(4).

Begg, I. G. and G. C. Cameron, 1988, 'High Technology Location and the Urban Areas of Great Britain', *Urban Studies* **25**, 361–379.

Bezdek, Roger H., 1975, 'The 1980 Economic Impact Regional and Occupational – of Compensated Shifts in Defense Spending', *Journal of Regional Science* **15**(2), 183–98.

Bernstein, J. I. and Ishaq Nadiri, 1988, 'Interindustry R&D Spillover, Rates of Return and Production in High-Tech Industries', *American Economic Review* **78**(2), 429–434.

Browne, L. E., 1984, 'High Technology and Regional Economic Development', *Economic Indicators*, Federal Reserve Bank of Boston.

Carlino, G. A., 1980, 'Contrasts in Agglomeration: New York and Pittsburgh Reconsidered', *Urban Studies* **17**, 3433—3451.

Caves, Richard E. and Thomas Pugel, A., 1980, *Intra-Industry Differences in Conduct and Performance: Viable Strategies in U.S. Manufacturing Industries*, New York, New York: New York University Press.

Chinitz, B., 1961, 'Contrasts in Agglomeration: New York and Pittsburgh', *American Economic Review* **50**, 279—89.

Edwards, Keith L. and Theodore, J. Gordon, 1984, 'Characterization of Innovations, Introduced on the U.S. Market in 1982', *The Futures Groups*, U.S. Small Business Administration, Contract No. SBA—6050—0a—82.

Employment and Earnings. U.S. Bureau of Labor Statistics, 1990 and 1975.

Evans, A. W., 1986, 'Comparisons of Agglomeration: Or What Chinitz Really Said', *Urban Studies* **23**, 387—389.

Galbraith, C., 1985, 'High Technology Location and Development: The Case of Orange County', *California Management Review* **28**(1), 98—109.

Grilliches, Zvi, 1979, 'Issues in Assessing the Contribution of R&D to Productivity Growth', *Bell Journal of Economics* **10**, 92—116.

Hill, A. and C. Naroff, 1984, 'The Effect of Location on the Performance of High Tech Firms', *Financial Management* **13**, 27—36.

Jaffe, Adam B., 1986, 'Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents Profits and Market Value', *American Economic Review* **76**, 984—1001.

Jaffe, Adam B., 1989, 'Real Effects of Academic Research', *American Economic Review* **79**(5), 957—970.

Lund, Leonard, 1986, 'Locating Corporate R&D Facilities', Conference Board Report No. 892, Conference Board, New York.

Mansfield, Edwin, 1981, 'Composition of R and D Expenditures: Relationship to Size of Firm Concentration and Innovative Output', *Review of Economics and Statistics* **63**, 610—615.

Mansfield, Edwin, 1984, 'Comment on Using Linked Patent and R&D Data to Measure Interindustry Technology Flows', in Zvi Grilliches (ed.), *R&D, Patents and Productivity*, Chicago: University of Chicago.

Markusen, A., P. Hall, and A. Glasmeier, 1986, *High Tech America*, Boston: Allen & Unwin.

Miller, J. P., 1989, 'The Product Cycle and High Technology Industry in Non-Metropolitan Areas, 1976—1980', *The Review of Regional Studies* **19**(1), 1—12.

Riche, R., D. E. Hecker, and J. U. Burgan, 1983, 'High Technology Today and Tomorrow: A Small Slice of the Employment Pie', *Monthly Labor Review*, 50—58.

Saxenian, A. 'The Genesis of Silicon Valley', in P. Hall and A. Markusen (eds.), *Silicon Landscapes*, Boston, MA: Allen & Unwin.

Scott, A. J. and Storper, M., 1987, 'High Technology Industry and Regional Development: A Theoretical Critique and Reconstruction', *International Social Science Journal* **112**, 216—232.

Smith, T. R. and M. Borowski, 1985, 'High-Technology Development in the Tenth District', *Economic Review* **924**.

Vozikis, G. S. and E. Gross, 1987, 'High Tech Venture Initiation in High Tech vs Low Tech Regions', A presentation at the 1987 Annual Meeting of the Academy of Management, New Orleans, LA.

Winter, Sidney G., 1984, 'Schumpeterian Competition in Alternative Technological Regimes', *Journal of Economic Behavior and Organization* **5**, 287—320.