12-3-1993

Development of High-technology Industries in the Portland/Vancouver Metropolitan Area: an Analysis of Regional and Intraregional Factors Affecting High-tech Firm Locations

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https://doi.org/10.15760/etd.6777

THESIS APPROVAL

The abstract and thesis of Ulf Eichner for the Master of Arts in Geography were presented December 3, 1993, and accepted by the thesis committee and the department.

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AN ABSTRACT OF THE THESIS OF Ulf Eichner for the Master of Arts in Geography presented December 3, 1993.

Title: Development of High-Technology Industries in the Portland/Vancouver Metropolitan Area: An Analysis of Regional and Intraregional Factors Affecting High-Tech Firm Locations.

This thesis aims to investigate local conditions of high-tech industry development in the Portland/Vancouver CMSA. To do so, the research proceeds in four major stages. First, it is analyzed how historical factors contributed to the rise of high-tech industries in the CMSA. The second part consists of mapping the distribution pattern of high-tech establishments. The U.S. Bureau of Census' County Business Patterns statistics are used to calculate the number of high-tech establishments and employees by branch (SIC code) and county; two high-tech directories help to identify the exact firm locations. Thirdly, an explanatory set of locational factors is established, based on interviews with various regional and local economic development agencies and on a review of relevant economic theories. Finally, the impact of state and local policies on high-tech firm locational decisions is elaborated.

The development of high-tech industries in the Portland/Vancouver CMSA can be divided up into three phases. While the first phase (1945 to 1974) is mainly distinguished by local entrepreneurship, the second phase (1975 to 1984) is characterized by an in-migration of high-tech firms headquartered outside the Pacific Northwest. Beginning in 1985 (phase III), Japanese high-tech investment became the most significant growth factor.

High-tech establishments are not evenly distributed over the metropolitan area, but their locations are rather marked by distinctive clusters. Recent high-tech industry development is largely a suburban phenomenon, avoiding inner-city areas and the CMSA's eastside with its traditional metalworking industry base.

Most Californian and foreign-owned high-tech companies have established only standardized branch production and assembly facilities in the Portland/Vancouver CMSA to take advantage of low business costs. Although the high quality of life enables high-tech firms to recruit easily scientific, engineering, and technical personnel to the CMSA, the majority of companies has not yet set up R&D centers. Main reason is the missing link to a prominent research university nearby. Therefore, state and local policies have shifted their focus from attracting foreign branch plants to improving the quality of educational institutions.

DEVELOPMENT OF HIGH-TECHNOLOGY INDUSTRIES IN THE PORTLAND/ VANCOUVER METROPOLITAN AREA: AN ANALYSIS OF REGIONAL AND INTRAREGIONAL FACTORS AFFECTING HIGH-TECH FIRM LOCATIONS

by

ULF EICHNER

A thesis submitted in partial fulfillment of the
requirements for the degree of

MASTER OF ARTS
in
GEOGRAPHY

Portland State University
1995

ACKNOWLEDGEMENTS

First of all, I am indebted to my adviser, Dr. Thomas Harvey, for reviewing earlier drafts of this thesis and thereby enabling me to sharpen up the direction of my research. I also wish to thank Mrs. Carolyn Perry for helping me with the technical aspects of the thesis preparation. Finally, I am especially grateful to my parents for their financial support, without it the completion of this research project would have been impossible.

Ulf Eichner

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CHAPTER I

INTRODUCTION TO THE RESEARCH PROBLEM

The Portland/Vancouver metropolitan area (CMSA; Consolidated Metropolitan Statistical Area) has become a major center for high-technology industries, often labeled with fairly grandiose names like "Oregon Silicon Forest" or "Silicon Valley North", indicating the degree to which Silicon Valley is accepted as a model for economic development. What contributed to the rise of high-tech industries in the Portland/Vancouver CMSA and how significant is the region's high-tech industry in terms of its scale, diversity, and dynamics?

This study investigates local conditions of high-tech development - an approach that contrasts with much of the previous work in industrial geography. Rather than focusing on the global environment and corporate strategy of multilocation firms, regional and intraregional factors that influence patterns of high-tech industry locations in the Portland/Vancouver CMSA will be discussed. Knowing these factors is important for developing state and local policy strategies to generate the regional or local conditions that would promote high-technology development. To date most regions, including Portland, are actively pursuing economic development by attempting to enhance the technological level of their firms and to nurture new local or indigenous firms. The emergence of new high-tech centers has raised the hopes of local and state leaders throughout the U.S. and elsewhere that high-tech regions can be created and fostered away from high-tech cores such as Silicon Valley and Boston's Route 128 (Gaile and Willmott 1989).

The analysis of high-tech development in the Portland/ Vancouver CMSA employed in this research project consists of four major elements. The first section describes how historical factors contributed to the rise of high-tech industries in the CMSA. Three phases are identified to explain the growth of high-tech industries in the area from 1945 to the present. The first phase from 1945 to 1974 is mainly distinguished by local entrepreneurship, while the second phase from 1975 to 1984 marks the beginning of an in-migration of out-of-state U.S.-owned and later foreign-owned high-tech firms. The third phase, starting in 1985, represents the arrival of Japanese high-tech firms as the most significant growth factor.

The second part of the analysis focuses on the distribution pattern of high-tech establishments in the Portland/Vancouver CMSA. Two data sets are available providing fairly recent information on the number of high-tech establishments, their locations and employment data, as well as to which branch (SIC code) they belong. The first data set comprises the U.S. Bureau of Census' County Business Patterns covering all five counties of the Consolidated Metropolitan Statistical Area (Multnomah, Washington, Clackamas, Yamhill, OR, and Clark Co., WA) as of 1988. The second source is two high-tech directories for the Portland/Vancouver CMSA offering brief information on individual firms as of 1991. The research shows that high-tech establishments are not evenly distributed over the metropolitan area, but that their locations are rather characterized by distinctive clusters.

After mapping the distribution of high-tech establishments the next questions to arise are why high-tech industries locate in the Portland/Vancouver CMSA and what determines their locational choice within the region. Chapter III will address these issues using information obtained from various state, regional, and local economic development agencies. The aim is to establish an explanatory set of locational factors and also to analyze what may be disadvantageous for high-tech companies when locating in the CMSA. In a separate paragraph, those factors influencing the intraregional pattern of high-tech industry locations within the Portland/Vancouver CMSA will be discussed. They can aid in explaining concentrations of high-tech establishments in particular parts of the metropolitan area.

In the final section of the analysis state and local policy strategies relating to high-tech industry development are summarized. Policy decisions that were found to have had an impact on high-tech firm locational decisions are elaborated, as are the current business assistance programs - as far as they are dealing with high-tech companies.

WHAT DOES HIGH-TECHNOLOGY MEAN?

One problem with research on high-technology industries is that there is no widely accepted definition of what "high-technology" means. Generally, two different approaches to defining high-tech industries are discussed in the literature: they are based on the occupational composition of industry classes, on expenditures for applied R&D relative to total industry sales, or on a combination of both.

Markusen, Hall, and Glasmeier (1986) define high-technology industries on the basis of occupational profile. Accordingly, high-tech industries are those in which the proportion of engineers, engineering technicians, computer scientists, life scientists, and mathematicians exceeds the manufacturing average.

The Bureau of Labor Statistics has identified three groups of "high-technology" industries depending on different criteria being applied to each group (Office of Technology Assessment 1984). The first group comprises industries which employ a proportion of technology-oriented workers greater than 1.5 times the average for all industries - or 5.1% of the total number of employees. The resulting list includes 48 three-digit industries based on SIC codes (see Table I, p.6/7, col.1). This group represents the broadest of the three high-tech industry definitions developed by the Bureau of Labor Statistics.

The second group contains a very narrow range of industries. Criterion is the ratio of R&D expenditures to sales which has to be greater than twice the average for all industries - or a minimum of 6.2%. As Table I (p.6/7, col.2) shows, the second group includes only six three-digit industries.

In the third group, the proportion of technology-oriented workers has to be greater than the average for all manufacturing industries (6.3%) and the R&D expenditures-to-sales ratio has to be close to or above the average for all industries (3.1%). The resulting list includes 28 three-digit industries (see Table I, p.6/7, col.3).

The third group corresponds closely to two other definitions used to investigate the structure and regional distribution of high-technology industry. One, developed by Glasmeier, Hall, and Markusen (1983), leads to a selection of 29 three-digit industries which have greater than the national manufacturing average of scientific and technical occupations (Table I, p.6/7, col.B). In the other, developed by Armington, Harris, and Odle (1983), high-technology

TABLE I

DEFINITIONS OF HIGH-TECHNOLOGY INDUSTRY

SIC	Industry	--BLS-- 1	2	3	A	B
131	Crude petroleum and natural gas	x			x	
1321	Natural gas liquids				x	
162	Heavy construction, except highway and street	x				
281	Industrial inorganic chemicals	x		x	x	x
282	Plastic materials and synthetics	x		x	x	x
283	Drugs	x	x	x	x	x
284	Soaps, cleaners, and toilet preparations	x		x		x
285	Paints and allied products	x		x		x
286	Industrial organic chemicals	x		x	x	x
287	Agricultural chemicals	x		x		x
289	Miscellaneous chemical products	x		x	x	x
291	Petroleum refining	x		x	x	x
301	Tires and inner tubes	x				
3031	Reclaimed rubber					x
324	Cement, hydraulic	x				
348	Ordnance and accessories	x		x	x	x
351	Engines and turbines	x		x	x	x
352	Farm and garden machinery	x				
353	Construction, mining, and material handling machinery	x			x	x
354	Metalworking machinery	x				x
355	Special industry machinery, except metalworking	x		x		
356	General industrial machinery	x			x	x
357	Office, computing and accounting machines	x	x	x	x	x
358	Refrigeration and service industry machinery	x				
361	Electric transmission and distribution equipment	x		x		x
362	Electrical industrial apparatus	x		x	x	x
363	Household appliances	x				
364	Electric lighting and wiring equipment	x				
365	Radio and TV receiving equipment	x		x	x	x
366	Communication equipment	x	x	x	x	x
367	Electronic components and accessories	x	x	x	x	x
369	Miscellaneous electrical machinery	x		x		
371	Motor vehicles and equipment	x				
372	Aircraft and parts	x	x	x	x	x
3743	Railroad equipment					x
376	Guided missiles and space vehicles	x	x	x	x	x

TABLE I

DEFINITIONS OF HIGH-TECHNOLOGY INDUSTRY
(continued)

		--BLS--				
SIC	Industry	1	2	3	A	B
381	Engineering, laboratory, scientific, and research instruments	x		x	x	x
382	Measuring and controlling instruments	x		x	x	x
383	Optical instruments and lenses	x		x	x	x
384	Surgical, medical, and dental instruments	x		x	x	x
3851	Ophthalmic goods				x	
386	Photographic equipment and supplies	x		x	x	x
3872	Watches, clocks				x	
483	Radio and TV broadcasting	x				
489	Communications services, n.e.c.	x				
491	Electric services	x				
493	Combination electric, gas, and other utility services	x				
506	Wholesale trade, electrical goods	x				
508	Wholesale trade, machinery, equipment, and supplies	x				
737	Computer and data processing services	x		x	x	
7397	Commercial testing laboratories				x	
7391	Research and development laboratories	x		x	x	
891	Engineering, architectural, and surveying services	x				
892	Noncommercial educational, scientific, and research organizations	x			x	

A: Def. developed by Armington, Harris, and Odle (1983);
B: Def. developed by Glasmeier, Hall, and Markusen (1983).

Source: Office of Technology Assessment 1984, p.19.

industries are also defined based on occupational composition, but those industry categories with lower proportions of scientific and technical personnel but high R&D expenditures are added. These are "radio and TV receiving equipment", "surgical, medical, and dental instruments", "ophthalmic goods", and "watches, clocks". As a result, 29 three-digit industries were also identified to satisfy these criteria (Table I, p.6/7, col.A), but there are slight variations in the selected SIC codes as compared to the Glasmeier, Hall, and Markusen definition.

The definition representing the third group of SIC codes as identified by the Bureau of Labor Statistics is used in this research project. This "mid-range" definition incorporates the two most commonly utilized measures to define high-tech industries which are R&D expenditures-to-sales ratio and proportion of scientific, engineering, and technical personnel in the industry's total work force. Although the definition involves certain problems (see below), it was adopted since most studies agree that the two variables, R&D spending and percentage of SE&T personnel, should influence how "high-technology" is defined.

However, all attempts to define high-technology are fairly arbitrary, and the research definition above shares along with the other definitions several aspects that affect its usefulness:

1. The definition refers to industry categories (SIC codes), not individual firms. The criteria R&D spending and SE&T employment are applied to industry averages, not to firms. Firms in any SIC code can vary greatly in size and structure which influences their role in the innovation process. Thus, not every firm in each industry category identified as high-tech industry satisfies the criteria and can be considered as high-tech establishment.

2. The production of computer software remains camouflaged in SIC 737 - computer and data processing services. However, parts of the software industry might be better classified in the high-technology manufacturing sector. Furthermore, many service companies can be considered extensions of firms they support. Therefore, their employment would be more appropriately credited to the supported industries. This may have important implications for comparing employment growth rates between the manufacturing and service sectors (Office of Technology Assessment 1984).

In summary, all definitions of high-technology are attempts to find quantifiable measures for the technological innovation process in order to enable analysis, but innovative behavior of firms and industries is clearly difficult to measure, and relative R&D spending or SE&T employment are only imperfect proxies.

THE THEORETICAL BASE: REGIONAL GROWTH THEORIES, INDUSTRIAL LOCATION THEORY, AND MARXIST ECONOMIC THEORIES AND HOW THEY APPLY TO HIGH-TECH INDUSTRY DEVELOPMENT

To understand how high-technology industrial complexes develop, two major bodies of economic theory are taken into consideration and discussed in the literature:

(1.) Regional Growth Theories;

(2.) Industrial Location Theory.

Theories of regional economic growth provide a better understanding of the role of high-technology complexes in regional economic development at a macroeconomic level but explain only partially the factors that influence the creation of those high-technology centers. Industrial location theory, in turn, identifies the determinants of locational decision-making on a microeconomic level (Rees and Stafford 1983). In addition, it will be examined if theories belonging to the Marxist tradition within economic geography can aid in explaining high-technology industry development.

Regional Growth Theories

There is no single, comprehensive regional growth theory, but rather a set of partial theories that explain different aspects of the regional development process (Rees and Stafford 1986).

Export-Base Theory. This theory emphasizes the role of a region's exports as the initial trigger for regional growth. Accordingly, a region's growth rate is a function of interregional and international export performance. Weinstein and Firestine (1978) point out that "export industries tend to be technologically advanced and to operate at higher levels of productivity" (p.62), generating income that helps to spur development of other industries. Thus, export-base theory recognizes that high-tech industries have higher multiplier effects, although the nature of such multipliers has not yet been thoroughly investigated.

Regional Income Inequality Theories. These theories describe regional growth in terms of income inequality. There are two major types of theories: The basic assumption of factor-price equalization models is that capital and labor flow between regions seek their point of highest return, leading eventually to convergence in regional incomes. Wheaton (1979) cites as an example the flow of investment capital from Northern to Southern States in the U.S. during the 1970s. Regional income convergence between North and South has been led historically by the decentralization of standardized production facilities. This trend can also be explained as a regional manifestation of the product-cycle theory discussed later.

The second type is unbalanced growth theories, mainly represented by Myrdal (1957) and Hirschmann (1958). Myrdal (1957) suggested that market forces tend to attract economic activity to areas that have an initial advantage (e.g., location, technological knowledge). This process becomes self-sustaining, resulting in little growth in peripheral regions. For Myrdal and Hirschmann, economic development is a function of interaction between leading (core) and lagging (peripheral) regions. Only when spread effects are stronger than the backwash (polarization) processes, new regional economic centers will develop.

Growth-Pole Theory. This theory was initially developed by the French economist Francois Perroux whose conception of growth poles, however, referred to industry sectors and was therefore originally nonspatial. Later, regional planners transformed growth-pole theory into a geographical concept using the term "growth center" (Darwent 1969). In Perroux's model the growth of such poles depends on fast-growing, innovative industries with well developed supplier and market links. Compared to the other theories discussed so far, growth-pole theory recognizes more explicitly the importance of the link between technology, innovation, and regional economic growth. Furthermore, the theory provides an understanding how such growth centers can perform as incubators or seedbeds for the birth of new companies.

Diffusion Theory. The theory explains the determinants of technology transfer and shows that the speed with which productivity-enhancing innovations spread between regions can play a critical role in accelerating economic growth. Diffusion theory does not offer an explanation with regard to the generation of innovation and has yet to be integrated into regional growth theory (Rees and Stafford 1983).

Product-Cycle Theory. This theory is based on the premise that products evolve through three distinct stages. The identification of these product-cycle notions is seen as critical to understand the nature of regional economic change, since each stage of the cycle has different locational requirements (Thomas 1975). R&D, innovation, and other nonroutine functions are the primary focus of the first stage (innovation phase), requiring a skilled labor force and minimal automation. The second stage - the growth phase - in the cycle involves capital investment and automated production. By the third stage (mature phase), little further innovation takes place, and routine production of standardized goods is the characteristic element, accomplished by unskilled labor. This includes shifting production to low-cost locations. If the product-cycle model is applied to regional development, it also implies that over time regions can change their roles from recipients of innovation via branch plants to become generators of innovation through indigenous growth.

Industrial Location Theory And Locational Factors Influencing High-Technology Industry

As far as industrial location theory addresses the decision-making of high-technology firms, it can provide an understanding of what conditions of particular communities are most likely to attract those companies. Therefore, it is necessary to examine how locational factors implicit in industrial location theory may relate to high-tech industry (Rees and Stafford 1986).

Industrial location theory builds on the foundations of Weber (1929) and Hoover (1948), and has been extended in the central-place formulations of Lösch (1954). Weber explains the location of industry as a response to two interconnected sets of forces. Regional forces, which determine the general locational framework of manufacturing, include costs of transportation and labor costs. Regional forces result from spatial variations of raw material and labor costs. Agglomerating forces, on the other hand, cause the pattern of manufacturing to deviate from the optimal patterns produced by regional forces alone. By clustering in close spatial proximity to other activities, firms will benefit from a particular kind of external economy of scale that Weber describes as economies of agglomeration (Lloyd and Dicken 1990).

Weber's theory can be presented graphically as a location triangle, at whose corners are arrayed raw materials, labor, and markets. An industry locates somewhere within the triangle, determined by the relative weights of the forces described above.

However, traditional industrial location theory is only of limited use for explaining locational patterns of high-technology industries. It generally underscores the important role of transportation costs in locational decision-making (Markusen, Hall, and Glasmeier 1986).

Locational factors may be separated into two types:

(1.) those relating to the friction of distance; and

(2.) those relating to the attributes of areas.

Friction-of-distance variables measure the costs of moving materials or products across space. These costs can be measured in terms of miles, money, time, or, psychologically, by ease or convenience. The second category is concerned with the characteristics of the area itself, such as labor, agglomeration and infrastructure, power, water, and the quality of life. Industrial location theory has traditionally emphasized the friction-of-distance variables. For high-technology industries though attributes-of-area factors are more important than friction-of-distance variables because they manufacture high value-added products for which transportation costs per unit of value are low. Their inputs come from a variety of sources and locations, and their markets also tend to be spatially scattered. Therefore, the advantages of locating near one supplier are neutralized by the distances separating them from others.

The various factors influencing high-technology plant location decisions may differ in relative significance from firm to firm; nevertheless, based on a survey of 104 plants, Stafford (1983) attempted to rank the ten most frequently mentioned location factors as considered by high-technology and non-high-technology plants (Table II, p.16).

Another survey in a Joint Economic Committee staff study (1982) shows - as Table III (p.16) indicates - that the factors influencing location decisions for high-technology plants may vary at the regional and within-regional scales (regional and intraregional factors, respectively).

TABLE II

LOCATIONAL DETERMINANTS FOR HIGH-TECHNOLOGY VS. NON-HIGH-TECHNOLOGY PLANTS

Rank	High-technology plants	Non-high-technology plants
1	Labor	Labor
2	Transportation availability	Market access
3	Quality of life	Transportation availability
4	Market access	Materials access
5	Utilities	Utilities
6	Site characteristics	Regulatory practice
7	Community characteristics	Quality of life
8	Business climate	Business climate
9	Taxes	Site characteristics
10	Development organizations	Taxes

Source: Stafford, Survey of 104 Plants, 1983.

TABLE III

LOCATIONAL DETERMINANTS FOR HIGH-TECHNOLOGY PLANTS BETWEEN AND WITHIN REGIONS

Rank	Selection of region	Selection within region
1	Labor skills/availability	Labor availability
2	Labor costs	State/local tax structure
3	Tax climate within region	Business climate
4	Academic institutions	Cost of property/construction
5	Cost of living	Transport availability for people
6	Transportation	Ample area for expansion
7	Market access	Proximity to good schools
8	Regional regulatory practices	Proximity to amenities
9	Energy costs/availability	Transport facilities for goods
10	Cultural amenities	Proximity to customers

Source: Joint Economic Committee 1982, pp.23 and 25.

Labor stands out unquestionably as the most important location determinant in the search for a new site. This factor is also a major element of Weberian location theory, but in terms of labor costs rather than labor skills. While labor costs are of some importance for high-technology plant locations, the two surveys show that the availability, attraction, and retention of skilled technical and professional personnel are the primary concerns when high-technology firms locate or expand production facilities.

The Joint Economic Committee study (1982), as well as other studies (Deuterman 1966, Gibson 1970) in the U.S. emphasize the importance to high-tech industries of nearby scientific and technical education-oriented universities, because they train the needed engineers and technicians and serve as sources of technical information. The Portland/ Vancouver CMSA, however, lacks a prominent research university nearby, whose presence was a critical factor in the rise of Silicon Valley (Stanford) or Boston's Route 128 (Massachusetts Institute of Technology), suggesting that there are limits to the growth of high-tech industries in the Portland area.

Quality of life and the existence of cultural and recreational amenities, though difficult to measure, are equally critical in locational decisions because highly skilled professionals put a high value on quality-of-life and amenity factors (because of their affluence). In Tables II and III (p.16) these include not only "quality of life" and "proximity to amenities", but also "academic institutions", "proximity to good schools", and "cultural amenities".

Transportation is a factor of some locational importance for high-technology plants, but in terms of transit time rather than transportation costs. Easy access to major airport passenger facilities for the movement of managerial and technical staff is essential. The same is true for market access where the emphasis is again on ease and speed, but hardly on costs. This factor can in part explain why high-tech manufacturing has dispersed to a considerable degree, enabling the emergence of new high-tech complexes fairly distant from large urban regions with the presence of agglomeration economies.

The influence of taxes on high-tech locational decisions is difficult to assess. The Joint Economic Committee survey (Table III, p.16) indicates that taxes are the second most important locational determinant for high-technology plants, whereas Stafford's survey (Table II, p.16) places taxes as a minor locational variable. To some extent, the differences may be of methodological nature; the Joint Economic Committee study asked directly about the influences of taxes, while in Stafford's survey the companies were asked to list the most important factors in their location decisions. It seems that changes in Oregon's tax system have led to significant in-movement of Japanese high-tech firms in the Portland area (see Chapter IV).

The Markusen, Hall, and Glasmeier study (1986) on locational factors influencing high-tech firms shows similar results, though a few noteworthy differences occur. They looked both at the pattern of high-tech industry locations in 1977 and over the period 1972-77 to determine if certain factors were more powerful in explaining recent changes than the overall array of plants and jobs. Surprisingly, traditional labor supply characteristics seem to be not very significant in explaining the distribution of high-tech industries at the metropolitan level. However, educational options and climate appear to be strongly related to high-tech location. Transportation access and agglomeration features were relatively less closely associated with the redistribution of plants in the period 1972-77 than they were in the longer run. Markusen, Hall, and Glasmeier conclude that cost factors in general are less crucial than amenities, the availability of business services, and favorable receipts of defense spending. It should be noted that no major defense-related contracts have ever been placed with firms in Oregon. While federal defense spending has greatly contributed to the growth of many high-tech complexes throughout the U.S., federal policy has played little role in the Portland/Vancouver CMSA's high-tech industry development (Hamilton 1987).

In another investigation using the same data set (Census of Manufactures 1972 and 1977), Glasmeier, Hall, and

Markusen (1983) have demonstrated that the distribution and growth of high-tech industry cannot be statistically explained in terms of a number of key locational factors. Thus, high-tech industries must be highly heterogenous and display disparate spatial tendencies. To understand the location of these industries, disaggregated industry-by-industry and place-based analysis will be required.

An interesting aspect of metropolitan business formations with regard to the site selection process was discovered by Armington (1986). Therefore, "potential entrepreneurs in high-tech industries behave much the same as other businesses in choosing sites for their operations" (p.88). They are attracted to areas with lower business costs, healthy local economies, and a high quality of life. What differentiates high-tech firms from other manufacturing activities is the greater importance of locational factors such as the existence of an educated, skilled labor force and urban amenities. Consequently, the quality of labor and the attractiveness of the metropolitan area, to both labor and management, are more crucial to high-tech firm locational decisions than to other industries. According to Armington (1986), this relationship is even stronger for small firms. These findings are consistent with the results of Stafford's analysis (1983) and the Joint Economic Committee study (1982).

Finally, Malecki (1986) points out that the built environment and cultural amenities are more important in the context of quality-of-life locational factors than the physical setting of an area. A variety of restaurants, shopping opportunities, as well as musical and theatrical facilities found in larger metropolitan areas reinforces the the advantages of urban size (e.g., labor market and infrastructure).

It has been shown that traditional industrial location theory is only partially relevant for explaining the locations of high-technology industries, because the theory emphasizes transportation costs which are but a small proportion of total costs for products manufactured by high-tech firms. However, a theory of location for high-technology industry does not exist. This requires the use of above reviewed empirical studies on locational decisions of high-tech industries - along with fragments of regional growth theories - as a framework for the analysis.

Marxist Theories On Spatial Structures Of Production

There is a series of approaches that Marxist insights have spawned within economic geography. The restructuring or structural approach is undoubtedly a key theme in radical (Marxist) economic geography. Lloyd and Dicken (1990) summarize the basic concepts of the restructuring approach as follows:

1. Location is only one element in the complete decision-making process of an (capitalist) enterprise that has a significant spatial impact.
2. Location theory is a subset of investment theory with the investment decision preceeding the location decision, and investment theory is part of a general theory of capitalist accumulation.
3. The investment and thus locationally significant decision is a dynamic ongoing process dominated by the necessity for expanded accumulation.
4. Investment has an upside and downside effect ("disinvestment"), both producing geographically significant events.
5. "Geographic outcomes both reflect the constellation of social relations in capitalism and [...] represent an active force conditioning the evolution of that constellation of social relations" (p.368).

The essence of the restructuring approach is that the process of accumlation as central to capitalism contains an built-in tendency toward cycles of expansion and contraction (waves of development and restructuring). Kondratiev (1935) argued that capitalist development follows a regular cycle of about 50 years, from boom to bust and then to boom again. These long or Kondratiev waves are characterized by upswings of about 25 years followed by downturns of roughly the same length.

Hall (1985) interprets Kondratiev's notion of recurring cycles with respect to the role of technical change in economic development. Therefore, technological development creates new economic opportunities and so generates economic expansion. After some time, however, these industries find their markets saturated, and thus recession and then depression ensues, until a new wave of innovation sets the entire process off again.

Schumpeter (1939) refined Kondratiev's theory, arguing that two shorter cycles are laid over the long waves. His hypothesis was that the interrelationship between these cycles can explain the process of economic expansion and contraction in modern capitalism. Schumpeter regards innovations as the most important forces in driving upswings of capitalist development.

Mandel (1980) discusses the long-wave phenomenon as reflecting phases of intensive accumulation followed by periods of crisis. It means that the emergence of realization crises and the rising power of labor at the top of the upswing demand social and economic restructuring to restore accumulation. The restructuring approach thus implies that these waves will produce spatial effects in the form of the built environment (towns, cities, regions, or nations).

A central element in the restructuring approach relates to the "labor process" which means in Marxist terms that the main source of value in capitalism is the application of human labor in the process of producing goods for the marketplace. Compared to traditional industrial location theory which emphasizes labor costs in explaining spatial differences, this approach states that the "control of labor" and its "reproduction" also play a critical role whether a region or place is able to attract new waves of development. "Reproduction" may represent demographical development and availability of skills, but stable industrial relations, attitudes, and supportive local institutions are important as well (Lloyd and Dicken 1990). Hence, Braverman (1974), a major contributor to literature on the labor process, points to the need for capital (entrepreneurs) to be more concerned with the "struggle for control" of the production process than solely with costs of labor.

To understand the various roles played by places over time in the capitalist system, the concept of "spatial divisions of labor" has been developed (Massey 1984). Accordingly, places are not only ordered by their position within the headquarters-branch hierarchy, but also by the particular functions that individual plants assume in the production process itself. Places associated with capital (corporate headquarters) achieve control ("centers of control") while places closely related to labor (e.g., branch/assembly-plant facilities) are subordinate. Some places gain a special degree of autonomy, because they are receiving a major share of corporate R&D.

Recently, a new debate commonly termed with the word "flexibility" has developed within the Marxist literature. This approach focuses on the question whether a new regime of "flexible accumulation" is succeeding the "Fordist" regime of accumulation. Harvey (1988) states that this new regime has replaced the "Fordist" era at a time of crisis for capitalism, when cities in the industrial regions of the United States and Western Europe experienced a process of deindustrialization and job loss over the 1970s and early 1980s. The base of the "post-Fordist" stage is flexible forms of technology, production organization, and labor markets (Gaile and Willmott 1989). Firms are increasingly making use of subcontracting (deintegration) and franchising and leasing arrangements.

The new regime has also been associated with the emergence of "new industrial spaces" which has occurred in areas that are generally free from intensive Fordist forms of industrialization (e.g., Silicon Valley and Orange County). These new industrial regions are based on flexible patterns of production, particularly high-technology industries (Scott 1988). However, the issue whether an essentially new regime of flexible accumulation has emerged or old structures are transformed into different but less rigid forms is still fiercely debated.

HOW THE PORTLAND/VANCOUVER CMSA COMPARES TO OTHER HIGH-TECH INDUSTRY LOCATIONS IN THE U.S.

Markusen, Hall, and Glasmeier (1986) provide a detailed analysis of regional (state level) and urban (SMSA level) distribution patterns of high-tech industries in the U.S. Regrettably, their investigation is based on data available for the 1970s. They found five major "regional agglomerations" of high-tech industry in the U.S., and five smaller ones. Major core high-tech states include the Pacific Southwest (California, Arizona), Western Gulf (Texas, Louisiana, Oklahoma), Chesapeake/Delaware River (New Jersey, Maryland), "Old New England" (Massachusetts, Connecticut), and Lower Great Lakes (Illinois). "Minor high-tech cores" are the following single states whose neighbors are not similarly specialized: Florida, Minnesota, Kansas, Colorado, and Utah (Figure 1, p.27).

The Pacific Southwest is dominated by post-World War II high-tech industries (aerospace, electronics). The Western Gulf States also host aerospace and electronics industry, but combined with oil extraction and chemical industries. The Illinois and Chesapeake/Delaware River complexes have the most diverse high-tech base, dominated by older industries. "Old New England's" high-tech industry structure is similar to the Pacific Southwest, though more diverse with some older high-tech industries.

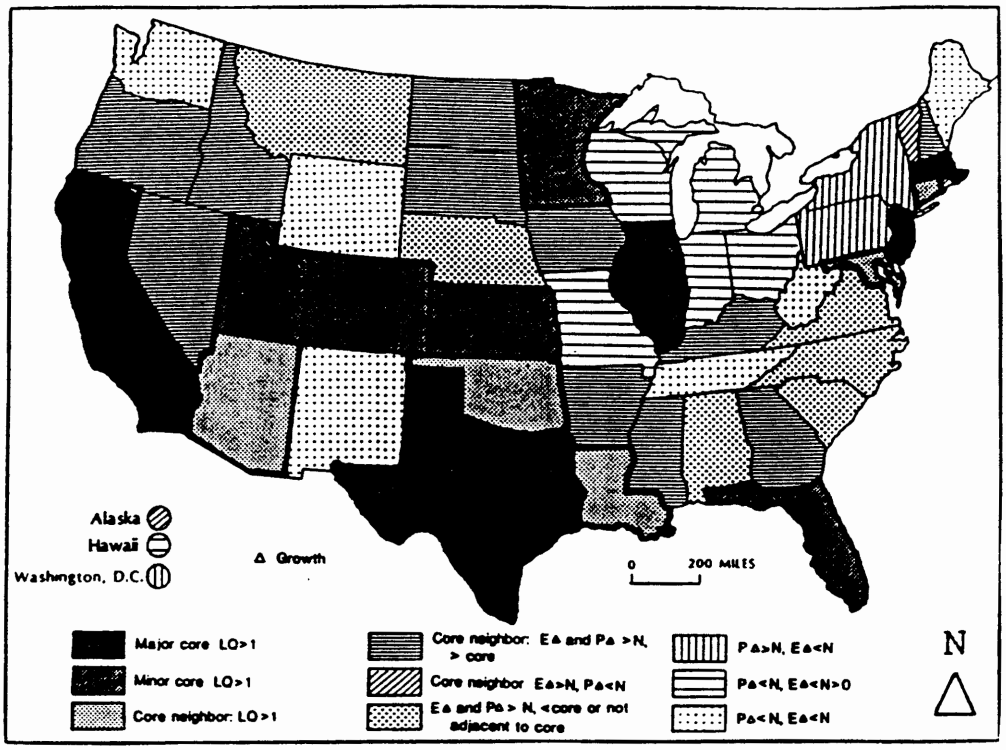

Figure 1. The five major and five minor high-tech core states and their fringes. LQ = location quotient, E = employment, P = population, N = national average.
Source: Markusen, Hall, and Glasmeier 1986, p.102.

Markusen, Hall, and Glasmeier (1986) point out that high-tech plant and job growth is not only a "Sunbelt" phenomenon, as frequently perceived. Although the high-tech agglomerations in the "Frostbelt" generally grew less rapidly than those in the "Sunbelt", Massachusetts, for instance, hosted job growth greater than the national pace. The same is true for Minnesota, an important minor core. However, high-tech industries apparently are avoiding the older midwest industrial belt from Buffalo to St.Louis and Milwaukee with the sole exception of Chicago.

Neither Oregon nor the Portland/Vancouver CMSA are described in the Markusen, Hall, and Glasmeier study (1986) as regional or metropolitan high-tech agglomerations, suggesting that there are no distinctive concentrations of high-tech industries in the area. Similar results can be obtained from Armington, Harris, and Odle (1983). They analyzed total high-tech employment and employment changes over the 1976-80 period for selected SMSAs in the U.S. Of the 35 SMSAs examined, the Portland/Vancouver CMSA had the 10th lowest number (19,214) of high-tech employees in 1976, making up 4.3% of total employment. Its high-tech employment growth rate of 18.3% between 1976 and 1980 was also comparably low, ranking 22nd among the SMSAs analyzed. Therefore, most high-tech industry growth in the Portland/ Vancouver CMSA must have occurred in the 1980s. In fact, figures for 1988 indicate that high-tech employment has more than doubled since 1976, totaling 33,340 - 42,976 (estimation according to County Business Patterns Oregon and Washington 1988; for explanation see Methodology section).

Table IV (p.29) shows a comparison of 1975 employment and 1975-88 employment growth rates in the CMSA for the manufacturing, service, and high-tech sector, as well as for the economy as a whole. Clearly, high-tech employment grew much faster (70.3% - 123.2%) between 1975 and 1988 than total employment (49.9%) and particularly the manufacturing sector with its modest growth rate of 21.2%. However, the

TABLE IV

COMPARISON OF 1975 EMPLOYMENT AND 1975-1988 EMPLOYMENT GROWTH IN MANUFACTURING, SERVICES, AND HIGH-TECH IN THE PORTLAND/VANCOUVER CMSA (BY COUNTY)

COUNTY	1975 EMPLOYMENT				1975-1988 EMPLOYMENT GROWTH IN %			
	Total	Manufg.	Services	High-Tech+)	Total	Manufg.	Services	High-Tech+)
Clackamas	47,628	12,288	7,887	1,987- 2,534	54.3	36.4	126.2	57.8/101.7
Clark, WA	28,553	10,237	5,662	850- 1,747	101.3	71.2	150.6	334.6/346.3
Multnomah	234,794	48,051	55,548	4,193- 5,568	27.8	-7.8	71.6	48.3/ 52.1
Washington	51,416	20,968	8,926	7,656-14,881	111.6	46.9	191.3	38.2/155.1
Yamhill	8,268	3,153	1,562	250- 499	89.9	69.1	171.6	140 /150
Portland/Vancouver CMSA	370,659	94,697	79,585	14,936-25,229	49.9	21.2	98	70.3/123.2

+) For reasons of confidentiality about specific firms, several SIC entries provide only a range of minimum and maximum number of employees (employment-size classes).

Source: U.S.Bureau of the Census, County Business Patterns Oregon and Washington, 1975 and 1988.

service sector also experienced remarkable employment growth at a rate of almost 100% over the period 1975-88.

At the county level, it is evident that Multnomah County exhibited the slowest growth rates in all economic sectors and even a decline in manufacturing employment (-7.8%). The sharpest rise in high-tech employment occurred in Clark County; it should be noted, however, that the employment base in 1975 was very small. Washington County, in turn, is characterized by the highest service sector employment growth rate in the entire CMSA (191.3%). In all counties, high-tech employment rose more significantly than overall employment - with the possible exception of Washington County, because insufficient data on 1975-88 high-tech employment changes do not allow such a conclusion in this case.

The Oregon Economic Development Department (1986) claims that high-tech employment makes up 6.8% of the total employment in the Tri-County area (Washington, Multnomah, and Clackamas counties). This is above the U.S. average of 6.0% (1985) and comparable to the Washington-Baltimore Corridor, another developing high-tech region (6.9% in 1985 as supplied by Hahn and Wellems 1989).

A more recent report by the Oregon Economic Development Department (1989) provides further evidence that Oregon has become a prominent location for high-tech firms. According to this study, Oregon ranks third nationally after the traditional core states California and Massachusetts in density of high-tech manufacturing firms based on population ratio (one firm for every 7,333 people). Most of the growth of high-tech industries in Oregon is localized in the Portland area.

Rogers and Larsen (1984) compare twelve "Silicon Valleys" in the U.S., recognizing the Portland/Vancouver CMSA as well which is labeled as "Silicon Valley North". Each high-technology complex listed in Table V (p.31) is rated on the main factors which they found being involved in the rise of Silicon Valley.

Table V (p.31) indicates that there are three planned attempts to create other "Silicon Valleys" at Research

TABLE V

A COMPARISON OF HIGH-TECH COMPLEXES IN THE U.S.

High-Technology Complex	Was the High-Tech Complex Spontaneous or Planned?	Research University	Is Venture Capital Present?	Is Entrepreneurial Spirit Demonstrated by Spin-Offs?	Climate and Quality of Life	Prognosis
1.Silicon Valley	Planned somewhat	Stanford	Yes	Yes	Sunny climate; high quality of life	Will remain the leading HT complex
2.Route 128	Planned somewhat	MIT	Yes	Yes	Good quality of life	Second only to Silicon Valley
3.Research Triangle	Planned	U.of NC, NC State, Duke	No	No	Good	Rising gradually in prominence
4."Bionic Valley" (Salt Lake City)	Planned	U.of Utah	Little	Some	Good	Off to a promising start
5."Silicon Valley East"	Planned	RPI, SUNY Albany	No	No	Cold climate	Just getting started
6."Silicon Prairie" (Dallas-Austin)	Spontaneous	U. of Texas at Austin	Some	Some	Good	Shows potential
7."Silicon Mountain" (Colorado Springs)	Spontaneous	None	Little	Few	Good	Shows potential
8."Silicon Valley North" (Portland)	*Spontaneous*	*None*	*No*	*No*	*Good*	*Shows potential*
9."Silicon Desert" (Phoenix)	Spontaneous	Arizona State	Little	Few	Hot climate	Shows potential
10.Minneap.-St.Paul	Spontaneous	U. of Minnesota	Little	No	Cold	Some potential
11.Seattle	Spontaneous	U. of Washington	No	Some	Good	Some potential
12.Orange County(LA)	Spontaneous	UC Irvine	Some	Yes	Smog	Good potential

Source: Rogers and Larsen 1984, pp.248-249.

Triangle in North Carolina, the University of Utah Research Park in Salt Lake City, and at Rensselaer Polytechnic Institute and SUNY in Troy and Albany, New York, respectively. In each of these cases, a research university and/or a state government took the lead in facilitating the development of high-tech industries.

Rogers and Larsen (1984) identified a second set of "Silicon Valleys" emerging around Dallas and Austin, Phoenix, Minneapolis-St.Paul, Colorado Springs, Seattle, Orange County (Los Angeles), and Portland, Oregon. They argue that these complexes spring up rather spontaneously in the form of manufacturing facilities particularly for microelectronics firms headquartered in Silicon Valley where limited space and skyrocketing land and housing prices preclude further expansion. Policies may contribute to the growth of these high-tech complexes by offering tax breaks or other financial incentives, but high-tech industry development here was not initiated by a government or governmental organization. Table V (p.31) prognosticates that Portland "shows potential", but the absence of a research university and venture capital may limit future expansion of the high-tech complex.

METHODOLOGY

For analyzing the distribution of high-tech industries and high-tech employment within the Portland/Vancouver CMSA, the following statistical data sources are used: The first data set contains the U.S. Bureau of Census' County Business Patterns Oregon and Washington covering the five counties

(Multnomah, Washington, Clackamas, Yamhill, and Clark, WA) of the CMSA which include information on the number of establishments and employment figures by industry (SIC code) and county. However, these data are five years old (as of March 12, 1988). Additionally, some Standard Industrial Classification (SIC) entries do not provide exact employment; it is rather shown as a range of a certain number of employees (0 - 19, 20 - 99, 100 - 249, etc.). Therefore, high-tech employment in the CMSA can only be estimated.

More recent data are obtained from two high-tech directories which comprise the second source of the statistical analysis:

(A.) the Quanix Directory and Guide 1991 (7th Edition) to Advanced Technology in the Pacific Northwest; and

(B.) the Resource Guide Oregon High Technology 1991-92.

The Quanix Directory has proved to be more useful because supporting products and services are listed separately, as are manufacturer's representatives and distributors. Another advantage of the Quanix Directory is that each company or establishment (in case of multisite corporations) is listed only once in the product category that best identifies its main products. These two directories are the sole sources covering high-tech industries in the Portland/Vancouver CMSA including locations, employee count, product descriptions, parent company (if any), and the date of establishing.

Information on the market area served and the space occupied is not given for all company entries. Based on these sources, it is possible to calculate high-tech employment and the number of high-tech establishments in the entire CMSA, at the county level, and - by using the high-tech directories - also at the municipal level. The County Business Patterns statistics enable to broadly determine the proportion of high-tech sector employment in the local economy and in relation to other economic sectors.

However, to understand why high-tech firms locate in the Portland/Vancouver CMSA, it is necessary to go beyond the pure analysis of statistical data. The statistical analysis can reveal the distribution pattern across the metropolitan area, but does not give clues as to the regional and intraregional locational factors affecting high-tech industries. For this reason, several agencies concerned with issues of economic development in the CMSA were interviewed: the state of Oregon (Oregon Economic Development Department), the Portland Development Commission, the Portland Chamber of Commerce, the Hillsboro Chamber of Commerce, the International Trade Institute, the Sunset Corridor Association, and the Clackamas County Economic Development Commission.

To allow the use of the U.S. Bureau of the Census' County Business Patterns statistics, the high-tech research definition was derived - as explained earlier - from the federal Bureau of Labor Statistics (1983). Accordingly, the proportion of technology-oriented workers has to be greater than the average for all manufacturing industries (6.3%), and the R&D-to-sales ratio has to be close to or above the average for all industries (3.1%). This leads to a selection of 28 three-digit industries (Standard Industrial Classification codes) considered as high-tech branches.

Beginning with the 1988 County Business Patterns series, industry classifications are based on the revised 1987 edition of the SIC Manual. Since the high-tech definition was developed on the basis of the 1972 SIC Manual, slight variations occur in the classification. Table VI (p.36) shows how the research definition applies to the revised 1987 SIC Manual, and indicates those SIC codes (branches) that do not exist in the Five-County area (CMSA).

In addition, it has to be investigated how well companies appearing in the two high-tech directories match the criteria of the research definition. The Quanix Directory uses the list as shown in Table VII (p.37) to identify products or services provided by a company regarded as high-tech establishment. Therefore, it was attempted to assign every product subcategory of the Quanix Directory a SIC code according to the research definition. Since SIC code product groupings do not exactly match the categories used in the Quanix Directory, it may be possible to assign more than one SIC code to a certain category. Taking this

TABLE VI

DEFINITION OF HIGH-TECHNOLOGY INDUSTRY BASED ON THE REVISED 1987 SIC MANUAL

SIC code	Industry	
	MANUFACTURING	
281	Industrial inorganic chemicals	
282	Plastic materials and synthetics	(0)
283	Drugs	
284	Soap, cleaners, and toilet goods	
285	Paints and allied products	
286	Industrial organic chemicals	(0)
287	Agricultural chemicals	
289	Miscellaneous chemical products	
291	Petroleum refining	(0)
348	Ordnance and accessories	(0)
351	Engines and turbines	(0)
355	Special industry machinery	
357	Computer and office equipment	
361	Electric distribution equipment	
362	Electrical industrial apparatus	
365	Household audio and video equipment	
366	Communications equipment	
367	Electronic components and accessories	
369	Miscellaneous electrical equipment and supplies	
372	Aircraft and parts	
376	Guided missiles and space vehicles	(0)
381	Search and navigation equipment	
382	Measuring and controlling devices	
384	Medical instruments and supplies	
386	Photographic equipment and supplies	
	SERVICES	
737	Computer and data processing services	
8731	Commercial physical research	

(0): No establishments in the Portland/Vancouver CMSA.

Sources: BLS 1983; SIC Manual 1987; author.

into account, all companies listed under each Quanix product subcategory were examined - as far as they are located in the Portland/Vancouver CMSA - concerning their main products

TABLE VII

QUANIX PRODUCT SUBCATEGORIES AND ASSIGNED SIC CODES
OF THE RESEARCH DEFINITION

Quanix category	SIC code
1. Product Design and Manufacture	
Aerospace/Aviation/Military Equip./Sys.	372
Audio Equipment/Systems	365
Biotechnical Equipment/Systems	384
Communications Equipment/Systems	366
Computers/Peripherals	357
Consumer Electronics	369
Environment/Geophysical Test Equip.	381
Industrial Control Equipment/Systems	382
Marine Electronics Equipment	381
Medical Electronics Equipment	384
Robotic Systems	362
Security/Safety Equipment	382
Test/Measurement Instruments/Systems	382
Transportation Equipment/Systems	362
2. Components and Materials Mfg.	
Antennas	366
Board-Level Circuit Products	367
Cables, Wire, Springs	369
Ceramic Components	367
Coils	367
Controls, Control Devices	382
Converters	367
Electro-Mechanical Parts, Assemblies	369
Electromagnetic Beam Products	369
Fiber Optics Equip./Components	366
Hybrid Circuits	367
Integrated Circuits	367
Inverters	367
Laser, Laser Accessories	367
Magnetic Devices	367
Memory Storage Devices	357
Meters	382
Microcomputer/Microprocessor Comp.	357
Microwave Components	367
Motors	362
Panels/Panel Components	369
Power Supplies/Equipment	369
Printers/Printer Components	357
Relays	362
Robotic Parts	362
Semiconductor Devices	367
Semiconductor Materials	367
Switches	361
Telecommunication Components	366
Temperature Controls	382
Transformers	367
4. Software Developers	737

Quanix category	SIC code
3. Supporting Products and Services	
Assembly Contracting	-
Assembly, Surface Mount	-
Assembly Aids	-
Biotech Services	-
CAD/CAE/CAM Graphic Services	737
CAD/CAE/CAM Systems/Components	737
Castings	-
Chemicals, Chemical Treatment	281
Circuit Board Design	-
Circuit Board Manufacturing	367
Clean Room Design/Construction	-
Communications System Design	737
Computer System Design	737
Consultants to Electronics OEMs	-
Containers/Packaging	-
Contract Electronic Systems Mfg.	-
Custom Electronic Systems Design	-
Dies/Molds	-
Documentation Services	-
Drafting, Graphics	-
Electroplating	-
Engineering Services	-
Environmental Control Service	-
Environmental Test/Control Sys.	382
Extrusions	-
Hardware/Hand Tools	-
IC/Hybrid Circuit Design	-
IC, Hybrid Contract Manufacturing	-
Industrial Control Systems/Services	-
Laboratory Equipment/Services	-
Laser Service/Repair	-
Laser Systems	-
Machining/Machined Components	-
Materials Recovery	-
Materials/Parts Handling	-
Metal Fabrication	-
Metal Finishing	-
Metal Stamping	-
Optics Systems/Components	382
Panels/Nameplates/Labels	-
PCB Imaging	386
Plant Furnishing/Equipment	-
Plastics Molding/Fabrication	-
Processing Equipment/Systems	367
Prototype Manufacturing	-
Repair/Maintenance/Calibration	737
Research	-
Test Chambers	-
Testing/Test Fixtures	-
Training, Technical	-
Wire/Cable Preparation	-

Sources: Quanix Directory 1991; author.

to find a SIC code that most appropriately encompasses the majority of them.

As Table VII (p.37) indicates, product subcategories arranged under the main headings "Product Design and Manufacture", "Components and Materials Manufacturing", and "Software Developers" can all be linked to a SIC code that is part of the research definition. However, only a fairly small portion of product subcategories labeled as "Supporting Products and Services" is covered by the research definition. These supporting industries will also be considered in the analysis, if they were found significant in the context of explaining high-tech development in the Portland/Vancouver CMSA.

Seven SIC codes of the research definition (SIC codes that do not appear in the statistics for the Five-County were excluded) could not be assigned to any Quanix category. Three of them - SIC 283, drugs, SIC 284, soap, cleaners, and toilet goods, and SIC 285, paints and allied products - are not included in the Quanix Directory at all; the other - SIC 287, agricultural chemicals, SIC 289, miscellaneous chemical products, SIC 355, special industry machinery, and SIC 8731, commercial physical research - are not appearing in Table VII (p.37), although Quanix regards them as high-tech branches, because other SIC codes were identified to match the Quanix categories more adequately, incorporating the majority of the firm entries.

Since the U.S. Bureau of the Census' County Business Patterns SIC statistics withhold data on individual firms, the Quanix Directory needs to serve as a source for all sub-county-level information. Thus, statistical material utilized in this study and referring to counties and the entire CMSA is normally obtained from the County Business Patterns while those on municipalities and microlocations of high-tech establishments in the Portland/Vancouver CMSA is derived from the high-tech directories.

Finally, all company entries in the Quanix Directory were double-checked regarding their occurrence in the Resource Guide. Eighty-five percent of those companies are listed in the Resource Guide as well. An evaluation of the Resource Guide's product classification index revealed that the scope of companies viewed as high-tech is much wider than the research definition and the criteria applied in the Quanix Directory. Aside from the inclusion of manufacturer's representatives and distributors, the Resource Guide also contains firms that sell non-technical products or services into high-technology markets (e.g., public relations firms and personnel recruiters). For this reason, the Resource Guide supported only the other sources to compare employment data, location and product descriptions, and to complement material on company entries listed in both directories.

CHAPTER II

DEVELOPMENT AND DISTRIBUTION OF HIGH-TECH INDUSTRIES IN THE PORTLAND/VANCOUVER CMSA

The purpose of this chapter is twofold: First, it analyzes the historical development of high-tech industries in the Portland/Vancouver CMSA, and second, the distribution pattern of high-tech establishments in the CMSA is investigated.

HOW THE PORTLAND/VANCOUVER CMSA HIGH-TECH INDUSTRY COMPLEX EVOLVED: THE MAIN CONTRIBUTING FACTORS

This section attempts to divide the development of high-tech industries in the Portland/Vancouver CMSA up into three phases representing the major factors that were found to have driven their growth.

Phase I: 1945-1974

The beginning of high-technology industry development in the Portland/Vancouver CMSA can be traced back to the 1940s, when Tektronix and Electro Scientific Industries (ESI) were established in Southeast Portland on Hawthorne Boulevard. ESI's early production included a variety of electronics products, at first impedance bridges (an instrument for measuring alternating-current resistance), later precision voltage dividers and a new type of analog computer. At least until the mid-1960s, the Department of Defense was the company's major market. Tektronix started making the world's first synchronized oscilloscopes (Dodds and Wollner 1990).

In 1951 Tektronix moved to Washington County and ESI followed in the early 1960s. Both company locations in Washington County represent the initial core of high-tech industry development in the Portland area. ESI is located near the junction of Murray Road and U.S.26 in Sunset Science Park what is now called the "Sunset Corridor" (see Figure 2, p.42).

The Sunset Science Park project was based on the success of the Stanford University Science Park. Sunset Park was officially dedicated in 1963, and it became the first science park in the Pacific Northwest designed to attract light manufacturing industries interested in pursuing R&D. However, the difference between Stanford and Sunset Science Park is that the latter is not associated with university research laboratories.

Tektronix's first plant in Washington County was established at the intersection of Barnes Road and Sunset Highway, but like the Hawthorne plant, it also proved to be too small. In 1956 land available west of the Beaverton city limits was purchased. This newly acquired land eventually became Tektronix's headquarters known as the Tektronix

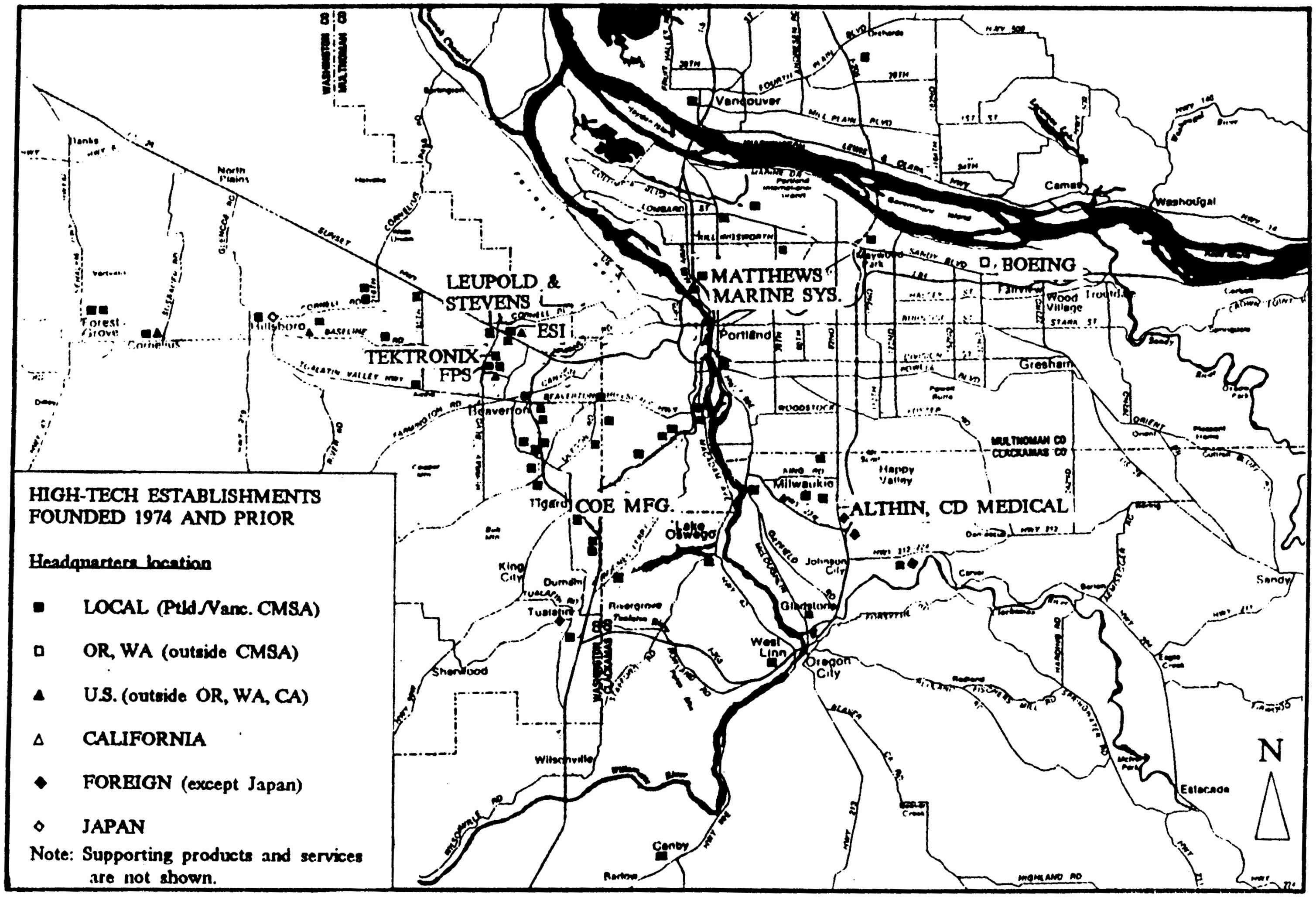

Figure 2. High-tech manufacturing and service establishments founded 1974 and prior in the Portland/Vancouver CMSA excluding Yamhill County (1991). Sources: Quanix Directory 1991; Resource Guide 1991; PDC 1991; author.

Industrial Park. Nevertheless, Tektronix has recently moved its corporate headquarters to Wilsonville (as of July 1992).

Until the mid-1970s most of the growth associated with high-tech industrial development in the Portland/Vancouver CMSA can be attributed to local entrepreneurship. ESI and Tektronix also stimulated new locally-owned high-tech establishments to supply materials, parts, and components, but the majority of high-tech firms established in the 1950s and 1960s showed primarily market linkages to local and Pacific Northwest staple industries. Examples include Coe Manufacturing of Tigard, established in 1952, and Frank Electric of Beaverton, established 1960, manufacturing industrial control equipment particularly for the timber industry, Leupold & Stevens (Beaverton) making hydrologic instruments, and Matthews Marine Systems, located in North Portland, producing electronic controls for marine steering systems used in the shipbuilding industry. Additionally, a number of medically-oriented high-tech firms were established, among them Althin, CD Medical, a Swedish-owned firm established in 1964, manufacturing artificial kidney dialysis equipment.

A new type of high-tech development in the Portland/ Vancouver CMSA has its starting-point in 1970, when Tektronix gave birth to its first successful spin-off formed by former Tektronix employees: Floating Point Systems (see Figure 3, p.44). The company (now FPS Computing, Inc.)

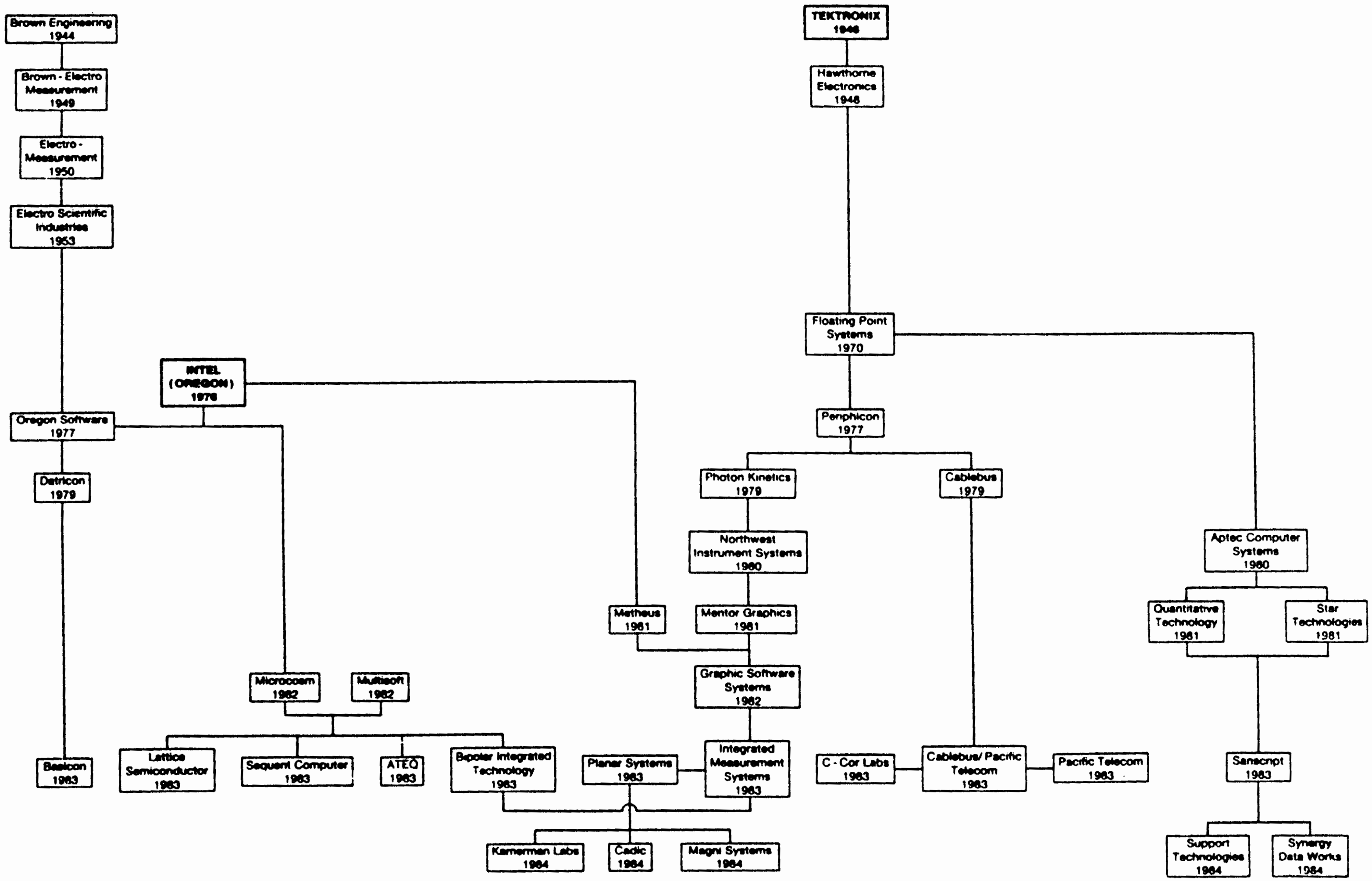

Figure 3. Home-grown Tektronix and Electro Scientific Industries plus California arrival Intel as the most important sources of spin-offs in the Portland/Vancouver CMSA.
Source: Hamilton 1987, p.180.

started manufacturing a hardware attachment that improved the performance of minicomputers. In 1974 FPS entered the array processing market and moved two years later to Beaverton, its new headquarters (Figure 2, p.42). This new development began to diversify and expand the high-tech base in Washington County provided by Tektronix and ESI, creating a business environment in terms of market needs, parts, and ideas that was able to attract more entrepreneurial activity.

Simultaneously, the early 1970s marked the beginning of a deepening economical crisis of staple industries in the Pacific Northwest, forcing many high-tech firms with linkages to these staples to find new markets or alter their product lines. By the end of phase I, the first large high-tech firm headquartered outside of Oregon established a plant in Gresham: In 1974 the Boeing Company of Seattle, WA started manufacturing a variety of parts for commercial airplanes and aerospace equipment. However, this was a rather singular event that did not lead to new spin-offs or startups in the Portland/Vancouver CMSA. In summary, only about one-fourth of all high-tech establishments existing today were founded prior to 1975.

Phase II: 1975-1984

By the mid-1970s a significant change in the Portland/ Vancouver CMSA's high-tech industrial development took place, marked by the arrival of several California-based firms. These out-of-state headquartered high-tech firms became a second driving force behind the industry's growth. As to be elaborated in Chapter IV, changing attitudes of the state's politicians towards industrial development and new state and local policy initiatives to encourage investment can explain this new development.

First in 1976 came Santa Clara (Silicon Valley)-headquartered Intel to establish a semiconductor manufacturing plant in Aloha at SW 198th and Tualatin Valley Highway (Figure 4, p.47). Of all out-of-state high-tech companies, Intel has unquestionably shaped the direction of high-tech industry growth the most for the following years, since the company produced a wide range of spin-offs (Figure 3, p.44).

Why did Intel come to the Portland area? According to Dodds and Wollner (1990), the Portland area was chosen because it is still relatively close to the San Francisco Bay area in terms of air travel time (less than two hours) where Intel's headquarters and major suppliers and customers are located. Land prices and construction costs are far below those of the Bay area and other West Coast metropolitan areas. Portland could also offer appropriate supplies of inexpensive electric power (provided by the Bonneville Power Administration) and clean water.

By 1978 almost one-fourth of Intel's U.S. work force was employed in the Portland area; meanwhile, most of the

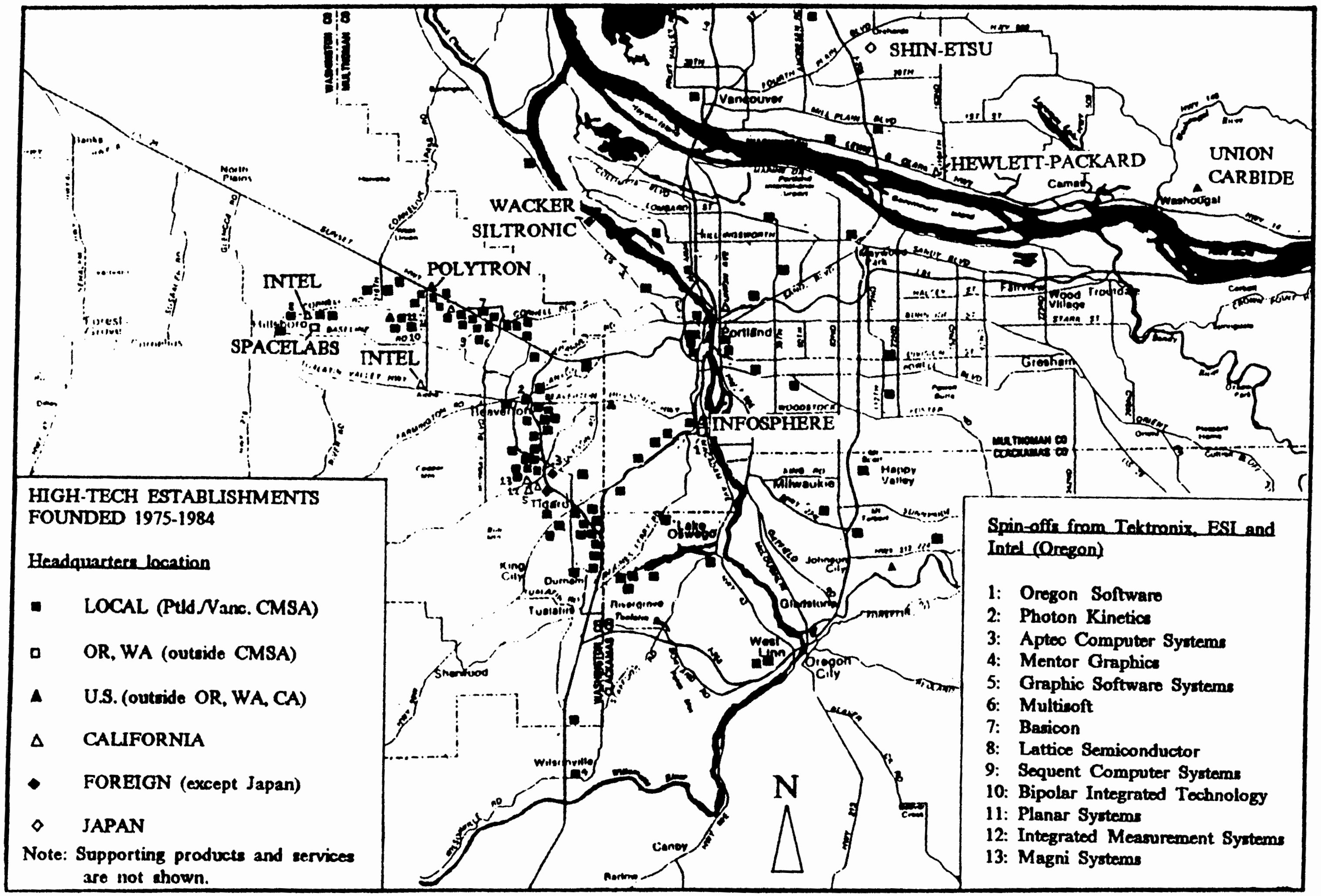

Figure 4. High-tech manufacturing and service establishments founded 1975-1984 in the Portland/Vancouver CMSA excluding Yamhill County (1991). Sources: Quanix Directory 1991; Resource Guide 1991; PDC 1991; author.

company's design work has been transferred to Oregon. Today Intel dominates the market for microprocessors and is the Portland/Vancouver CMSA's second largest high-tech firm (Russell 1990).

The second big California-headquartered high-tech firm to arrive in the Portland/Vancouver CMSA on a large scale was Hewlett-Packard of Palo Alto in 1979. Hewlett-Packard has already been present since 1973 with a small branch in Mc Minnville (Yamhill County), producing medical electronic equipment (e.g., X-ray equipment). Hewlett-Packard's branch plant in Vancouver (see Figure 4, p.47), making ink-jet printers, is one out of seven plants that have been established at different locations throughout the Pacific Northwest (other locations are Corvallis, OR, Boise, ID, Everett, WA, and Spokane, WA). Both Hewlett-Packard and Intel have their largest single manufacturing sites located in the Pacific Northwest (H/P in Corvallis, OR, and Intel in Hillsboro).

Other firms from California and elsewhere in the U.S. followed, such as a Union Carbide Chemicals and Plastics unit of the Union Carbide Corporation, Danbury, CT, established 1977 in Washougal; Spacelabs of Seattle-headquartered Westmark International, established 1981 in Hillsboro, making clinical information and patient monitoring products and services; and San Francisco-based

AT&E Laboratories, established 1982 in Tigard, manufacturing communications equipment.

A decisive factor in explaining the growth of high-tech industries in the late 1970s and early 1980s was the frequent occurrence of spin-offs - mainly from Tektronix, Intel, and ESI (see Figure 3, p.44). This process can be elucidated by analyzing the role of organizational structure and corporate policy in spin-off mechanisms. Rees and Stafford (1986) classify three types of spin-off firms based on how they were established:

1. Competitive spin-offs. In this case, employees leave a firm and establish their own companies whose products compete directly with those of the parent.
2. Backward-linked spin-off means that the spin-off is encouraged by the parent to supply needed materials and parts.
3. Forward-linked spin-off. In terms of contributing to the innovative potential of a region, this is the most significant category. Employees set up a company to market products on which they worked for the parent. This may occur when a potential entrepreneur is not encouraged by his present employer to pursue an innovation and decides to market the idea himself.

Some firms try to limit the number of external spin-offs by rewarding product and process innovation within the company, i.e., by stimulating internal spin-offs for risky

R&D ventures. In a number of cases existing firms encourage employees to start a "spinout" firm by assisting with capital, laboratory space, and technical support. Therefore, the parent firms themselves provide the technological infrastructure (Office of Technology Assessment 1984). Tektronix has also assisted internal entrepreneurs with spinout firms, for instance, TriQuint Semiconductor, a wholly owned subsidiary that manufactures high-speed integrated circuits, and leases space from Tektronix.

Tektronix alone gave birth after 1976 to more than fifteen new firms. Its most successful spin-off happened in 1981 when Mentor Graphics was founded. The company, now headquartered in Wilsonville, has become the Portland/ Vancouver CMSA's second largest indigenous high-tech employer (after Tektronix), holding a 35% share of the CAD/ CAE equipment market in the U.S. (Quanix Directory 1991). Planar Systems, established in 1983 to manufacture electroluminescent display panels, is Tektronix's first spin-off supported with its own venture capital.

Spin-offs from Intel include Lattice Semiconductor Corporation, located in Hillsboro in the Sunset Corridor with 185 employees, and founded in 1983 by a former circuit designer at Intel. Lattice introduced a new process to produce high-speed semiconductor devices. The company is sub-contracting chip manufacturing to Californian and

Japanese suppliers, and concentrates on R&D (design) and marketing in its Hillsboro complex (Hamilton 1987).

Another spin-off occurred in 1983 when the general manager of Intel's microprocessing unit together with seventeen former employees of Intel, who were all engaged in a parallel processing project, established Sequel (later called Sequent) Computer Systems in Beaverton (Figure 4, p. 47). Sequent belongs to a handful of firms specializing in developing and marketing parallel processing, a technology which can provide more computing power at lower costs. According to Cohn (1988), "the Portland area has a 'critical mass' of expertise [in this technology] which may draw support firms and related companies to the area" (p.33). The Portland area-based firms' share of the U.S. market for parallel processing computers is about 35%. Many of these firms - like Sequent - grew out of Intel's parallel processing project that was started in 1976 at its Aloha plant. NCube, which also spun off in 1983, produces a computer out of custom chips built into machines assembled at the firm's Beaverton plant. NCube's customers include universities, laboratories, and commercial research centers.

The period from 1975 to 1984 also saw a distinct rise in the number of new software firms. In fact, 40% of all high-tech establishments founded during this phase were software developers, among them several out-of-state firms like Verdix of Chantilly, VA in Hillsboro; Polytron - a division of Sage Software, Rockville, MD (in Beaverton); and two California-headquartered companies: Infosphere, Inc. on Macadam Ave. in Southwest Portland (see Figure 4, p.47) and Infotec Development, located in the Lloyd Center area. While software firms established before 1975 showed - similar to high-tech manufacturing - a heavy focus on locally- and Pacific Northwest-oriented business applications, e.g., saw mill and agricultural management, as well as education, health care, and utilities, the second half of the 1970s experienced a shift as newly founded companies began to concentrate on supporting engineers, engineering applications, and computers. This coincided with an expanding high-tech manufacturing base in Washington County. However, the increase in software firm formation rates in the Portland/Vancouver CMSA during the late 1970s and early 1980s followed for the most part national trends induced by the personal computer advent in 1981 (Resource Guide Oregon High-Technology 1991).

Finally, two major foreign-owned silicon wafer manufacturers established plants in the CMSA. In 1979 came German-owned Wacker Siltronic, and in 1984 Japanese-owned Shin-Etsu relocated from San Jose, CA (Silicon Valley) to Vancouver (Portland Development Commission 1991).

Phase III: 1985 to present

The most recent change in the Portland/Vancouver CMSA's high-technology development has been large-scale in-movement of Japanese firms. Major Japanese companies arrived within a few months' of each other in 1985, beginning with Nippon Electric Company (NEC; Figure 5, p.54). The firm has built a plant in Hillsboro in the Sunset Corridor to manufacture fiber-optic transmissions systems, data modems, and cellular telephones. NEC's communciations business group designated a subsidiary - NEC America, Inc. - to operate that plant. NEC's other facilities in the U.S. are located in California, Texas, and Virginia (Dodds and Wollner 1990).

NEC was followed by Seiko Epson Corporation of Tokyo, an important manufacturer of computers and peripherals. The firm's marketing and sales subsidiary in the U.S., Epson America, Inc., had earlier established a research and development center (the Epson Technology Center) in Santa Clara in California's Silicon Valley, but until 1985 Epson did not manufacture in the U.S. Epson chose to build its first manufacturing plant in the U.S. in the Portland area, and also established a subsidiary, Epson Portland Inc., to operate the new plant in Hillsboro. The 180,000 sq.ft. manufacturing facility assembles dot-matrix computer printers; there is a separate division in Beaverton manufacturing personal computers (Resource Guide Oregon High-Technology 1991).

Fujitsu has two plants in the Portland/Vancouver CMSA, one in Hillsboro, the other in Gresham (see Figure 5, p.54): The Hillsboro plant in the Sunset Corridor is operated by

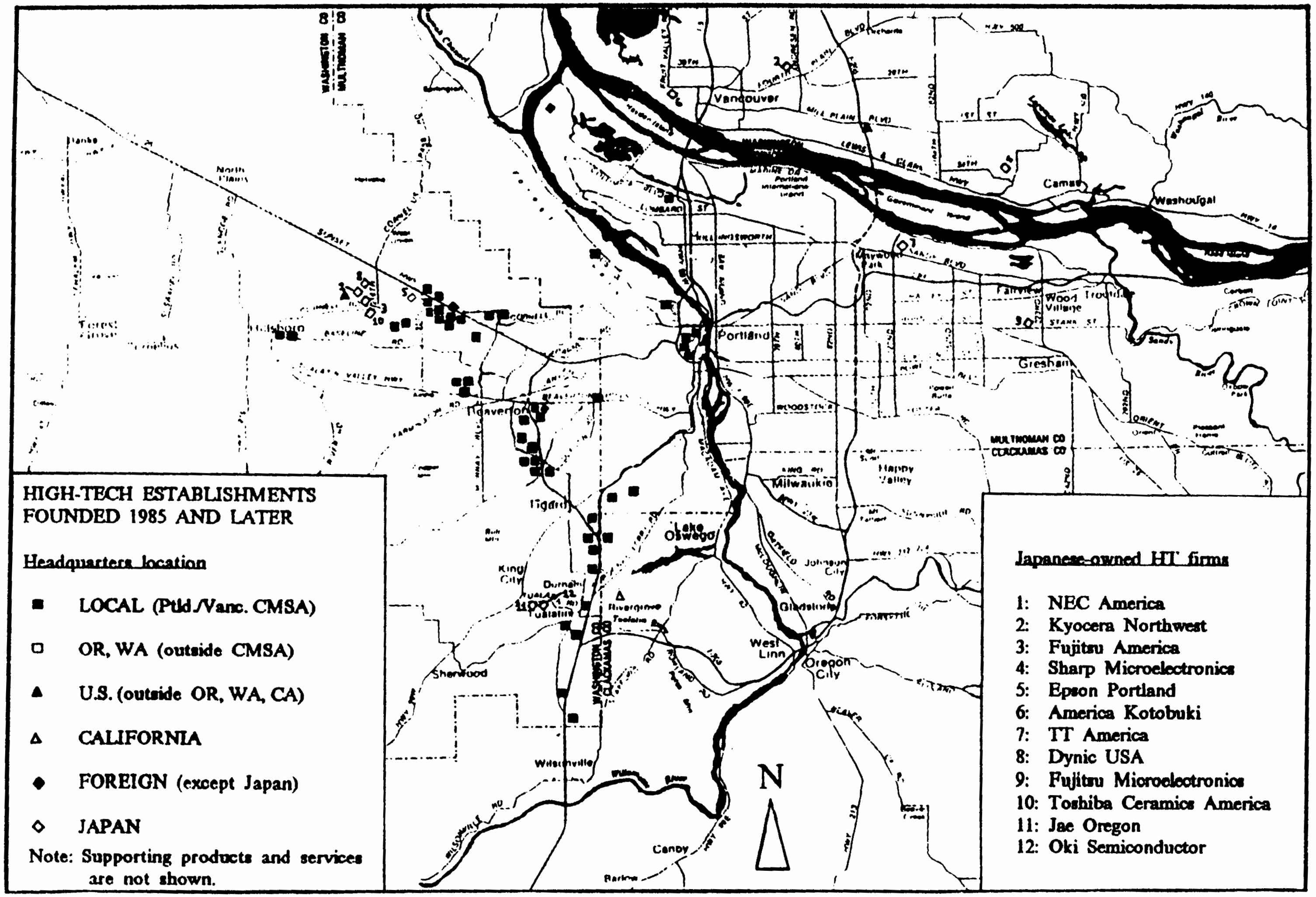

Figure 5. High-tech manufacturing and service establishments founded 1985 and later in the Portland/Vancouver CMSA excluding Yamhill County (1991). Sources: Quanix Directory 1991; Resource Guide 1991; PDC 1991; author.

San Jose, California-headquartered Fujitsu America (a subsidiary founded in 1968), and was set up to manufacture disk drives. Fujitsu's Gresham plant was established in 1987 as a division of Fujitsu Microelectronics, Inc. (an U.S. subsidiary) to produce integrated circuits (Quanix Directory 1991).

What has caused the sudden arrival of these Japanese high-tech firms? It appears that it is linked to the state of Oregon's decision in August 1984 to repeal its unitary tax requirements which taxed corporations on the basis of their worldwide earnings. Of those states that had a unitary tax, including California, Oregon was the first to replace this tax by taxing only a company's Oregon operations. Since Japanese firms have refused to locate plants in states that have an unitary tax, the decision to repeal this tax helped legitimize Oregon's claim as an excellent location for foreign businesses. Although the repeal of the tax may be the single most important explanatory factor, the arrival of Japanese high-tech companies has to be seen in the broader context of policy decisions aimed at stimulating high-tech growth, as well as within a set of other locational factors which will be the focus of Chapters III and IV.

The latest Japanese high-tech firms that have located in the Portland/Vancouver CMSA are Toshiba Ceramics (1989) in Hillsboro, making quartz crucibles for silicon wafer manufacturers, Jae Oregon (1990) manufacturing electrical components for the automotive industry, and Oki Semiconductor (1990), both in Tualatin. However, the last half of 1991 and all of 1992 has seen a significant decrease in Japanese investment due to overall worsening economic conditions in Japan and in the U.S. One indication is Toshiba's decision to postpone indefinitely construction of a semiconductor plant planned for a site in Hillsboro west of Toshiba Ceramics America's location (Read 1992).

The in-movement of Japanese-owned high-tech firms since 1985 is not only confined to the Oregon counties of the CMSA. After Shin-Etsu, Vancouver could attract another semiconductor materials manufacturer: Kyocera Northwest, a subsidiary of Kyocera Corporation, Kyoto, is making multilayer ceramic capacitor chips (see Figure 5, p.54). Nearby Camas hosts an integrated circuit design center (R&D unit), employing 175 people of Sharp Microelectronics Technology Inc. whose parent is the Sharp Corporation of Osaka, Japan. It should be emphasized that the state of Washington has provided financial incentives in terms of cash payments to these firms to locate in Vancouver, a policy which thus far has not been pursued by Oregon (OEDD 1992).

Altogether, Japanese high-tech companies have invested more than $ 750 mill. in the Portland/Vancouver CMSA since 1985, and employ about 6,300 people (Yang 1992). Already, four of the nine biggest high-tech companies in the

Portland/Vancouver CMSA are foreign-owned, three of them Japanese firms, showing the degree to which foreign high-tech investment has become an integral part of the area's most recent high-tech industry development.

DISTRIBUTION OF HIGH-TECH ESTABLISHMENTS IN THE PORTLAND/VANCOUVER CMSA

Over three-fourths of Oregon's high-technology employment is located in the Tri-County area of Multnomah, Washington, and Clackamas (Oregon Economic Development Department 1986). According to the 1988 County Business Patterns, total high-technology employment in the Portland/ Vancouver CMSA is estimated as between a minimum of 33,340 and a maximum of 42,976, making up 6.0 - 7.74% of total employment, and 24.38 - 32.78% of all manufacturing employment in the CMSA is tied to high-tech manufacturing (see Table VIII, p.58). Based on these data, there are 704 high-tech establishments - 366 belonging to the manufacturing and 338 to the service sector.

However, the Quanix Directory (1991) lists only 566 high-tech establishments having a total employment of 46,979. This figure excludes Tektronix's employees, Oregon's largest electronics company (because of insufficient data). Tektronix's total employment in the Portland/Vancouver CMSA is estimated at 7,300 (Portland Chamber of Commerce 1991) bringing high-tech employment in the CMSA to a total of 54,279.

TABLE VIII

HIGH-TECH EMPLOYMENT IN THE PORTLAND/VANCOUVER CMSA IN 1988 BY COUNTY

County	No.of HT employees	% HT employees of total empl.	% employees in HT services of total HT empl.	% employees in HT manufacturing of total manuf.empl.
Clackamas	3,136 - 5,112	4.27 - 6.96	5.32 - 8.67	17.08 - 28.07
Clark, WA	3,694 - 7,796	6.43 - 13.56	1.53 - 3.22	20.4 - 43.81
Multnomah	6,379 - 8,255	2.13 - 2.75	36.33 - 47.01	7.63 - 11.87
Washington	19,531 - 20,565	17.95 - 18.9	9.6 - 10.1	56.98 - 60.34
Yamhill	600 - 1,248	3.82 - 7.95	-------------	11.25 - 23.4
Portland/Vancouver CMSA				
	33,340 - 42,976	6.0 - 7.74	12.48 - 16.09	24.38 - 32.78

Note: For reasons of confidentiality about specific firms, most SIC data on employment are only available as a range of minimum and maximum number of employees in a certain category.

Source: U.S. Bureau of the Census, County Business Patterns Oregon and Washington 1988.

Table IX (p.59) shows the number of high-tech employees and high-tech establishments in the CMSA divided by SIC codes. SIC 382 - measuring and controlling devices - counts for almost one-third of total high-tech employment, a field dominated by Tektronix. It is followed by SIC 737, computer and data processing services, with 5,293 employees. Further major products include SIC 367, electronic components and accessories, SIC 357, computer and office equipment, SIC 355, special industry machinery, SIC 372, aircraft and parts, SIC 366, communications equipment, SIC 384, medical instruments and supplies, and SIC 369, miscellaneous electrical equipment and supplies. These nine SIC codes account for more than 90% of high-technology employment and 85% of all high-tech establishments in the Portland/

TABLE IX

HIGH-TECH EMPLOYMENT AND NUMBER OF HIGH-TECH ESTABLISHMENTS IN THE PORTLAND/VANCOUVER CMSA IN 1988 (BY SIC CODE)

SIC code	Industry	No. of employees	No. of establishments
	MANUFACTURING	27,976 - 37,612	366
281	Industrial inorganic chemicals	100 - 249	5
283	Drugs	330 - 409	13
284	Soap, cleaners, and toilet goods	120	10
285	Paints and allied products	324 - 403	10
287	Agricultural chemicals	161	5
289	Miscellaneous chemical products	243 - 322	20
355	Special industry machinery	2,131	62
357	Computer and office equipment	3,716 - 5,714	21
361	Electric distribution equipment	120 - 348	5
362	Electrical industrial apparatus	239 - 388	14
365	Household audio and video equipment	120 - 348	4
366	Communications equipment	1,528 - 1,607	17
367	Electronic components and accessories	4,603 - 6,251	59
369	Miscellaneous electrical equipment and supplies	986 - 1,883	20
372	Aircraft and parts	1,000 - 2,499	2
381	Search and navigation equipment	120 - 348	7
382	Measuring and controlling devices	10,663 - 12,162	41
384	Medical instruments and supplies	1,266 - 1,914	43
386	Photographic equipment and supplies	206 - 355	8
	SERVICES	5,364	338
737	Computer and data processing services	5,293	330
8731	Commercial physical research	71	8
	TOTAL	33,340 - 42,976	704

Note: In some categories, data are only available as a range of employees.

Source: U.S.Bureau of the Census, County Business Patterns Oregon and Washington 1988.

Vancouver CMSA. SIC 372 is dominated by a single company, Boeing of Portland, which has 2,038 employees. About 47% of the total number of high-tech establishments belongs to the category of computer and data processing services (SIC 737).

Given the striking domination of these nine industry groups among high-tech establishments in the Portland/Vancouver CMSA, it is justified to concentrate upon them in this study, because they may provide clues as to the regional and intraregional locational factors.

Figure 6 (p.61) indicates that the distribution of high-tech establishments in the Portland/Vancouver CMSA is characterized by clusters. Washington County has by far the largest concentration of high-technology, both in terms of the number of establishments and high-tech employment. Fifty-seven percent of all high-tech establishments in the CMSA are located here, and the county's share of the CMSA's total high-tech employment is 54.3% (Quanix Directory 1991). The dominant aggregation is along U.S.26 in the "Sunset Corridor" in Beaverton and Hillsboro.

Washington County adopted the "Sunset West Plan" for the zone along U.S.26 in 1981. The Sunset West Plan, together with plans for adjacent parts of Clackamas and Multnomah counties, embraces two-thirds of the buildable land within the metropolitan area, thus determining the economic future of the entire region. The Sunset Corridor has drawn extensive investment in recent years, particularly by major international electronics manufacturers (see Figure 5, p.54). According to the Portland Development Commission (1991), over 4,000 acres of vacant land is available in the

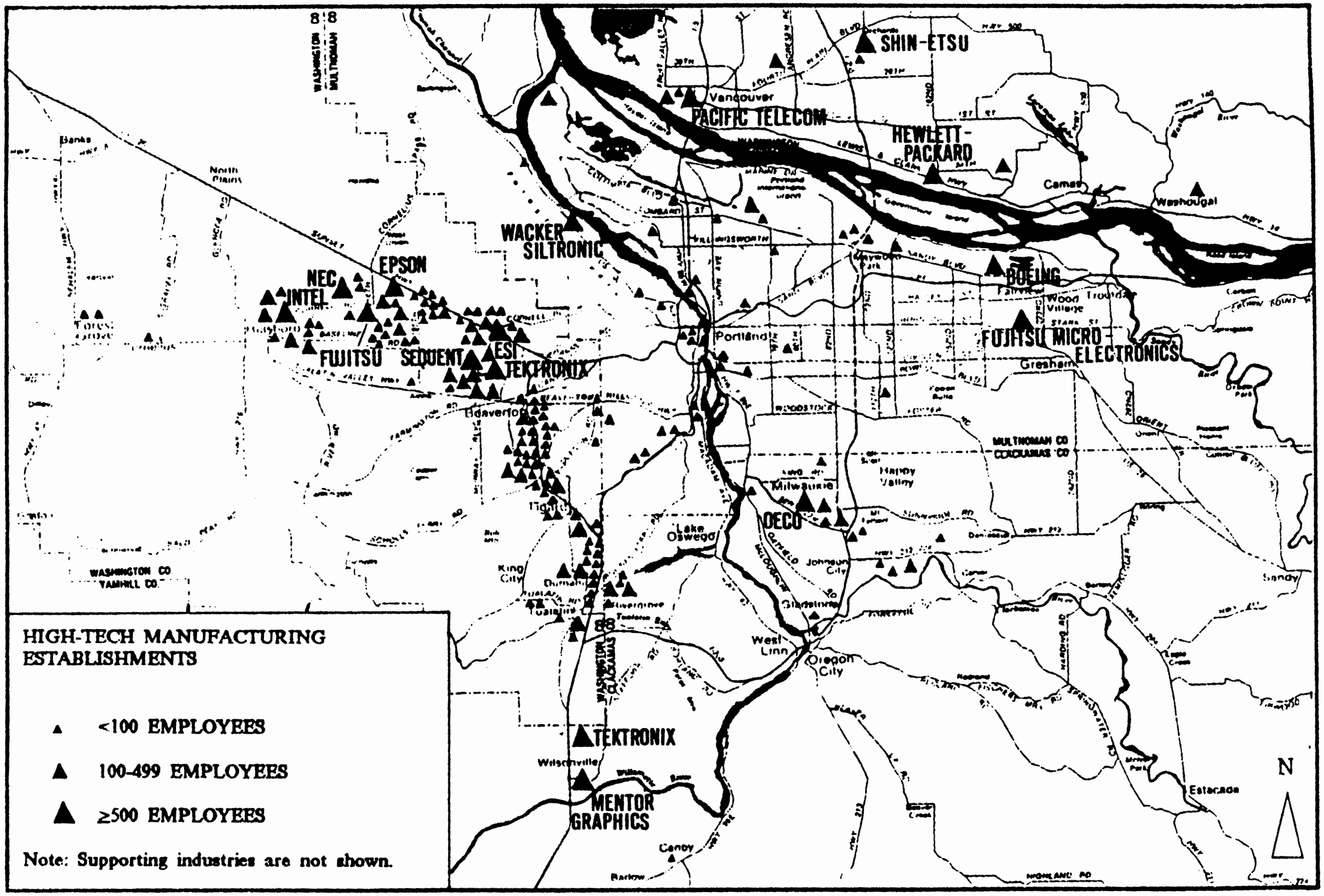

Figure 6. Locations of high-tech manufacturing establishments in the Portland/Vancouver CMSA excluding Yamhill County, 1991.
Sources: Quanix Directory 1991; Resource Guide 1991; author.

Sunset Corridor for single users and campus-style development.

Another cluster of high-tech establishments can be found along Hwy.217 also in Beaverton and Tigard, as well as along I-5 in Tigard and Tualatin (Figure 6, p.61). Obviously, Beaverton and Hillsboro are the centers of high-tech development in Washington County. Six of the CMSA's thirteen largest high-tech manufacturing establishments are located in either Beaverton or Hillsboro, occupying spacious sites, with a total of 14,825 employees: Tektronix (approx. 7,300 employees) and Sequent Computer Systems (1,700 employees) in Beaverton, and Intel (3,300 empl.), Fujitsu America, Inc. (900 empl.), Epson Portland, Inc. (1,000 empl.), and NEC America, Inc. (625 empl.) in Hillsboro (Portland Chamber of Commerce 1991). As a consequence, Beaverton and Hillsboro exhibit the highest number of employees in high-tech manufacturing of all municipalities, accounting for more than half of total high-tech employment in the Portland/Vancouver CMSA (Figure 7, p.63).

The presence of these large electronics companies also shows in Washington County's distribution of high-tech employment based on industry categories (SIC codes). According to Table X (p.64), SIC 382, measuring and controlling devices, SIC 367, electronic components and accessories, SIC 357, computer and office equipment, and SIC

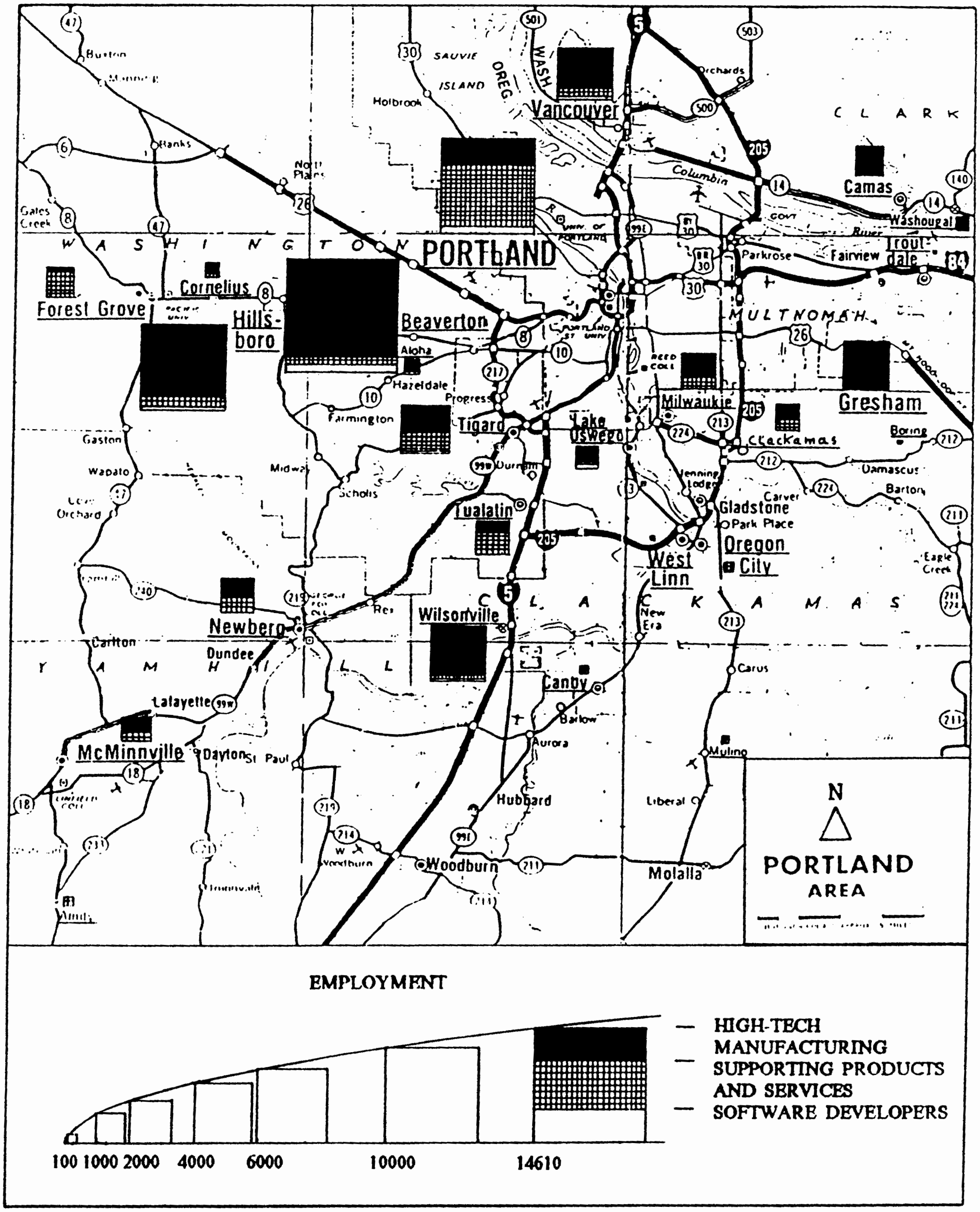

Figure 7. Distribution of high-tech employment (manufacturing, supporting products and services, software) in the Portland/Vancouver CMSA by municipality, 1991. Sources: Quanix Directory 1991; author.

TABLE X

HIGH-TECH EMPLOYMENT AND NUMBER OF HIGH-TECH ESTABLISHMENTS IN 1988 BY COUNTY AND SIC CODE

SIC code	CLACKAMAS No.of empl.	CLACKAMAS No.of firms	CLARK, WA No.of empl.	CLARK, WA No.of firms	MULTNOMAH No.of empl.	MULTNOMAH No.of firms	WASHINGTON No.of empl.	WASHINGTON No.of firms	YAMHILL No.of empl.	YAMHILL No.of firms
MANUFACT.	2864-4840	43	3575-7677	33	3380-5256	123	17557-18591	156	600-1248	11
281	....	..	....	..	100- 249	5	....	...	....	..
283	123	5	....	..	187	5	20- 99	3	....	..
284	....	..	....	..	120	10	....	...	....	..
285	20- 99	3	....	..	304	7	....	...	....	..
287	....	..	....	..	161	5	....	...	....	..
289	....	..	20- 99	4	223	16	....	...	....	..
355	281	18	735	9	581	24	534	11	....	..
357	1000-2499	3	500- 999	1	....	...	2216	17	....	..
361	....	..	....	..	20- 99	1	100- 249	4	....	..
362	....	..	100- 249	4	....	...	139	10	....	..
365	....	..	100- 249	1	....	...	20- 99	3	....	..
366	....	..	20- 99	2	....	...	1508	15	....	..
367	1090	7	1000-2499	3	67	7	2346	36	100- 249	6
369	250- 499	3	100- 249	4	136	8	500- 999	5	....	..
372	....	..	....	..	1000-2499	2	....	...	....	..
381	....	..	....	..	100- 249	4	20- 99	3	....	..
382	....	..	1000-2499	5	120	10	9543	26	....	..
384	100- 249	4	....	..	155	15	511	19	500- 999	5
386	....	..	....	..	106	4	100- 249	4	....	..
SERVICES	272	40	119	18	2999	153	1974	127	....	..
737	272	40	119	18	2999	153	1903	119	....	..
8731	....	..	....	..	....	...	71	8	....	..

Note: In some categories, data are only available as a range of employees.

Source: U.S.Bureau of the Census, County Business Patterns Oregon and Washington 1988.

366, communications equipment, contribute to 84 - 89% of total high-tech manufacturing employment in the county.

Interestingly, NEC's, Epson's, and Fujitsu America's plants are all clustered in the Sunset Corridor close to the

Hillsboro Airport within short distance of each other (see Figure 6, p.61). Mike Ogan with the Portland Development Commission (interview 1992) pointed out that especially managers of Japanese high-tech companies emphasize the agglomeration advantage of having customers and suppliers (e.g., Intel) located in close proximity. However, social factors may also explain the clustering, resulting in a "little Japan". In fact, Japanese firms generally tend to remain insulated from the rest of the state, both in terms of business practices and social interaction. There are few social ties between Japanese managers and workers and the local communities, and they are hardly involved in community activities. This is mostly due to cultural misunderstanding on both sides, and leads to the insulation of Japanese high-tech operations from the larger society.

Altogether, 57 - 60% of total manufacturing employment in Washington County is tied to high-tech manufacturing which further emphasizes the important role of high-tech industries in the county (see Table VIII, p.58). Additionally, Beaverton hosts a significant number of software developing establishments (Figure 8, p.66). One of them is Central Point Software, the Portland/Vancouver CMSA's largest software firm with 265 employees, developing software utilities for personal computers. The distribution of software developers follows a similar pattern as the locations of high-tech manufacturing, concentrating in the

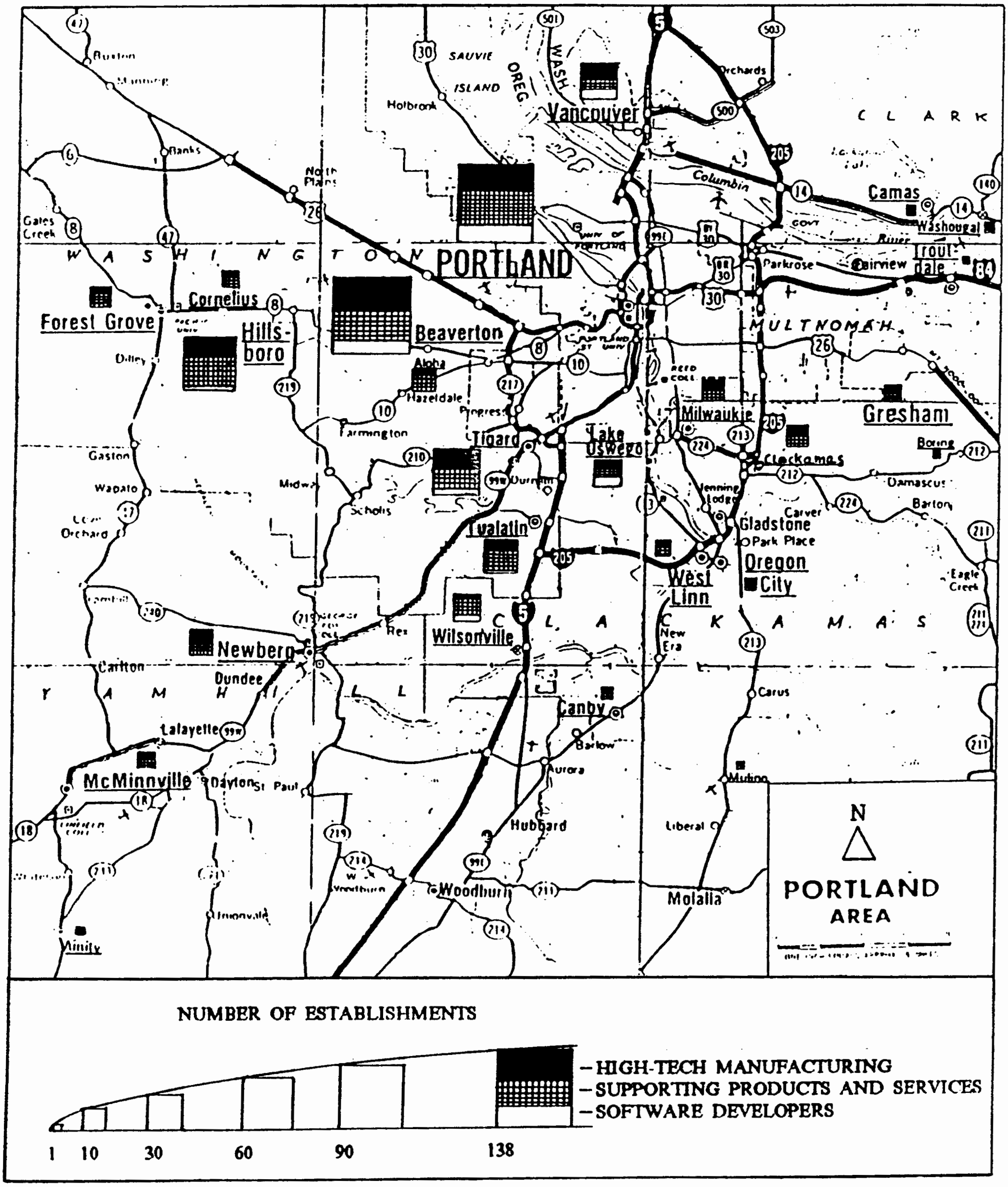

Figure 8. Distribution of high-tech establishments (manufacturing, supporting products and services, software) in the Portland/Vancouver CMSA by municipality, 1991. Sources: Quanix Directory 1991; author.

Beaverton area of the Sunset Corridor, and along Hwy.217 in Beaverton and Tigard (see Figure 9, p.68). The corresponding SIC code 737, computer and data processing services, shows the fourth-highest number of employees (1,903) in the high-tech sector in Washington County behind the electronics-related categories.

Multnomah County contains the second-highest number of high-tech establishments (110) and high-tech employment (11,615) in the Portland/Vancouver CMSA. The county's share of the total number of high-tech establishments and high-tech employment in the CMSA is 19% and 21.4%, respectively (Quanix Directory 1991). For the purpose of this study, the terms 'Multnomah County' and 'Portland' can be used as equivalents because almost all high-tech establishments in the county are located within Portland city limits - with one notable exception. Gresham's high-tech employment is of some significance in Multnomah County, since two large out-of-state high-tech companies have established branch plants: the Boeing Company of Seattle, and Fujitsu Microelectronics of Fujitsu Limited, Tokyo (500 employees). Therefore, total high-tech manufacturing employment in Gresham is almost as high as in the entire city of Portland (Figure 7, p.63).

Portland's high-tech industry structure is somewhat different from Beaverton, Hillsboro, and elsewhere in Washington County. First of all, high-tech manufacturing establishments are far less clustered. Some minor

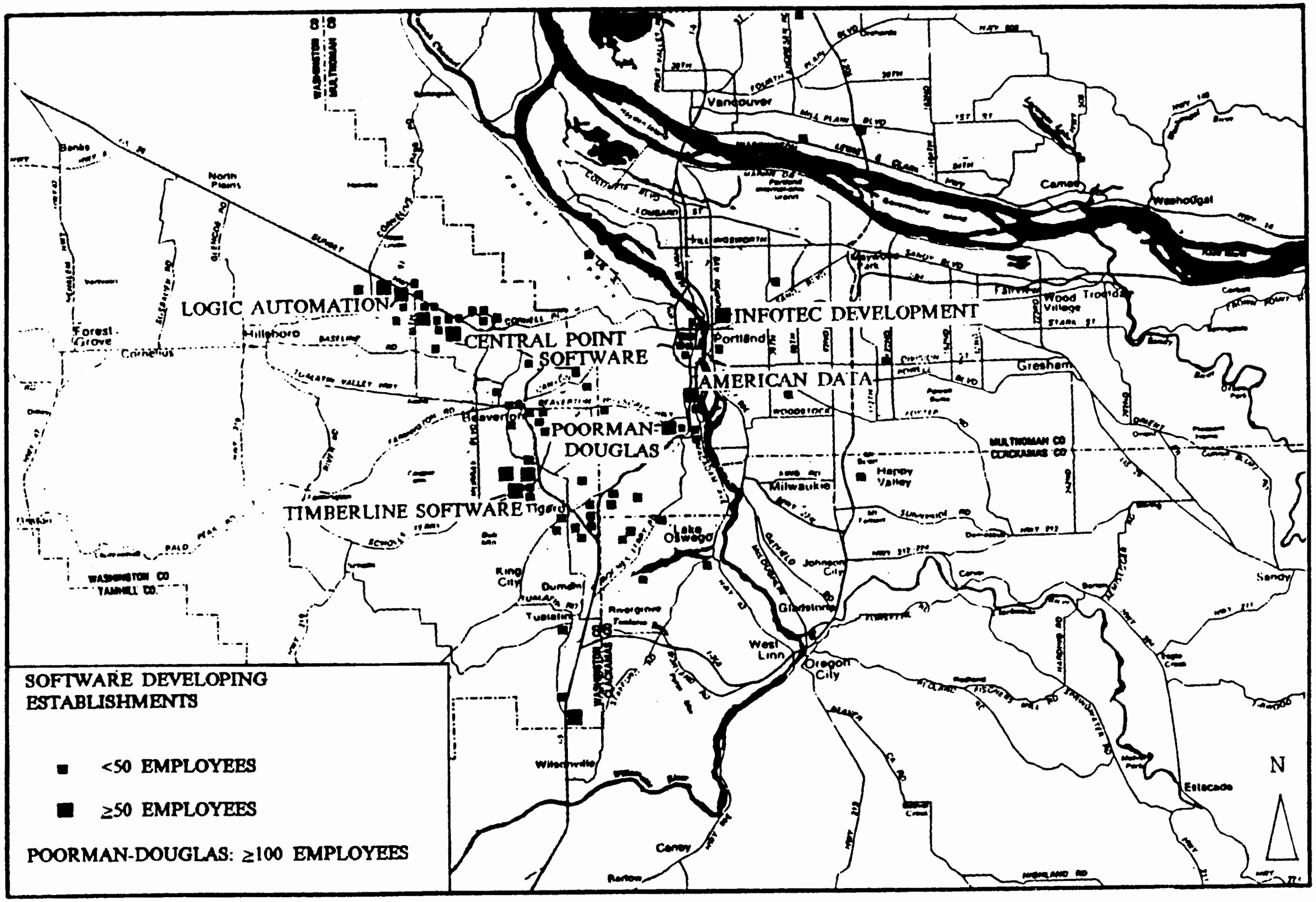

Figure 9. Locations of software developing establishments in the Portland/Vancouver CMSA, 1991.
Sources: Quanix Directory 1991; Resource Guide 1991; author.

concentrations can be found in central and inner Portland, as well as along Macadam Ave. and I-5 in Southwest Portland. The area around Portland International Airport in Northeast Portland has also attracted some medium-sized firms, but otherwise there are no distinctive concentrations of high-tech manufacturing and the establishments are merely scattered throughout Portland (Figure 6, p.61). Wacker Siltronic, a subsidiary of Wacker Chemie GmbH, München, Germany, forms a major "outlier" along the Willamette River in Northwest Portland, and is with its 1,050 employees the city's largest high-tech company (seventh-largest in the CMSA).

Figure 10 (p.70) underscores the importance of high-tech-oriented services in Multnomah County. These include both supporting services like computer maintenance/repair and computer system design, as also software developers. Indeed, 55% of all high-tech establishments in the county are computer and data processing services, and Multnomah County exhibits the highest percentage of employees in high-tech-oriented services (36.3 - 47% of the county's total high-tech employment) in the CMSA.

In contrast to high-tech manufacturing, software developing establishments are rather confined to certain parts of the city of Portland. They are concentrated in central Portland (especially in the Downtown area) and along Macadam Ave. and I-5 south of the Downtown area (Figure 9,

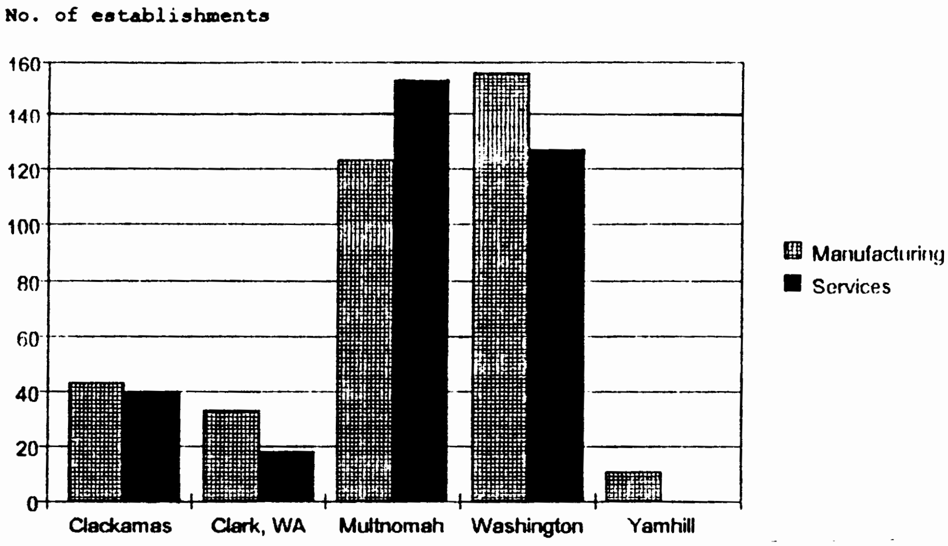

Figure 10. Number of high-tech establishments in manufacturing and services in 1988 by county. Source: U.S.Bureau of the Census, County Business Patterns Oregon and Washington 1988.

p.68) which are also minor aggregations of high-tech manufacturing. About two-thirds of Portland's software establishments are located in Southwest Portland, and software production is insignificant on the eastside. The only large software developer here is Infotec Development of Santa Ana, California, established in 1983 in the Lloyd Center area (200 employees), and a contractor for Bonneville Power Administration and other federal agencies for computer engineering services (Resource Guide Oregon High-Technology 1991).

As Figure 7 (p.63) indicates, high-tech employment in Portland has to a great extent to be attributed to supporting firms. Aside from supporting services, there are several manufacturers that are selling technical products mostly into high-technology markets. A typical case is Precision Castparts Corporation (PCC), located in Southeast Portland, which is a producer of jet engine castings and catering to the aerospace industry (3,500 employees, established in 1953), accounting for 30% of total high-tech employment in Multnomah County. In fact, 45.6% of the Portland/Vancouver CMSA's employment in the category of supporting products and services occurs in Multnomah County (Washington County: 35%) and this group includes 57.8% of total high-tech employment in the county (Washington County: 17.5%).

Clackamas County ranks third in the CMSA in terms of the number of high-tech establishments and high-tech employment. There are two notable high-tech aggregations: 1. in the Milwaukie/Clackamas area along Hwy.224 near the I-205 interchange; and 2. in Wilsonville along I-5 (Figure 6, p.61). Wilsonville is the new headquarters of Mentor Graphics; almost 40% of high-tech employees in Clackamas County are on Mentor Graphics' payroll (2,500; Resource Guide Oregon High-Technology 1991).

The Milwaukie/Clackamas area hosts mostly medium-sized, older electronics companies, established in the 1960s and 1970s. The only new high-tech facility in the area is a result of OECO's relocation from inner Southeast Portland to Milwaukie in 1986. OECO manufactures and services specialized products for the electronics industry. Lake

Oswego has half of Clackamas County's software developers with the remaining but two located in Wilsonville.

Clark County's 35 high-tech establishments (29 of them located in Vancouver) employ a total of 4,706 people, making up 8.7% of the CMSA's high-tech employment. The largest company is Shin-Etsu (formerly SEH America, Inc.) of Tokyo (1,200 employees). Many of these establishments are branch plants of out-of-state U.S.-owned and Japanese-owned high-tech companies.

Finally, Yamhill County's share of the Portland/ Vancouver CMSA's high-tech employment and number of high-tech establishments is fairly small: about 3.5% in both categories (Quanix Directory 1991).

After describing the locations of high-tech establishments in the Portland/Vancouver CMSA, the next chapter explains this distribution pattern in the context of regional and intraregional locational factors.

CHAPTER III

THE WHY OF HIGH-TECH INDUSTRY LOCATIONS IN THE PORTLAND/ VANCOUVER CMSA: REGIONAL AND INTRAREGIONAL FACTORS

This chapter tries to answer the why? question of high-tech industry locations in the Portland/Vancouver CMSA. What factors can explain locations of high-tech establishments in the CMSA and what influences their intraregional distribution pattern? Information gathered from various regional and local agencies concerned with issues of economic development is used as a framework to identify at first regional locational factors and secondly intraregional factors. The analysis is based on the economic theories and empirical studies on locational decision-making as reviewed in Chapter I.

REGIONAL LOCATIONAL FACTORS

First of all, it is necessary to distinguish two categories of factors which can explain high-tech industry locations in the Portland/Vancouver CMSA:

1. those relating to the process of high-tech development as elaborated in Chapter II and the companies themselves; and
2. those relating to other characteristics or attributes of the area (e.g., quality of life, business costs).

The first set of factors, also used by Bathelt (1993) to explicate the rise of high-tech industries in certain areas of the "Sunbelt", describes locations of high-tech establishments in the CMSA by interpreting their development as an evolutionary process. Therefore, high-tech firms themselves create a regional business einvironment according to their needs. By positive feedback, initial locally-founded high-tech companies (e.g., Tektronix) reinforce clustering and agglomeration effects, generating the conditions for self-sustaining growth and nurturing new local and indigenous high-tech firms (i.e. spin-offs and startups). Main causes for the emergence of such self-sustaining growth processes are agglomeration advantages in terms of markets, information, technology, labor force, capital, and materials which are demanded by firms.

The interviews supported this view that the presence and early success of a few indigenous high-tech companies like ESI and Tektronix, including their spin-offs, induced other firms from outside the Pacific Northwest to establish plants in the Portland/Vancouver CMSA. According to the Portland Development Commission (Ogan 1992), this is particularly true for Japanese high-tech companies, while out-of-state U.S.-owned high-tech firms seem to pay less attention to the mix of firms already here.

The second category encompasses attributes-of-the-area variables which were found to have influenced high-tech firm locational decisions. Although these locational factors are not exclusive charcteristics of the Portland/Vancouver CMSA, they have contributed to the growth of high-tech industries, particularly at the latter stages, when high-tech firms became increasingly drawn in from California and Japan.

Interviews with regional and local business development agencies (Greater Hillsboro Area Chamber of Commerce, Portland Metropolitan Chamber of Commerce, Portland Development Commission, Oregon Economic Development Department, Clackamas County Economic Development Commission, and Sunset Corridor Association) produced the following list of attributes-of-the-area factors considered important for high-tech companies when locating in the Portland/Vancouver CMSA:

(A.) costs of doing business;

(B.) quality of life; and

(C.) availability of a well-trained, stable labor force.

These three factors were unanimously cited by all agencies interviewed; however, the agencies did not provide an exact ranking scheme. Other factors mentioned by some of the development organizations include appropriate supply of clear water (Hillsboro Area Chamber of Commerce and Portland Development Commission) and the ability to recruit scientific, engineering, and technical personnel to the CMSA (Sunset Corridor Association, Clackamas County Economic

Development Commission, and Portland Development Commission).

Costs Of Doing Business

The interviews revealed that costs of doing business appeared to be a key locational reason for out-of-state U.S.-owned (mainly from California) and Japanese high-tech firms establishing branch plants in the Portland/Vancouver CMSA to manufacture standardized goods. According to the product-cycle theory, such locations are highly dependent on business costs-related factors, especially the search for lower labor costs, and the highly automated production process generally requires only semi-skilled or unskilled labor which is available nearly everywhere.

The Bureau of Labor Statistics' Employment and Earnings figures (1991) indicate that in 1990 the average weekly wage in Oregon in the manufacturing sector was clearly below the U.S. average and lower than in all major core high-tech states (California, Arizona, Connecticut, Illinois, Louisiana, Maryland, Massachusetts, New Jersey, and Texas) as identified by Markusen, Hall, and Glasmeier (1986) except for Oklahoma. Of the five minor high-tech cores, Minnesota and Colorado showed significantly higher wages than Oregon, while they were lower in Kansas, Florida, and Utah (see Table XI, p.77).

It has to be stressed that the agglomerations of high-tech firms that are so prominent in Silicon Valley and the

TABLE XI

1990 AVERAGE WEEKLY WAGES IN THE MANUFACTURING SECTOR IN HIGH-TECH CORE STATES AND OREGON

Rank	State	1990 average weekly wage in $
1.	Connecticut	687
2.	New Jersey	658
3.	Massachusetts	631
4.	California	613
5.	Illinois	590
6.	Colorado	588
7.	Maryland	586
8.	Minnesota	579
9.	Arizona	559
10.	Louisiana	548
11.	Texas	546
12.	OREGON	515
13.	Kansas	507
14.	Florida	494
	Oklahoma	494
16.	Utah	477
	U.S. average	555

Source: U.S.Bureau of Labor Statistics, Employment and Earnings 1991.

Boston area arose from a local high-tech infrastructure which cannot be transplanted along with branch plants of large corporations (Malecki 1986). Thus, the locations of large companies' branch plants as part of the third stage of the product-cycle are very susceptible to short-term cyclical fluctuations and have the potential of being relocated eventually to even lower business-costs areas.

The degree of linkage with local firms by multi-establishment corporations locating branch-plant facilities in the CMSA tends to be minimal. Bain (1991) has shown for

Japanese high-tech firms that local subcontractors supply in no case even half of a company's needed parts. As an integral part of a multi-establishment firm's corporate structure and global planning strategy, branch plants have little control over their activities and in most cases do not source the local market.

The concentration of several large foreign-owned silicon wafer manufacturing plants in the Portland/Vancouver CMSA can largely be attributed to business-costs factors. Additionally, the CMSA could offer clear water with a very low silicate content which is the key to successful crystal growing. Although the Portland/Vancouver CMSA is not unique with this aquifer, it is the combination of inexpensive electric power and access to clear water that have made the area such a prominent location for silicon wafer manufacturers (Russell 1990).

Quality Of Life

A second locational factor cited by regional and local business development agencies encompasses the quality-of-life issue or livability of the CMSA. Based on earlier discussions, it should be expected that this factor is of particular importance to attract and retain scientific, engineering, and technical personnel.

To remain competitive, high-tech firms have to achieve a significant degree of innovative activity and market flexibility. It means that R&D are central elements of the companies' planning strategies. Since qualified R&D workers are scarce, it is consistent to locate R&D units in areas which are also preferred residences of engineers and other scientific personnel. As indicated, highly skilled professionals are inclined to put a high value on quality-of-life factors because of their affluence. In fact, the Portland/Vancouver CMSA has been able to attract to some extent engineers particularly from high-tech centers in California (Silicon Valley, Orange County) who came to the CMSA mainly for quality-of-life-related reasons (less urban congestion, shorter commuting times, and less polluted environment than in California high-tech cores; Yang 1992), thus confirming the results of the interviews that the perceived high quality of life enables high-tech companies to recruit SE&T personnel to the CMSA. An example is Intel's decision to transfer most of its design work force to the Portland area.

How does the quality of life in the Portland/Vancouver CMSA compare to other metropolitan areas in the U.S.? Empirical studies support the view that Portland has a favorable quality-of-life or livability rating. Liu (1975) compared the quality of life in 65 American cities in 1970 based on economic, political, and social characteristics, as well as the quality of the health and education system and the environment. Portland was the only city receiving the best possible rating in all of these categories.

In Boyer and Savageau's "Places Rated Almanac" (1989) the Portland MSA ranks 24th among the 333 metropolitan areas investigated in terms of livability. To determine "the best places to live in America", they used nine categories: costs of living, jobs, crime, health care and environment, transportation, education, the arts, recreation, and climate. The ranks for each city for each of the factors were added together for a cumulative score. It should be noted that the ratings apply to the officially defined metropolitan area; nevertheless, Vancouver, WA (Clark County) is regarded as a separate unit.

In addition to this ranking scheme, Boyer and Savageau (1989) supply a list of metropolitan areas that show steady strength in all categories, even though they might not have any first-place showing. These metropolitan areas should not have more than one rank below 200th. As a result, the Portland MSA moves from 24th to 10th place, because fourteen metropolitan areas with higher overall ranks had to be excluded from the list. Portland's best rating appears in the category "climate" (16th rank) while its worst is in "crime" (322nd).

Boyer and Savageau (1989) ranked a metropolitan area's climate based on its mildness, using a combination of temperature and humidity factors. 'Mild' thus refers to the absence of great variations or extremes of temperatures, and mildest climates are defined as those whose mean temperatures remain closest to 65 degrees Fahrenheit for the greatest percentage of time.

Undoubtedly, Portland's crime rate - the 12th highest of all metropolitan areas - is a disturbing phenomenon, but caution needs to be exercised when interpreting these data. The Boyer and Savageau study does not reveal any comparative information with respect to the reporting rates of crime victims.

A different approach to capture the livability of the Portland area was undertaken by Chapman (1987) who tried to incorporate both quantitative measures - as relied upon by Liu (1975) and Boyer and Savageau (1989) - and subjective impressions expressed by Portland residents. These subjective impressions of Portland were derived from questionnaire responses of Portland City Club members. The cities' physical environment generated the most positive comments, especially its scenic setting and diversity of its surroundings, along with easy access to a wide range of outdoor recreational opportunities, as well as its size, providing the amenities of a large city and a small town atmosphere at the same time. In the social environment the open political climate and informal, slow-paced ambience of the city were most frequently mentioned as contributing to the livability.

Although the studies differ in their choice and weight of indicators to measure quality of life, they all rate

Portland or the Portland/Vancouver CMSA (depending on the selection criteria) as among the top 25% metropolitan areas in livability.

The attraction of the Portland/Vancouver CMSA to some engineers and other scientific personnel from California can partly also be attributed to the comparably low living and housing costs. Figure 11 shows the cost of living index for selected large metropolitan areas in the western portion of the U.S. The index is based on a national average of 100, and comprised of six components: grocery items, housing, transportation, utilities, health care, and miscellaneous goods and services. This survey by the American Chamber of

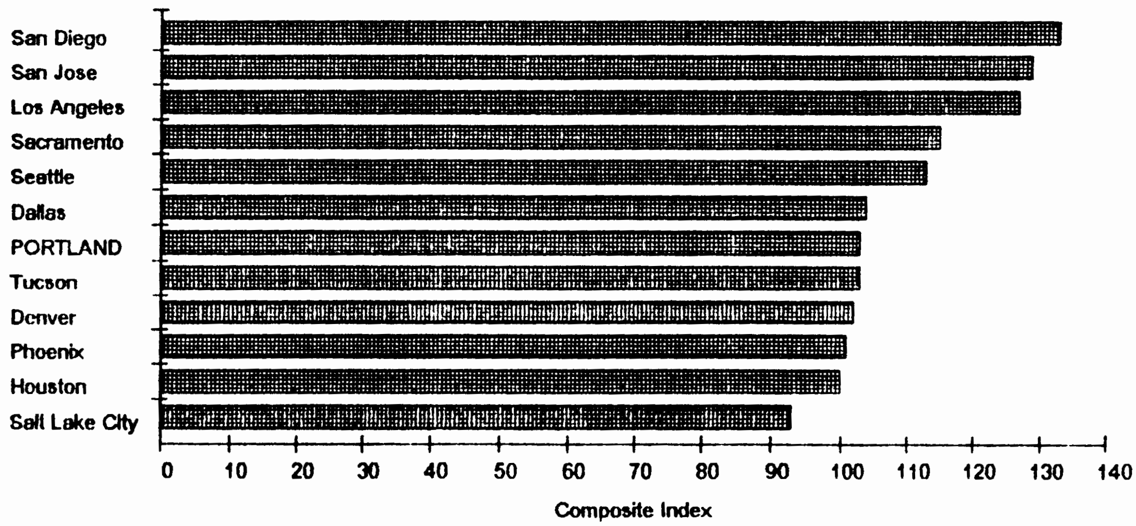

Figure 11. Cost of living index for selected large metropolitan areas in the western U.S. in 1990 (1st and 3rd quarter; national average = 100). Source: American Chamber of Commerce Researchers Association (ACCRA) 1990.

Commerce Researchers Association (1990) indicates that Portland has the lowest index within the Pacific region

(California, Washington, and Oregon), while it holds a medium rank if the Intermountain region and Texas are included.

Furthermore, the Coldwell Banker Home Price Comparison Index reveals that Portland has become the most affordable choice in terms of housing among major metropolitan areas in the western U.S. - with a little more than $ 100,000 to purchase a house (as described in Figure 12) in a neighborhood typical for a corporate transferee. The portion

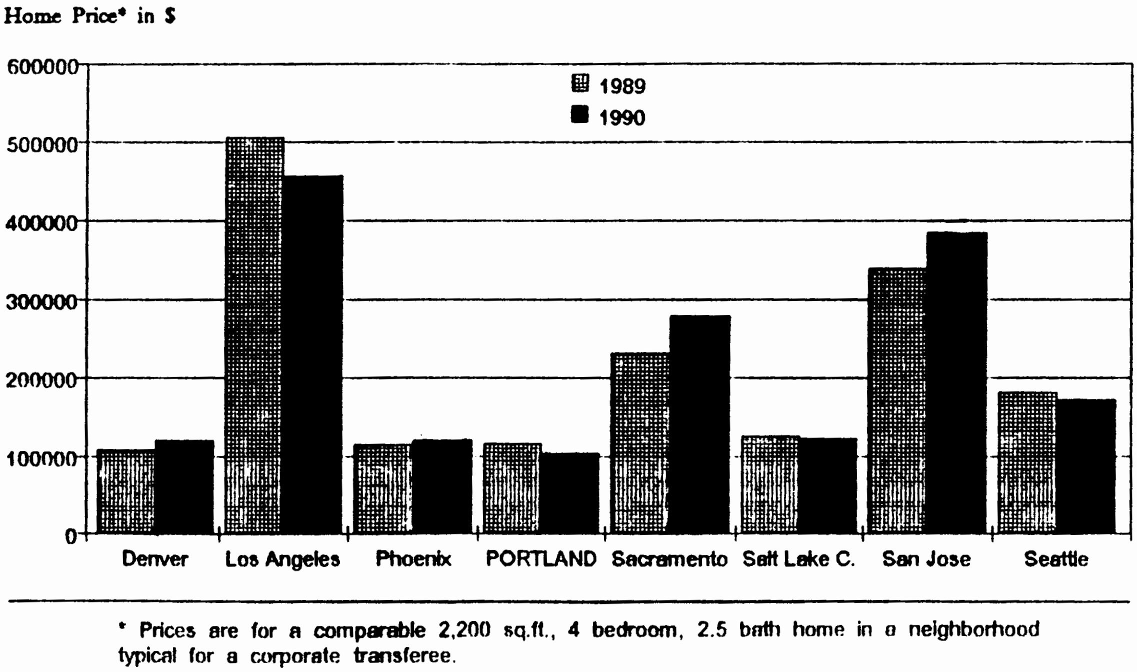

Figure 12. Comparison of median home sales prices for major metropolitan areas in the western U.S., 1989 and 1990.
Source: Coldwell Banker Home Price Comparison Index, 1990 and 1991.

of income spent on mortgage payments amounts to a modest 12.9% in the Portland/Vancouver CMSA, ranking 17th in the

U.S. which is, for instance, much lower than in Denver (16.4%, 50th place), Seattle (23.7%, 103rd place), and Los Angeles (36.7%, 147th place; after Oregon Economic Development Department 1991).

However, only a few out-of-state high-tech firms have invested so far on a large scale in R&D facilities in the Portland/Vancouver CMSA, and except for NEC's small R&D center and Sharp's semiconductor design center in Vancouver none from Japan (Atteberry 1992). Japanese high-tech operations in the CMSA are overwhelmingly standardized manufacturing establishments belonging to the third stage of the product cycle and locating here to take advantage of inexpensive land, labor, energy, etc.

Obviously, quality of life alone may not be able to attract R&D units of high-tech companies. What other factors could possibly work as counteracting forces to discourage high-tech firms from setting up R&D centers in the Portland/ Vancouver CMSA?

The interviews proved that the missing link to a prominent nearby research university is the CMSA's main drawback. Portland does not offer the richness and depth of university technical talent found in Silicon Valley or Boston, and has only a fairly small local base of qualified workers capable of pursuing R&D. As shown earlier, research universities are essential for the firms' R&D units, because they are sources to recruit needed scientific and engineering personnel, as well as provide academic expertise and access to the latest research findings. On the other hand, R&D workers themselves prefer to live in locations that offer further training and alternative job opportunities. In this respect, the Portland/Vancouver CMSA cannot compete with the density of high-tech firms and degree of entrepreneurial and innovative activity of high-tech core locations. Since scientists and engineers have a great influence over the locations firms can choose, it is a logical consequence that R&D activities as part of the innovation stage remain - along with administrative functions and the corporate headquarters - mostly concentrated in large urban high-tech core areas while only the production of standardized, matured goods has widely dispersed. Particularly large high-tech companies are minimizing their costs (e.g., labor) in standardized-product plants, but still choosing large-city high-tech core sites for administrative and R&D functions (Malecki 1983).

Availability Of A Well-Trained Labor Force

The third locational factor - availability of a well-trained labor force - as described by local business development agencies needs more detailed investigation. Weiss (1985) points out that a characteristic element of the high-tech industry sector is its dual labor force requirement. On the one hand, there is an above-average proportion of the labor force employed in scientific, professional, and technical occupations which are generally well-paid jobs requiring at least an undergraduate college degree and filled to a great extent by white males. On the other hand, a significant proportion of the labor force consists of low-paid assembly and clerical work, mostly done by females and ethnic minorities.

As pointed out, qualified scientific, engineering, and technical personnel has largely to be recruited from elsewhere because it cannot be sourced locally. Thus, it must be inferred that the availability of a well-trained labor force rather relates to all economic sectors in the CMSA in general than solely to high-tech branches.

According to the American Electronics Association (1989), two-thirds of the technical employees in Oregon's work force are imported from other states. For example, of the people Mentor Graphics hired in 1989, 75% came from outside Oregon. Conversely, the company was able to fill almost all its clerical and technician positions locally. Oki Semiconductor, in turn, could recruit its entire work force, including at the professional level, in the Portland area, except for the general manager who received an in-house company transfer (Hellmann Hill 1990). How can the differences among high-tech companies with respect to their ability to recruit locally be explained? The answer lies in recognizing the implications of the product-cycle theory. Companies at different stages of the production process require different levels of skills. Oki Semiconductor's plant in Tualatin involves only assembly- and production-line operations, while Mentor Graphics needs for the design of CAE systems a much higher proportion of professional and engineering positions in its labor force. The combined graduates of Oregon's colleges and universities in engineering and computer science are not able to meet that demand. Data available for the period from 1983 to 1987 - covering the entire state - indicate that just 31.4% of the new employees coming directly from college were from Oregon (Dodds and Wollner 1990).

One positively rated labor force-related factor in the CMSA is a lower job turnover rate than in Silicon Valley, Los Angeles-Orange County or other California metropolitan areas. Especially scientists and engineers are not likely to change their jobs as often as their California counterparts simply because of fewer job opportunities. Oregon's turnover rate for engineers was 12.1% in 1984, the lowest of all 50 states, compared with a national average of 17% (American Electronics Association 1985).

Another conceivable indicator measuring the quality of the potential work force is the score of the college entrance exams (Scholastic Aptitude Test, SAT) where Oregon and Washington rank well among those states that have at least 35% of the eligible students taking the test (see Table XII, p.88). This, however, does not imply that there

TABLE XII

AVERAGE SAT SCORES: THE STATES RANKED 1989

Rank	State	% of College-Bound Seniors Tested (>35%)	Average Score
1.	WASHINGTON	37	942
2.	New Hampshire	68	933
3.	OREGON	50	923
4.	Alaska	43	916
5.	Vermont	64	909
6.	California	44	908
	Connecticut	81	908
	Maryland	60	908
9.	Massachusetts	73	906
10.	Virginia	63	902

Source: Boyer and Savageau 1989, p.214.

will also be sufficient supply of highly skilled professionals in the future who can fill R&D positions with high-tech companies.

In summary, it has been shown that the relative significance of the above stated locational factors varies depending on the kind of high-tech operation. It is more a combination of these factors along with agglomeration advantages that helped developing a threshold around the base provided by indigenous high-tech firms, generating sufficient volume in terms of market needs, parts, software, information, and ideas to enable self-sustaining growth.

In the next section, the focus shifts to the intraregional level in order to analyze what determines the distribution pattern of high-tech establishments within the Portland/Vancouver CMSA.

INTRAREGIONAL LOCATIONAL FACTORS

Why is it that the Sunset Corridor and Washington County have become the dominant aggregations of high-tech establishments in the Portland/Vancouver CMSA, while they are scattered with only a few minor concentrations in other parts of the metropolitan area? Undoubtedly, the historical component is the critical factor: Tektronix and ESI, the "high-tech pioneers" in the CMSA (see Chapter II), established their plants in an area that later would be called the "Sunset Corridor". These companies stimulated other local firms to supply them materials and components, and produced a wide range of spin-offs which preferred to locate as close as possible to the parent, since such linkages are essential in the first phase of a new firm. In particular, information needs compel spin-offs to cluster around their parent firms. Spin-offs also depend on the established pools of support services, and thus, agglomeration advantages tend to be more important to them than for large firms (Armington, Harris, and Odle 1983). As a result, the number and size of high-tech companies began to grow, at the latter stages supplemented by branch plants of out-of-state firms.

If high-technology was attracted to Washington County in part because of the availability of land, the county realized it needed to develop that land based on certain objectives. To avoid a repeat of the uncontrolled urban sprawl characterizing California's Silicon Valley, land-use planning preceded all but the earliest high-tech establishments in Washington County. In 1954 the county's voters created the East Washington County Planning and Zoning District which is governed by a five-member elected board. A similar motivation led to the creation of the Oregon State Land Conservation and Development Commission (LCDC) by the state legislature in 1973. The LCDC required each of Oregon's 36 counties to establish a comprehensive land-use plan on the basis of state-wide guidelines. Washington County's plan was finished in 1985, by which time most cities in the county were also in compliance. The LCDC guidelines included a requirement that outer territorial limits be designated for the growth of cities. Responsibility for determining the Portland metropolitan area's "Urban Growth Boundary" was assigned to the Metropolitan Service District. This boundary effectively reduced Portland's broad fringing zone to a sharp line of discontinuity (Poulsen 1987). In 1986 the Urban Growth Boundary received its first major change in Washington County to accommodate expansions plans of some influential high-technology companies.

The concentration of high-tech industries in the Sunset Corridor can also be attributed to the role played by the Sunset Corridor Association, a private business development agency. The organization was founded in 1983 by the vice president of real-estate finance for Standard Insurance Company of Portland which owns about 40% of the 9,000 acres encompassing the Sunset Corridor. The association was initially established to deal with a land-use issue. Standard Insurance Company along with two other landholders - Quadrant Corporation (the development arm of Weyerhaeuser) and Edwards Industries - with properties at NW Cornell Road and 173rd Ave. wanted to develop the land that was zoned for residential use, but could not agree on who would pay for the costs as the property developed. Many nearby landowners were also interested to allow mixed-use development of industrial, commercial, residential, and transport functions in the area. Therefore, the Sunset Corridor Association was created which worked with the county and landowners to gain approval for zoning changes and a traffic impact fee that equitably distributed costs. By 1984 most individuals and organizations with development interests in Washington County had joined the Sunset Corridor Association.

After a comprehensive land-use plan for the area was in place, the Sunset Corridor Association expanded its goals aiming at extending the infrastructure to what at the time was largely unincorporated Washington County. A local improvement district was formed that upgraded Cornell Road from U.S.26 to 185th Ave. and extended water and sewer lines as well (Mc Millan 1992). These actions opened up large parcels of developable land along U.S.26, offering high-tech companies (because they were the type of businesses the development community in Washington County was trying to attract) an already completed infrastructure, land ready for construction, and housing available nearby. Among the Sunset Corridor Association's developments are the Oregon Graduate Center's Science Park, the Wachovia Bank and Trust's Cornell Oaks Corporate Center, the Sea-Port Industrial Group's West Union Park, and Riviera Motors' Five Oaks Industrial Park. Meanwhile, the Sunset Corridor Association has grown into a marketing organization promoting Washington County as an attractive business location.

From the analysis of the intraregional distribution pattern of high-tech establishments in the Portland/ Vancouver CMSA as mapped in Chapter II can be derived that recent high-tech industry development is a suburban phenomenon, largely avoiding inner-city areas (an exception is software developing establishments in the Downtown area) and the CMSA's eastside with its traditional metalworking industry base. What other factors contributed to this development?

First of all, initially founded indigenous high-tech firms like Tektronix, Leupold & Stevens, among others, outgrew their original central- and inner-city sites, requiring to relocate to the semi-rural fringes of the CMSA where ample area for expansion was available.

Secondly, many of the more recent high-tech startups were established in suburban Washington County because that was were the founders lived (Clackamas County Economic Development Commission 1992).

Finally, Washington County could provide the needed local, technological infrastructure in terms of business and science parks, plus a sufficient supply of inexpensive real estate and multi-functional industrial buildings of different sizes which are not readily available in the city of Portland or elsewhere in the CMSA. Additionally, the county offers a high degree of internal accessibility, i.e. via the Sunset Hwy. (U.S.26), a major east/west arterial connecting with the interstate highway system (I-5/I-84) and allowing easy access to the Hillsboro Airport, as well as to Portland International Airport.

To conclude, the intraregional distribution of high-tech establishments in the Portland/Vancouver CMSA reflects the industry's historical development. Early high-tech firms originated in central and inner Portland and the eastern part of the CMSA which used to be the traditional center of manufacturing activities. However, some of these companies (e.g., ESI and Tektronix) relocated in the 1950s and 1960s to the at the time rural Beaverton area in Washington County to become a new "incubator zone" for high-tech firm spin-offs and startups. Thereafter, most of the growth associated with high-tech industry development has been localized in suburban Washington County while the CMSA's eastside attracted only a few new high-tech establishments.

CHAPTER IV

HOW STATE AND LOCAL POLICIES CONTRIBUTE TO THE DEVELOPMENT OF HIGH-TECH INDUSTRIES IN THE PORTLAND/VANCOUVER CMSA

In the final part of the thesis, the policy side of high-tech development in the Portland/Vancouver CMSA becomes the main focus of investigation. What factors, actions, or programs are seen as having had an impact on the growth of high-tech industries? As discussed, high-tech development here was not initiated or planned by a government to create another 'Silicon Valley' as, for instance, at Research Triangle in North Carolina and Rensselaer Polytechnic Institute in Troy, New York, but at the beginning rather a result of local entrepreneurship and innovative activities of a few home-grown firms.

To analyze the likely influence on high-tech industry growth, both business assistance programs provided by the state (Oregon Economic Development Department) and by local economic development agencies (Portland Development Commission) are elaborated, as far as they are dealing either implicitly or explicitly with high-tech industries. The important role played by the private Sunset Corridor Association in the building of the Washington County high-tech complex has already been addressed in the context of intraregional locational factors.

The Office of Technology Assessment (1984) has reviewed various state and local initiatives for high-tech development throughout the U.S. to describe their impacts on local economies and suggest possible improvements. Although the initiatives are rarely completely independent, they were analyzed separately as follows: (a.) state government initiatives; (b.) local government initiatives; (c.) initiatives by universities; and (d.) private sector initiatives. Since this chapter examines government initiatives, the focus here is on the first two categories.

A sample of sixteen states (Oregon and Washington are not included) shows that state governments approach high-tech development in varying ways. Main objective of states considered as high-tech cores is obviously to strengthen and retain what is already there (e.g., California, Massachusetts). States with a traditional manufacturing base emphasize economic diversification and the application of new production technologies in the manufacturing sector (e.g., Michigan, Ohio). A third category of states - to which Oregon and Washington would belong if they were included in the survey - pursues the production facilities of expanding high-tech firms to bolster their industrial base and provide a basis for future development (e.g., Georgia, North Carolina). Yet, all initiatives share three common goals: job creation, business development, and economic diversification.

At the local level, the Office of Technology Assessment (1984) identified in a survey of 22 communities five types of high-tech places based on the degrees of difference between the successful high-tech models and the localities that seek to emulate them (p.55):

1. "high-tech centers" (cores) with a strong base of high-tech firms, research universities, and venture capital (e.g., Lowell, MA);
2. "diluted high-tech centers", whose large high-tech base is spread through a larger and more mature local economy (e.g., Chicago, IL);
3. "spillover communities", located near high-tech cores, whose proximity allows them to take advantage of the cores' resources (e.g., San Diego, CA);
4. "technology installation centers", where the presence of a major research facility attracts specialized suppliers and creates a local base of scientific, engineering, and technical personnel (e.g., Austin, TX); and
5. "bootstrap communities", which lack many of the characteristics of high-tech centers, but offer low operating costs and a high quality of life that make them attractive to branch plants of expanding high-tech companies. The Portland/Vancouver CMSA certainly meets the criteria of this type of community.

Most common elements of local initiatives were found to be related to the following aspects:

- land use, planning, and zoning;
- university improvements;
- vocational-technical training;
- incubator buildings;
- marketing programs;
- high-technology task forces; and
- venture capital.

To a great extent, the localities direct their efforts toward attracting branch operations of large high-tech firms because of their immediate job creation effect.

As a result, initiatives by state and local governments fall into six general categories according to the Office of Technology Assessment (1984, p.59):

(A.) research, development, and technology transfer;

(B.) human capital;

(C.) entrepreneurship training and assistance;

(D.) financial assistance;

(E.) physical capital; and

(F.) information gathering and dissemination.

Research, development, and technology transfer is meant to make university resources more widely available, to raise the level of formal and informal communication between academic and industrial researchers, and to increase the speed with which research results become available to the industry. These initiatives may be most critical to high-tech development, since they aim to quicken the flow of innovation itself.

Human capital development focuses on two major aspects: (1.) improving science and engineering training; and (2.) providing continuing education for those already employed by the industry. Universities offer student internships in high-tech companies or - in cooperation with state governments and local employers - special training programs for technical workers. The Office of Technology Assessment survey (1984) shows that about half of all state high-tech development initiatives involve high-tech training or education. Human capital development also includes initiatives designed to provide training and technical and management assistance for those who set up new technology-based companies (entrepreneurship training and assistance).

Financial assistance is in most cases indirect in the form of tax credits, industrial revenue bonds, or loan guarantees. The Office of Technology Assessment (1984) found that 50% of all state government initiatives surveyed give some form of financial assistance to high-tech firms.

Local governments often attempt to promote high-tech development through changes in land use and zoning, as well as the provision of public services and facilities. An example is research and science parks - designed to host R&D-intensive firms - with varying tax incentives and eligibility requirements. All five types of communities identified earlier have established this kind of facility. Several research and science parks have also been built by universities on sites adjacent to the campus. The Stanford Research Park is frequently cited as a model for successful university/industry science parks.

Finally, the Office of Technology Assessment (1984) points out that the creation of a task force or commission and their recommendations with respect to high-tech industry development formed in almost all cases the basis for subsequent state and local initiatives. Initiatives relating to high-tech information dissemination are mainly marketing programs aimed at target firms and industries. Furthermore, at the local level virtually all communities have implemented marketing programs to attract new industries. However, the approaches differ among the five types of communities. Spillover communities, for instance, are more likely to direct their efforts towards companies located in the adjacent city, while bootstrap communities primarily try to attract branch plants of expanding high-tech firms.

The Office of Technology Assessment (1984) concludes that no single factor can explain why some communities have been more successful than others in nurturing high-tech industry development. It is always a combination of several locational factors, but even these factors may vary among the different localities and do not guarantee successful high-tech-based regional development. Communities need to identify their strengths and weaknesses that will influence their ability to attract or spawn high-tech industries.

Additionally, no state or community which sucessfully generated self-sustaining growth of high-tech industries has concentrated its economic development efforts exclusively on high-tech. Such initiatives are only one element of a broader economic development strategy: For example, efforts to attract high-tech branch plants are mostly part of an overall strategy to diversify the industrial base. The analysis of the locational decision-making by high-tech firm executives has also shown that in those cases where state programs were mentioned as having influenced the locational decision, a general economic development or training program - rather than a high-tech initiative - was the major factor (OTA 1984, p.71).

After providing an overview of state and local initiatives launched across the U.S. to promote high-tech development, it will now be investigated which programs are utilized in economic development strategies carried out in the Portland/Vancouver CMSA, and in how far they contributed to the growth of high-tech industries.

Policies aimed at stimulating new industrial investment are in fact a fairly new phenomenon in Oregon. Until the mid-1970s (corresponding to phase I according to Chapter II), state and local governments even discouraged investment from outside the state to prevent Oregon from "becoming another California" with its uncontrolled urban sprawl. The attitude of the state government towards investment was expressed in the early 1970s by the following motto: "Come and visit Oregon. Just don't stay." The state saw itself as an ecological paradise and economic growth was considered anathema (Rogers and Larsen 1984). It is documented that in the early 1970s the corporate managements of at least two large out-of-state U.S.-owned high-tech firms - Data General and Digital Equipment - decided not to locate in Oregon because of the state government's apathetic attitude towards new business investment (Hamilton 1987).

In the late 1970s, however, these policies gradually started to change; largely in response to a deepening economical crisis of the Pacific Northwest's staple industries (e.g., timber industry), the state was forced to attract new businesses in order to prevent from becoming an economically-distressed, high-unemployment area for an indefinite time.

A more active and focused approach to business recruitment was undertaken in the early 1980s. In 1983 the Business Recruitment Program was established by the Oregon Economic Development Department and the Portland Development Commission. This program targeted mainly foreign investment and was designed to lure especially Japanese high-tech companies to the Portland/Vancouver CMSA, because such firms were viewed as being 'clean industries' with little impact on the environment and thus not affecting the quality of life. Aside from solidifying Oregon's economy, the main intention was the hope for providing new jobs and additional tax revenue. This program obviously falls in the category of marketing efforts initiated to sell the advantages of locating in the Portland area and Oregon. The program was first carried out by sending several trade delegations to East Asia, above all to Japan. In 1984 the state also opened a trade office in Tokyo (Japan Representative Office, JRO) to emphasize its commitment to attract Japanese investment. It is noteworthy that Oregon's trade office in Japan was established by the legislature, not by the Governor, which helped maintain support through the years, since the office is not regarded as a single politician's project (Bain 1991).

With the implementation of the business recruitment program, the state became for the first time directly involved in promoting high-tech industry development (Ford, Oregon Economic Development Department 1992). However, as long as Oregon was retaining the unitary tax, these marketing efforts could hardly produce any results. For instance, NEC, Fujitsu, and Epson linked their plans to invest in the Portland area - presented to one Oregon trade delegation in 1984 in Tokyo - to the repeal of the unitary tax. Following the repeal of the tax in 1984, these companies soon began to build manufacturing facilities in the Sunset Corridor.

Chapter III has shown that the Portland/Vancouver CMSA could attract only a few R&D-intensive high-tech operations of firms headquartered outside the Pacific Northwest. Therefore, it is consequent for policies attempting to remove the barriers to entrepreneurship or/and mobilizing local resources needed to encourage technological innovation. Since most of these actions aimed at establishing R&D centers of high-tech firms in the CMSA have been launched only fairly recently, it is impossible to already make a final judgement whether they should be considered failures or successes. Such initiatives may have much more a long-term impact in that they create and can retain a larger pool of qualified scientific, technical, and engineering personnel and upgrade educational facilities which are capable of serving as technology transfer institutions for high-tech firms. Nevertheless, a brief description of these initiatives should be presented here:

1. In 1988 the Oregon Advanced Computing Institute (OACIS) was founded in Beaverton as a partnership between government, industry, and academia. Its focus is on solution-oriented research to expand the use of parallel processing technology. It is expected that the establishment of this institute will strengthen the Portland/Vancouver CMSA as a center for parallel processing. So far, there has

not been any related university research on this technology in the area (Cohn 1988).

2. The Oregon Center for Advanced Technology Education (OCATE), located on Portland Community College's Rock Creek campus in the Sunset Corridor, and established in 1986, assists in the coordination, enhancement, and expansion of master's and doctoral research-based programs relevant to high-tech industries through a partnership of research institutions including the Oregon Graduate Institute, Oregon Health Sciences University, Oregon State University, Portland State University, and University of Oregon, the state government, and local high-tech firms.

3. An early attempt to facilitate technology transfer was the establishment of the Oregon Graduate Institute of Science and Technology (OGI), chartered by the state of Oregon in 1963. The institute was founded mainly with capital from Tektronix as a private, non-profit graduate school for applied science and engineering education, and is housed on a combined campus and science park in the Sunset Corridor (OGC Science Park) which is also home to OACIS (see above).

4. Finally, there have been collaborative efforts among the electrical engineering and other science departments of Oregon's three major public universities - University of Oregon, Oregon State University, and Portland State

University - to develop links with high-tech firms and to pool research results (Hamilton 1987).

Another category of initiatives promoting high-tech development in the CMSA relates to improving the training of the labor force (corresponding to "human capital development" in the 1984 Office of Technology Assessment survey). One example is the "Semiconductor Training Initiative" which was established in 1990 at five Oregon community colleges. The purpose of the program is to enhance both the size and the quality of the labor force available to the semiconductor industry. The program is a result of a partnership between the Oregon Economic Development Department, the Portland Development Commission, and nine semiconductor firms (among them four Japanese firms). It is believed that the state Economic Development Department's and Portland Development Commission's commitment to set up this program influenced Toshiba's decision in 1990 to build a new semiconductor manufacturing plant in the Portland area, a plan, however, that meanwhile has been postponed due to overall economic conditions (Mayes and Colby 1990).

A similar goal has the Portland Development Commission's "JobNet" program, although it is not only confined to high-tech industries. The program works with new and expanding businesses on a range of employment and training services, representing and coordinating resources in the Portland area including community colleges, employment programs, schools, and the State Employment Division, among others. In partnership with the Oregon Economic Development Department and the Port of Portland, the program has already provided services to the following high-tech companies: Fujitsu Microelectronics, Wacker Siltronic, STC Submarine Systems, Epson Portland, Oki Semiconductor, and Japan Aviation Electronics (Portland Development Commission 1992). Main objective of the program is to assist firms in filling their specific employment needs.

In the meantime, state and local economic development agencies in the Portland/Vancouver CMSA have realized that it may be more beneficiary to encourage business development and technological innovation throughout the local economy, rather than simply attracting branch plants of large high-tech companies headquartered overseas. These companies are not very likely to produce spin-offs and contribute to the innovative potential of the region. When the business recruitment program was established in 1984, it almost exclusively concentrated on foreign branch-plant operations. Even though the Portland Development Commission and the Oregon Economic Development Department continue to be supportive to this kind of investment, more recent efforts to promote high-tech development have been directed - as indicated - especially toward improving the quality and access to education and training which actually relates to all economic sectors, but to R&D-intensive firms certainly in particular.

The scope of business recruitment efforts has also been extended in that more attention is paid to attracting high-tech supplier firms (since the number of local suppliers is still limited) by targeting mostly U.S.-owned companies located in California and Arizona. This includes supporting services as well, an economic sector that was previously nearly ignored in terms of business recruitment (Ogan, Portland Development Commission 1992).

However, it could take several years or even a decade until the impact of these long-term policy strategies on high-tech development in the Portland/Vancouver CMSA might become evident by generating new, indigenous firm growth and innovative activities.

CHAPTER V

SUMMARY AND CONCLUSIONS

To describe the emergence of high-tech industries in the Portland/Vancouver CMSA, this study first identified three phases representing the major factors that were found to have driven high-tech development since 1945 when Tektronix was established. In the first phase (until 1974), high-tech firm growth was predominantly a result of innovative activities by some locally-born and immigrant entrepreneurs. Many of these firms showed market linkages to local and Pacific Northwest staple industries. Although only 25% of all high-tech establishments existing today in the Portland/Vancouver CMSA were founded prior to 1975, they undoubtedly created the preconditions which later led to self-sustaining growth processes and stimulated new high-tech startups.

With the beginning of the second phase (in 1975), a significant change in the CMSA's high-tech development occurred, as high-tech firms headquartered in California - and at the latter stages also from overseas - began to set up branch-plant facilities (e.g., Intel, Hewlett-Packard). More important though in terms of contributing to the innovation process was that Tektronix, ESI, and California arrival Intel gave birth to about 30 spin-offs in the late 1970s and early 1980s, thereby considerably diversifying the high-tech base.

Most recent high-tech development in the Portland/ Vancouver CMSA as represented by the third phase (1985 to present) is characterized by in-movement of several Japanese high-tech companies that decided to build manufacturing plants.

Secondly, the research revealed that there is a distinctive metropolitan pattern of high-tech industry locations. The dominant aggregation of high-tech establishments is found in Washington County along the Sunset Highway (U.S.26) in Beaverton and Hillsboro, as well as along Hwy.217 and I-5 in Beaverton, Tigard, and Tualatin. Washington County accounts for 57% of all high-tech establishments and ca. 54% of total high-tech employment in the Portland/Vancouver CMSA. Other clusters are far less marked, and Multnomah County's high-tech employment - the second highest in the CMSA - has to a great extent to be attributed to supporting high-tech products and services.

In the course of the research it became obvious that this intraregional distribution of high-tech establishments is mainly a consequence of the industry's historical development. After relocating from their initial inner Portland sites to the Beaverton area, home-grown Tektronix's and ESI's plants served as an incubator for many small and medium-sized high-tech firms. Therefore, a threshold of high-tech manufacturers developed around their base in the Sunset Corridor that also attracted out-of-state U.S.-owned firms and investment from Japan.

Thirdly, this study analyzed reasons why high-tech companies from outside the Pacific Northwest chose to locate in the Portland/Vancouver CMSA. Most of the high-tech firms headquartered in California and other parts of the U.S., as well as in Japan have established standardized branch production and assembly facilities in the CMSA, in a few cases technical branch establishments undertaking product-line R&D and assembly/production (e.g., NEC), but they are still keeping their centers for basic R&D at high-tech core sites (Silicon Valley, Boston area). These branch-plant operations of expanding high-tech companies are attracted to the Portland/Vancouver CMSA chiefly because of lower business costs (e.g., land, utilities) than in core locations where space limitations and rising land prices preclude further expansion. Although the perceived high quality of life enables high-tech firms to recruit fairly easily scientific, engineering, and technical personnel to the CMSA, the overwhelming majority of companies has not yet established R&D units. The analysis proved that the main reason is the missing link to a prominent research university nearby.

On the policy side, the problem has been recently recognized and concern being expressed about the long-term perspective of this development. To a large extent, these manufacturing and assembly enterprises offer low-paid hourly wage jobs (as compared to highly-paid jobs in the traditional manufacturing sector, e.g., timber and metalworking industry) and are not using highly trained or educated employees who are among a region's most probable entrepreneurs. Consequently, this kind of high-tech facilities hardly contribute to the innovation process, and the Portland/Vancouver CMSA in fact competes with other low-business-costs regions - particularly in Third World countries - as possible sites for relocations. Thus, state and local policy strategies have shifted their focus from attracting foreign branch plants to improving the quality of and access to educational institutions.

However, it has to be emphasized that many of the conditions that created high-tech complexes like Silicon Valley and Boston's Route 128 cannot be replicated elsewhere, and the degree of entrepreneurial spin-off activity prevalent in those regions does not exist in any other metropolitan area. The Portland/Vancouver CMSA may never be able to compete with these high-tech complexes, and therefore, an economic strategy concentrating on high-tech-based regional development would not be very helpful. Research has shown that high-tech initiatives that are components of the broader economic development strategy, aiming at improving the technological infrastructure, have been more successful in attracting and sustaining high-tech industry development than those targeting one economic sector in isolation.

Finally, the development of high-tech branches must not necessarily solve other structural problems of a region. Even though new high-tech establishments have certainly diversified the Portland/Vancouver CMSA's economic base, it should be questioned if they can offset job losses in the traditional manufacturing sector. Taken the demographic characteristics of the dual high-tech work force, high-tech industries are unlikely to absorb the blue-collar workers displaced in declining staple industries.

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