Office Employment Growth Analysis in the Boston Metropolitan Area, Focusing on Differences among Industries

by

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Submitted to the Department of Urban Studies and Planning
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ABSTRACT

In this thesis, the location patterns of office industries in the Boston Metropolitan Area are examined using the office employment data for each municipality for the years 1980 and 1990.

The Herfindahl and Hirschmann Index (HHI) is used to analyze the degree of spatial dispersion for each office industry. Twelve industries are classified into five categories based on the criteria of the degree of dispersion in 1980 and the change that occurred between 1980 and 1990.

Two types of intrametropolitan office employment growth models are empirically tested; one, the logit model, is based on the discrete choice analysis and the other, the convergence model, is based on the regional growth analysis. The logit model estimates the growth level in number, while the convergence model estimates the growth rate. Both models show the evidence of the negative effect of specialization on the office employment growth, the positive effect of the accessibility to highways, and the clear trend of dispersion in office employment. They also reveal the difference between the determinants of the growth level and the growth rate.

These two models are applied to each of the disaggregated office industries and reveal their characteristics. Insurance agents and business services are classified as the most dispersed industries by the HHI. The convergence model shows their rapid convergence. The logit model shows that the accessibility to nearby labor and customers is a strong determinant in their growth, suggesting that the dispersion of these industries takes place as they follow the decentralized population. On the other hand, legal services and accounting are classified as concentrated industries by the HHI. The logit model shows that the accessibility to labor and customers does not affect their growth, suggesting that they tend to benefit from linkages with other firms and government agencies in the central business district, rather than with the decentralized population.

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CONTENTS

Chapter 1 Introduction

The urban form in metropolitan areas in the United States has dramatically changed over the last half of the twentieth century. These changes began with the suburbanization of the population. During the 1950s and 1960s, the population in central cities declined, whereas suburban areas experienced a rapid growth in their population (Wheaton, 1986). Then, decentralization extended to firms, which, historically, showed a strong monocentric locational pattern (DiPasquale and Wheaton, 1996). Firms in retail trade and personal services decentralized in order to follow their household customers. Firms in manufacturing and wholesale decentralized because of technological changes. The establishment of a "ubiquitous" transportation system by railroads and trucks freed their location from port areas. The changes in production technologies required more land to accommodate horizontal assembly lines, which drove firms to suburbs where more and cheaper land was available (Wheaton, 1993).

Finally, the tide of decentralization reached office firms. Xu (1996) examined the office space change in downtown and suburban areas in the 50 largest U.S. metropolitan areas between 1955 and 1994, and found that the downtown space had grown constantly over the 40-year period. While the suburban space started at only 15% of the downtown space in 1955, it grew much faster than the downtown in the 1980s and was 150% of the downtown space in 1994. Such decentralization in population as well as employment has created a polycentric urban pattern in place of the traditional monocentric pattern in the metropolitan areas in the United States.

Numerous researchers have studied the decentralization, especially that

of employment, both theoretically and empirically, in order to understand and predict the changes in urban structure and draw some useful policy implications which lead better urban conditions. Among early theoretical studies, White (1976) discussed basic models of firm location under two different urban settings; one is the setting in which the only export terminal is in the CBD, and the other is the setting in which another terminal is in the suburb in addition to one in the CBD. She related the firm suburbanization with reduced freight cost, lower wages, and labor scarcity in suburbs, and considered determination of the optimal location for a suburban freight terminal. Obviously, her focus was on the industries that shipped their substantial products. Ogawa and Fujita (1980), as opposed to White who introduced pre-specified multiple centers into the model, developed a model without pre-specifying any centers. With the model, they showed that the equilibrium land use patterns in a non-monocentric city depended on the values of parameters in the model, especially on a commuting rate and a transaction rate.

Later, these theoretical frameworks about urban structure were applied to more specialized topics in urban studies. White (1988) explored residential and job location patterns and commuting behavior in a monocentric urban model with decentralized employment. Sivitanidou and Wheaton (1992) developed models of the commercial land market within a two-center metropolis and analyzed how exogenous differences in production costs between centers were capitalized in rents and wages. Their findings showed that in a competitive market most of locational advantages were capitalized in wages, not in rents. These theoretical studies have described how subcenters develop and what impacts they have on various urban conditions (Giuliano and Small, 1991).

There are also a number of empirical studies to uncover basic facts about suburban employment centers and polycentric urban structure (McDonald and Prather, 1994). The identification of subcenters is one of the major interests in this field. Giuliano and Small (1991) established an objective and consistent method for identifying employment centers, based on gross employment density and total employment. Using the method, they identified 32 centers within the Los Angeles region in 1980. Moreover, they classified these centers by a cluster analysis of employment by industry and revealed several distinct types of centers, namely specialized manufacturing, mixed industrial, mixed service, specialized entertainment, and specialized service.

The examination of spatial patterns is another principal objective of the empirical studies in this field. Gordon, Richardson, and Wong (1986) and Small and Song (1994) examined the distribution of population and employment in the Los Angeles region during the 1970s by estimating monocentric and polycentric density functions (density gradients). They showed that polycentric models fitted better than monocentric models. Their results confirmed that both employment and population became more dispersed during the 1970s. McDonald and Prather (1994) also used monocentric and polycentric models to estimate employment density in the Chicago region in 1980. They identified three suburban employment centers and found that the density was influenced by proximity to these subcenters as well as to the Chicago CBD. They illustrated the importance of the subcenters with the fact that 27% of total employment growth in the Chicago region between 1979 and 1989 was concentrated in these three subcenters.

Lastly, Sivitanidou (1996) analyzed the impact of the access to employment centers on office firms' valuation of commercial properties. For

this purpose, she did not focus on the identification of general employment centers, as existing studies did, but rather focused on the identification of service employment centers, using employment data in financial, insurance, and real estate sector and a part of service sector. She also showed that subcenters neither fully substituted for the CBD nor fully substituted for each other. As the framework of this study shows, recent empirical studies, as well as theoretical studies, become to be applied to more specified urban topics.

This thesis focuses on the spatial patterns of office industries. One of the reasons for focusing on the office industries is that the office industries now play a leading role in the regional economies throughout the country. Therefore, better understanding of their locational patterns is important for urban planners to achieve successful economic growth in each region. The other reason is that the changes in the locational patterns of the office industries are relatively new and ongoing, and more importantly, not straightforward. Although the tide of decentralization has changed the locational pattern of the office industries significantly, downtown areas still hold a competitive office market in many metropolitan areas. The downtown market can be an attractive choice for the office firms pursuing agglomeration merits such as face to face communication, information sharing, and support services. On the other hand, the ongoing decentralization clearly shows that there are other types of merits that entice some firms to locate in suburban areas. As subcenters have been developed in the suburbs of metropolitan areas, office firms come to have a variety of choices in their location and are able to make more rational decisions based on their criteria for optimal location. Considering the wide range of office

industries, their criteria vary considerably and the location of the office industries has been diversified. Under these circumstances, it is not only difficult but also interesting and important task to shed light on the locational patterns of the office firms.

The objective of this thesis is to analyze location patterns of office industries and their changes, and develop a model to explain office employment growth for each city and town in the Boston Metropolitan Area by industry. In the literature, there exist a number of studies that construct and test office location models, but few of them focus on the differences among industries. This thesis explores these differences to reveal each industry's characteristics in its locational pattern and underlying criteria for location decision, and provides a knowledge of the locational patterns of the office industries. The findings from the analysis will be useful for urban planners in local government to design regional growth strategies, and for private developers to plan successful office development projects in terms of their marketing.

The thesis is organized as follows. Chapter 2 presents the results of basic analysis of office industries and major office employment centers in the Boston area. It shows the overall growth trend for each industry and the spatial distribution pattern of office employment, and forms a basis for understanding a further analysis. Chapter 3 gives a more detailed analysis of differences in locational patterns between office industries. The Herfindahl and Hirschmann Index is introduced to analyze each industry's degree of dispersion as well as to classify industries. The actual spatial distribution pattern for each industry is also closely examined according to

the classification. Chapter 4 reviews existing empirical studies relevant to the office growth model. Chapter 5 develops office employment growth models. Following the literature, two different types of model specification are tested; one is based on the discrete choice analysis and the other on the regional growth analysis with the notion of convergence. They are applied to disaggregated office industries. The interpretation of the differences in model estimation between industries reveals the differences in their location determinants. The results in this chapter are combined with those in Chapter 3 and summarized as the location characteristics for each office industry. Chapter 6 concludes the thesis by summarizing major findings and their implications.

Chapter 2 Basic Analysis of the Office Industries in the Boston Area

This thesis intends to analyze the office employment growth for each city and town by disaggregated office industries. In order to establish a basis for understanding more detailed analysis in later chapters, a general picture of the office industries in the area is presented in this chapter. First, I identify three basic elements of the analysis: study area, office industries, and the employment data which are the principal data throughout the thesis. Then I examine each office industry's employment change in the whole area to understand the overall trend for each industry. Lastly, I look into the spatial distribution of the aggregated office employment, identify major office centers in the area, and reveal their locational patterns. This chapter is concluded by the spatial clustering of the office centers and the evidence for the decentralization of the office employment.

2.1 Study Area

The Boston area was selected as the study area in this thesis for several reasons. First, the area serves as the employment center of the sixth largest metropolitan area in the U.S. and, in terms of both their amount and variety, contains a sufficient concentration of office industries to be analyzed. Second, there are a number of well developed subcenters of office industries in the periphery of the area. These subcenters have been developed in response to new technology, transportation changes, and other forces (Clapp, Pollakowski, and Lynford, 1992). Lastly, "Boston (area) has a strong central city which has withstood the challenge from the suburbs relatively better than the downtown of many other metropolitan areas" (Wheaton, 1993). Under such circumstances, office firms in the area have had

a variety of choices in their site selection decision, ranging from the central business district (CBD) to the suburban subcenters.

Five counties in eastern Massachusetts, namely Essex, Middlesex, Norfolk, Plymouth, and Suffolk compose the Boston area in this thesis. This geographical coverage roughly corresponds to the area surrounded by Route 495, the outer circumferential highway of this region (Figure 2.1). Within these five counties, there are 147 cities and towns. According to the 1990 Population and Housing Census, the total population in the area was 3.78 million and the population in each city and town ranges from 2,236 in Dunstable to 574,283 in Boston. The list of the 147 cities and towns is in Appendix A.

2.2 Identification of the Office Industries

Based on the empirical observations, a range of the office industries, in other words a range of industries that uses offices as a primary space for their business activities, is identified using the standard industrial classification (SIC) as follows: all of the industries in the finance, insurance, and real estate (FIRE) sector and some of the industries in the service sector, namely business services, legal services, social services, membership organizations, and engineering and management services.

One problem in performing an analysis using data at different time points results from revisions in the SIC codes. In recent years, revisions were made in 1977 and 1987. The time range intended in this analysis is from 1980 to 1990, and therefore, the revision in 1987 affects the analysis. Some SIC codes before and after the 1987 revision within the office industry identified above are inconsistent, and therefore not suitable for comparison. Considering this problem and the characteristics of each SIC, twelve

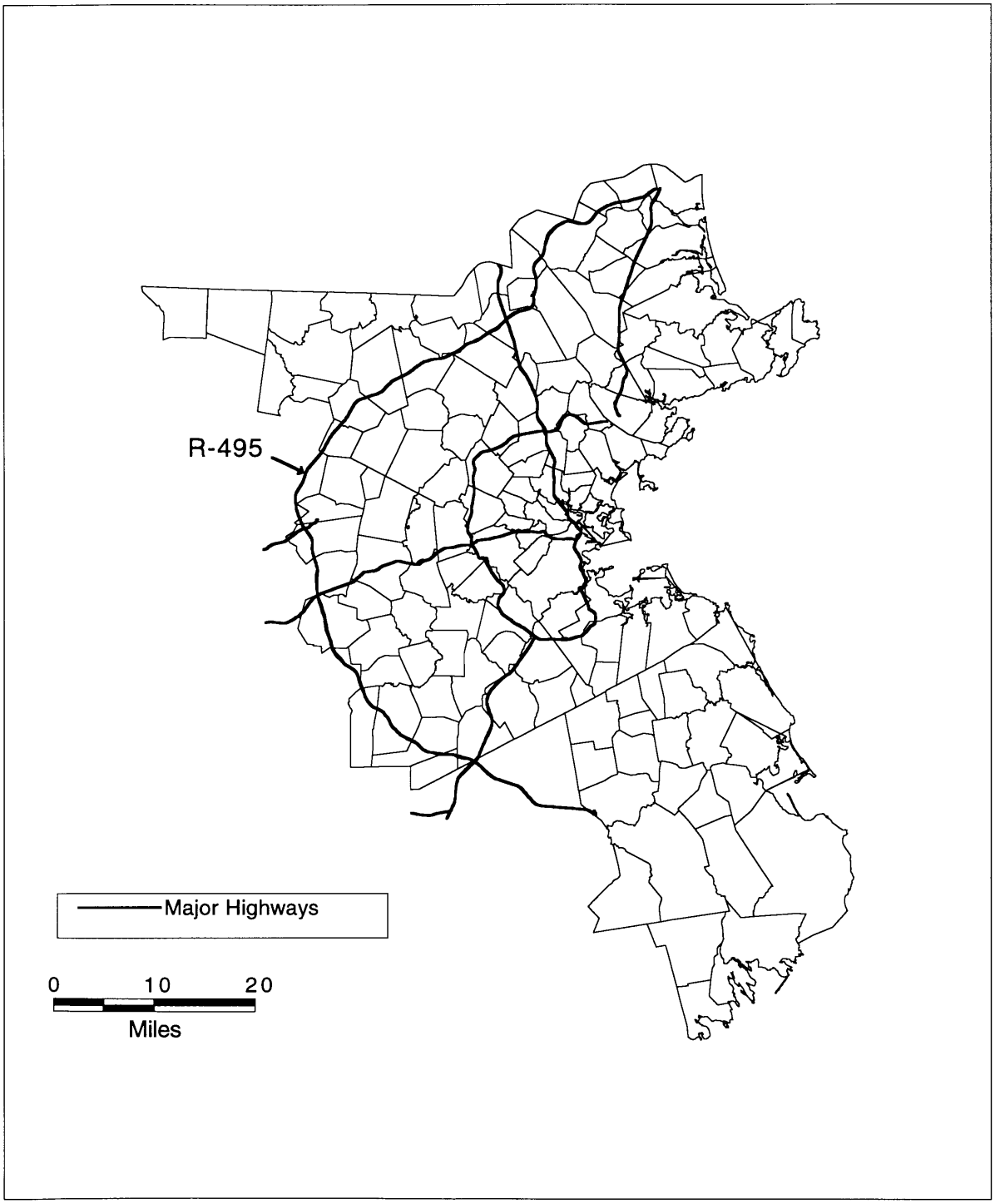

Figure 2.1 Study Area

industries corresponding to either the two- or three-digit SIC code are determined to be disaggregated office industries in this analysis. They are as follows (1987 SIC codes and shortened titles in this thesis, if any, are in parentheses):

1. Banking (60 and 61)
2. Security and commodity brokers (62, security brokers)
3. Insurance carriers (63)
4. Insurance agents, brokers, & service (64, insurance agents)
5. Real estate (65)
6. Holding and other investment offices (67, investment offices)
7. Business services (73)
8. Legal services (81)
9. Social services (83)
10. Membership organizations (86)
11. Engineering & architectural services (871, engineering services)
12. Accounting, auditing, & bookkeeping (872, accounting)

Research and testing services (873), and management and public relations (874) are included in the above-defined range of office industries, but omitted from the analysis due to the SIC code inconsistency before and after 1987. Also, depository institutions (60) and nondepository institutions (61) are combined for the same reason.

2.3 Employment Data

The office industry data employed here are from the Massachusetts Department of Employment and Training, which collects, processes, analyzes, and disseminates data relating to employment. It tabulates the average annual employment data for each city and town (based on workplace locations) in

Massachusetts by a three-digit SIC code. In addition to the employment data, it reports data on the number of establishments but the employment data is more directly related to the demand for office spaces which is the central interest for urban planners. For that reason, I chose the employment data. The Population and Housing Census also reports the employment data, but it is based on residential locations and by single-digit industries. Therefore, it is not suitable for this analysis. Although these data are available every year, the data in 1980 and 1990 are used in this thesis in order to match the data years with the Population and Housing Census, which is also used in the model analysis.

For the purpose of maintaining the confidentiality of respondents, the employment data are withheld for any industry level: 1) which consists of fewer than three establishments; or 2) in which a single establishment accounts for 80 percent or more of the industry's employment. This means that we have missing data for some of the 147 cities and towns. Judging from these definitions, confidential data are assumed to appear mainly when the employment in a city or town is considerably low. In such cases, the confidential data do not affect the analysis very much. However, in the case that the confidential data are actually big numbers, they might cause biased results. Such cases can happen, for example, when only one company exists in a city and the number of its employment is very big.

2.4 Change in the Office Industry Employment in the Whole Study Area

First, I examine the change in the office industry employment that happened in the study area as a whole between 1980 and 1990.

Table 2.1 presents employment data for the office industries in 1980 and 1990 and their growth over the decade. Business services had the largest

employment with 91,260 in 1980, followed by banking, insurance carriers, social services, and engineering services. Between 1980 and 1990, all office industries except insurance carriers increased in employment. Security brokers and legal services are especially noteworthy as they increased by more than 100%. Investment offices, social services, and accounting also substantially increased their employment by more than two thirds.

Overall, between 1980 and 1990, the total employment of the twelve office industries increased by 42.3% (3.6% annually), or 119,404 in number. This growth rate and number were much greater than other single-digit industries, such as manufacturing (-20.2%, -83,860), transportation and public utilities (4.6%, 3,938), wholesale trade (27.6%, 25,690), and retail trade (16.0%, 46,878). This comparison shows that the office industry led the regional economic growth in this decade.

Table 2.1 Number of Employment by Office Industries in the Study Area

SIC	OFFICE INDUSTRY	1980	1990	Growth
73	Business services	91260	124156	36.0%
60+61	Banking	41595	59061	42.0%
63	Insurance carriers	37257	35323	-5.2%
83	Social services	25557	43261	69.3%
871	Engineering services	20078	25561	27.3%
65	Real estate	15314	23402	52.8%
86	Membership organizations	12136	15000	23.6%
64	Insurance agents	10827	16579	53.1%
81	Legal services	10332	22106	114.0%
62	Security brokers	8278	20841	151.8%
872	Accounting	7404	12438	68.0%
67	Investment offices	2256	3970	76.0%
	TOTAL	282294	401698	42.3%

Source: Author's tabulation from Employment and Wages in Massachusetts Cities and Towns(selected years), Massachusetts Department of Employment and Training

2.5 Major Office Employment Centers in the Boston Area

As mentioned in Chapter 1, the identification of the employment centers is one of the major interests in the existing studies. However, most of them identified general employment centers using total employment data (e.g., Giuliano and Small, 1991), except for Sivitanidou (1996) who identified service employment centers.

In this section, I look into the spatial distribution of the office employment in the Boston area and identify major office employment centers by using the level of the employment in aggregated office industry. These employment data are obtained by summing up the data for FIRE (single-digit SIC) and five double-digit industries in the service sector. Unfortunately, the data for double-digit industries contain quite a few confidential data (missing values), and for those cities and towns, we can't obtain the aggregated office employment. However, as mentioned in Section 2.3, the confidential data are assumed to appear when the employment in a city or town is considerably low in most cases. Therefore, this problem seems not to affect the analysis very much with respect to identifying major office employment centers.

Table 2.2 shows the 25 largest cities and towns in terms of the number of office workers in 1990. Boston had 170,636 office workers, or 38.1% of the area total. Cambridge had the second largest with 35,393 workers or 7.9%. These two cities serve as the CBD holding 46.0% of the total office employment in this area.

Several suburban cities, i.e., Waltham, Quincy, Newton, Burlington, Framingham, and Wellesley, follow these two CBD's with shares between 1.6% to 4.0%. Except Framingham, these cities are located adjacent to Route 128, the area's inner circumferential highway. Framingham is located in a further

Table 2.2 Major Office Employment Centers in the Boston Area

	NUMBER			SHARE			SUB-AREA
	1980	1990	change	1980	1990	Change	
Boston	141,511	170,636	29,125	48.6%	38.1%	-10.5p.p.	CBD
Cambridge	18,862	35,393	16,531	6.5%	7.9%	1.4p.p.	CBD
Waltham	11,164	18,025	6,861	3.8%	4.0%	0.2p.p.	R-128
Quincy	6,363	17,110	10,747	2.2%	3.8%	1.6p.p.	R-128
Newton	6,557	10,155	3,598	2.3%	2.3%	0.0p.p.	R-128
Burlington	-	8,923	-	-	2.0%	-	R-128
Framingham	4,158	8,745	4,587	1.4%	2.0%	0.5p.p.	Outer Suburb
Wellesley	4,696	7,080	2,384	1.6%	1.6%	0.0p.p.	R-128
Malden	4,909	6,333	1,424	1.7%	1.4%	-0.3p.p.	Inner Suburb
Braintree	2,491	6,056	3,565	0.9%	1.4%	0.5p.p.	R-128
Woburn	1,860	5,717	3,857	0.6%	1.3%	0.6p.p.	R-128
Brockton	3,663	5,591	1,928	1.3%	1.2%	0.0p.p.	Outer Suburb
Lexington	-	5,426	-	-	1.2%	-	R-128
Somerville	1,987	4,924	2,937	0.7%	1.1%	0.4p.p.	Inner Suburb
Lowell	3,361	4,745	1,384	1.2%	1.1%	-0.1p.p.	Outer Suburb
Brookline	4,021	4,491	470	1.4%	1.0%	-0.4p.p.	Inner Suburb
Lawrence	3,156	4,178	1,022	1.1%	0.9%	-0.2p.p.	Outer Suburb
Medford	-	3,811	-	-	0.9%	-	Inner Suburb
Wakefield	3,061	3,763	702	1.1%	0.8%	-0.2p.p.	R-128
Needham	-	3,756	-	-	0.8%	-	R-128
Lynn	3,278	3,686	408	1.1%	0.8%	-0.3p.p.	R-128
Andover	1,251	3,635	2,384	0.4%	0.8%	0.4p.p.	Outer Suburb
Salem	2,200	3,537	1,337	0.8%	0.8%	0.0p.p.	R-128
Peabody	1,860	3,491	1,631	0.6%	0.8%	0.1p.p.	R-128
Norwood	2,265	3,242	977	0.8%	0.7%	-0.1p.p.	R-128

-: Confidential Data
p.p.: percentage points
Source: Author's tabulation from Employment and Wages in Massachusetts Cities and Towns(selected years), Massachusetts Department of Employment and Training

suburb close to Route 495, the outer circumferential highway. It is interesting that these cities are also located close to one or more radial highways. Waltham, Newton, Wellesley and Framingham are adjacent to I-90. Quincy is located along I-93, and Burlington is at the junction of Route 128 and US-3. From these observations, the spatial distribution pattern of office employment in the Boston area is summarized as being the monocentric pattern centered around Boston and Cambridge with several suburban subcenters

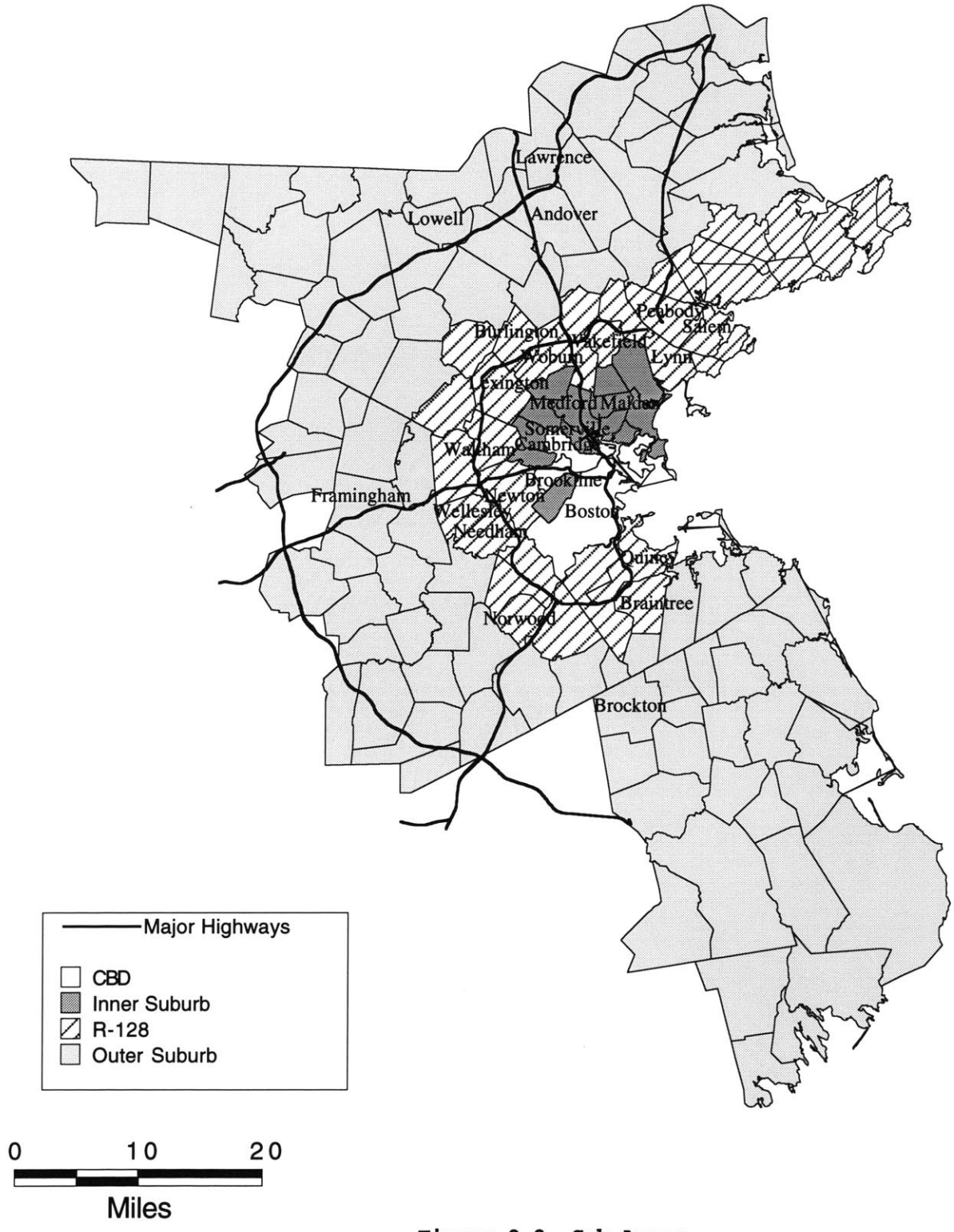

Figure 2.2 Sub-Areas

developed adjacent to the area's major highways, primarily the circumferential ones and secondarily the radial ones.

According to this locational pattern, I clustered cities and towns in Table 2.2 into four sub-areas: CBD, Inner Suburb, R-128, Outer Suburb (Figure 2.2). As mentioned before, Boston and Cambridge compose the CBD with 46.0% of the total office employment. Four cities and towns, Malden, Somerville, Brookline, and Medford are located in the Inner Suburb with 4.4% of the total area. Fourteen cities and towns fall into the R-128 Area and the sum of their office employment is 22.3% of the area total. This figure shows that the R-128 Area is dominant in the suburban office market. Five cities and towns, Framingham, Brockton, Lowell, Lawrence, and Andover, are located in the Outer Suburb. The sum of their share is 6.0%.

This clustering brings to light more interesting facts when we look at the growth rate of the office employment by sub-areas. From 1980 to 1990, employment in the CBD increased by 28.5%, which is smaller than 42.3%, the study area average. The Inner Suburb's growth rate was 44.3%. (Medford is omitted because its 1980 data are confidential.) The remaining two areas increased their office employment much more, suggesting the trend of decentralization: the R-128 Area increased by 78.8%, and the Outer Suburb by 72.5% (Burlington, Lexington, and Needham are omitted for confidentiality reasons). This trend can also be found by looking at the changes in each city and town's share of office employment. Boston's share dropped by 10.5 percentage points from 48.6% to 38.1%. Cambridge increased its share by 1.4 percentage points from 6.5% to 7.9%. Two cities in the Inner Suburb also lost their share: Brookline by 0.4 percentage points and Malden by 0.3 percentage points. On the other hand, many suburban office subcenters in the R-128 Area and the Outer Suburb increased their shares: Quincy by 1.6

percentage points, Woburn by 0.6 percentage points, Framingham and Braintree by 0.5 percentage points, and Andover by 0.4 percentage points. These changes clearly show that the decentralization of the office employment in the Boston area advanced a great deal between 1980 and 1990.

2.6 Summary

This chapter showed the results of the basic analysis of the office industries in the Boston area. The total employment of the twelve office industries increased by 42.3% between 1980 and 1990, which is much greater than other industries and shows their important role in the regional economy. Looking at the data for disaggregated industries, however, the growth rates vary from -5.2% for insurance carriers to 151.8% for security brokers. From the aggregated employment data for each city and town, the major office centers were identified. The suburban subcenters developed adjacent to major highways. Those centers were clustered into four sub-areas. The CBD, composed of Boston and Cambridge, accounted for 46% of the total employment in the area in 1990, but its growth rate was below average. The inner suburb's growth was about average. Both the R-128 Area, which contain many suburban subcenters, and the Outer Suburb had above average growth, showing the trend of decentralization.

Chapter 3 Differences in Locational Patterns between the Office Industries

The previous chapter presented the office location pattern using the aggregated office employment data. These office industries include a wide range of business activities, however, and their criteria for location decisions vary. Such different criteria might lead to different spatial growth patterns, especially with respect to concentration versus dispersion. Some industries might tend to be more concentrated in pursuit of agglomeration merits, or business synergy with other firms and government agencies. Others might tend to be more dispersed into suburban areas for other merits such as cheaper land availability, better labor accessibility, and better accessibility to customers which already dispersed in suburban areas. In this chapter, I analyze the differences in locational patterns between the office industries in two ways. First, I use the Herfindahl and Hirschmann Index which represents the degree of dispersion (or concentration) in each industry. Secondly, I examine the change of each industry's spatial distribution pattern by using the employment data and maps. The results of these are summarized into a classification of the industries with respect to the degree of dispersion and other characteristics in locational patterns.

3.1 Degree of Spatial Dispersion for Each Office Industry

In this section, I use the Herfindahl and Hirschmann Index (HHI) to analyze the locational pattern for each office industry. The use of this index enables us to compare the office industries according to their degrees of spatial dispersion.

The HHI is defined as the sum of squared percentages of market (Adelman, 1969). Using an equation, it can be represented as:

$$HHI = \sum_{i=1}^{n} (Ai / A)^2$$

'A' denotes the total market while 'Ai' denotes the market in a particular subcategory i. In the context of this thesis, 'Ai' can be interpreted as the amount of employment in a particular city or town (municipality) i, and 'A' as the total employment summed up across n municipalities. The HHI can be calculated for each industry for the purpose of cross-industrial comparison in terms of the degree of spatial dispersion.

The value of HHI ranges from (1/n) to 1. The value (1/n) occurs when the industry's employment is equally distributed among all the n municipalities. On the other hand, the HHI of 1 occurs when the industry is concentrated in only one municipality. The larger the HHI is, the lower the industry's degree of dispersion is.

Another interesting characteristic of the HHI is that the reciprocal of the HHI times n, or 1/(n*HHI), gives the percentage of the municipalities that contain the industry when the industry's employment is assumed to be evenly distributed among the municipalities (Xu, 1996). Suppose an industry is distributed evenly in only (1/a) of total n municipalities, or (n/a) municipalities. In that case, each of (n/a) municipalities contains (a/n) of the total employment, and HHI can be calculated as:

$$HHI = (n/a) * (a/n)^2 = a/n$$

From this result, the value of 1/(n*HHI) can be easily calculated as 1/a, which is the percentage of the municipalities that contain the industry. The preferable nature of this new index is that it is free from the total number of municipalities, i.e., n. Therefore, the index, 1/(n*HHI), can be used to compare the degree of dispersion among industries even if applicable numbers of municipalities in a data sample are different among the industries, which

is the case in this analysis due to confidential data. Because this index represents the percentage of the municipalities in which the industry is dispersed, the larger the value of the index is, the higher the industry's degree of dispersion is. (However, one should notice that the HHI does not take into account the geographic features of each municipality, especially the area size.)

The results of the calculations for HHI and 1/(n*HHI) by the twelve office industries are shown in Table 3.1. In 1980, the five most dispersed industries were business services, banking, social services, membership organizations and insurance agents with the 1/(n*HHI) value of 6.5%, 6.2%, 6.1%, 5.7%, and 5.7%, respectively. Three of these five industries were from the service sector. Banking and insurance agents are from the FIRE sector and might be characterized as doing more business with household customers than other industries in the FIRE sector. On the other hand, security brokers, insurance carriers, legal services, and accounting were the four most concentrated industries in 1980, with the 1/(n*HHI) value of 1.6%, 1.9%, 1.9%, and 2.4%, respectively.

As for the change between 1980 and 1990, only investment offices decreased the value of 1/(n*HHI), i.e., became more concentrated. The industries that had most dispersed over the decade were social services, insurance agents, business services, and engineering services. They increased their value of 1/(n*HHI) by 4.6, 4.5, 3.7, and 2.3 percentage points, respectively. Other industries increased their value by less than 1 percentage point and almost all remained the same in terms of the degree of dispersion.

This analysis of the degree of dispersion is summarized into the classification of the office industries, by using criteria about the value of

Table 3.1 Herfindahl and Hirshmann Indices for Office Industries

SIC	Office Industry	# of Samples	HHI 1980	HHI 1990	1/(n*HHI) 1980	1/(n*HHI) 1990	1/(n*HHI) 90-80
83	Social services	68	0.242	0.138	6.1%	10.6%	4.6 p.p.
64	Insurance agents	81	0.225	0.124	5.5%	9.9%	4.5 p.p.
73	Business services	97	0.159	0.101	6.5%	10.2%	3.7 p.p.
871	Engineering services	75	0.411	0.239	3.2%	5.6%	2.3 p.p.
872	Accounting	85	0.496	0.355	2.4%	3.3%	0.9 p.p.
65	Real estate	92	0.283	0.234	3.8%	4.7%	0.8 p.p.
60+61	Banking	33	0.487	0.436	6.2%	6.9%	0.7 p.p.
86	Membership organizations	80	0.218	0.195	5.7%	6.4%	0.7 p.p.
63	Insurance carriers	79	0.676	0.531	1.9%	2.4%	0.5 p.p.
81	Legal services	93	0.565	0.540	1.9%	2.0%	0.1 p.p.
62	Security brokers	67	0.948	0.925	1.6%	1.6%	0.0 p.p.
67	Investment offices	79	0.433	0.761	2.9%	1.7%	-1.3 p.p.

p.p.: percentage points

Source: Author's tabulation from Employment and Wages in Massachusetts Cities and Towns(selected years), Massachusetts Department of Employment and Training

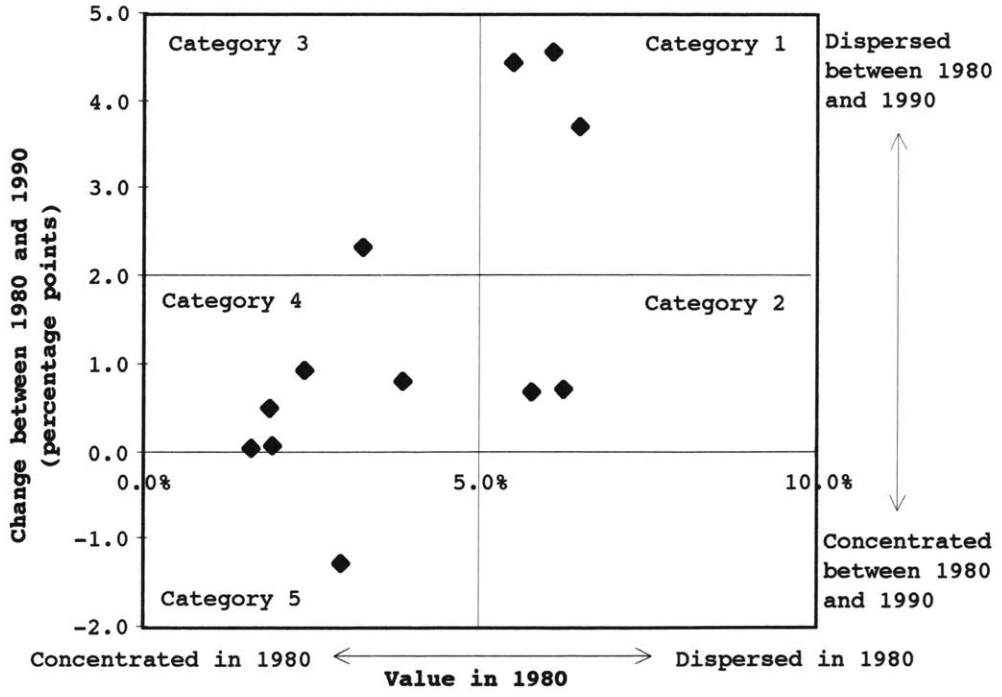

Figure 3.1 Criteria for Classification of Office Industries Using the Value of 1/(n*HHI)

1/(n*HHI) in 1980 and its change between 1980 and 1990. From Figure 3.1, we can find that, using the value in 1980, the twelve industries can be divided into two groups with a borderline at 5%. Also, using the change between 1980 and 1990, they can be divided into three with borderlines at 0 and 2 percentage points. Consequently, they are classified into five categories as follows.

1. Relatively dispersed in 1980 and more dispersed over the next decade

   Industries in this category seemed to start dispersing at an early stage in history and continued dispersing, which means they were most suitable for decentralization. Included in this categorization are social services, business services, and insurance agents.

2. Relatively dispersed in 1980 and unchanged over the next decade

   Possible interpretation for the industries in this category is that they once led the dispersion of office industries, and reached a kind of equilibrium in terms of centralization versus decentralization. Banking and membership organizations are included in this category.

3. Relatively concentrated in 1980 and dispersed in the next decade

   Decentralization occurred to the industry in this category, namely engineering services, relatively recently (after 1980). Therefore, we should watch their ongoing changes.

4. Relatively concentrated in 1980 and unchanged over the next decade

   Interpretation here is that these industries consistently prefer to concentrate. Included are real estate, insurance carriers, legal services, accounting, and security brokers.

5. Relatively concentrated in 1980 and more concentrated over the next decade

   Investment offices fall into this category. This industry was most likely to find advantages in concentrating.

3.2 Office Industry's Locational Patterns in the Boston Area

In the previous section, I analyzed the degree of dispersion in each office industry by using the value of 1/(n*HHI) that represents the industry's locational characteristics in terms of concentration versus dispersion as a form of a single number. In this section, I examine the change in the actual spatial distribution pattern in each office industry by using employment data for cities and towns in order to see if the results from the analysis with the HHI are consistent with the observed changes.

3.2.1 Industries Relatively Dispersed in 1980 and More Dispersed Over the Next Decade

The common characteristics observed in the three industries in this category, insurance agents, business services, and social services, are summarized as follows.

- Their customers include both firms and households.
- The percentage of municipalities containing these industries were around 90% in 1980 and close to 100% in 1990.
- Boston's employment share was around 40% in 1980 and 25-30% in 1990.
- Over the decade, there were some suburban municipalities, mainly in the R-128 area, that have increased their share significantly by up to 6 percentage points.

These industries tend to have a close relationship with their customers rather than to have agglomeration merits from linkages with other firms (in the same industries or other industries). Their customers are dispersed within the area. Therefore, they follow their dispersed customers and show very dispersed locational patterns. Below are the detailed characteristics by industry.

Insurance Agents

Unlike insurance carriers, insurance agents have to have a close relationship with their customers which include not only business establishments but also households, and hence, they tend to disperse a lot in relation to the dispersion of the population.

Among the 147 municipalities in the study area, 125 (85%) in 1980 and 138 (94%) in 1990 included this industry. These percentages are relatively high compared to other industries both in 1980 and 1990.

In 1980, Boston had the largest share (43.4%), and Norwood (9.1%), Brookline (3.7%), and Newton (3.6%) followed (Table 3.2). Between 1980 and 1990, however, all of these municipalities decreased their shares by 14.5, 3.9, 2.8, 1.0 percentage points, respectively. Figure 3.2 shows the changes in the regional share of this industry's employment between 1980 and 1990; these declines are presented by a whitened area around Boston.

Quincy and Waltham in the R-128 area, and Framingham in the Outer Suburb are the three municipalities whose regional shares increased by more

Table 3.2 Employment Data for Selected Municipalities: Insurance Agents

		1980		1990		Change	
		Number	Share	Number	Share	Number	Share
5 Largest Municipalities in Employment in 1980	1 Boston	4700	43.4%	4790	28.9%	90	-14.5 p.p.
	2 Norwood	984	9.1%	863	5.2%	-121	-3.9 p.p.
	3 Brookline	396	3.7%	148	0.9%	-248	-2.8 p.p.
	4 Newton	391	3.6%	437	2.6%	46	-1.0 p.p.
	5 Wellesley	282	2.6%	559	3.4%	277	0.8 p.p.
5 Most Increased Municipalities in Share between 1980 and 1990	1 Quincy	137	1.3%	1190	7.2%	1053	5.9 p.p.
	2 Waltham	126	1.2%	590	3.6%	464	2.4 p.p.
	3 Framingham	92	0.8%	501	3.0%	409	2.2 p.p.
	4 Needham	62	0.6%	374	2.3%	312	1.7 p.p.
	5 Woburn	34	0.3%	306	1.8%	272	1.5 p.p.

p.p.: percentage points

Source: Author's tabulation from Employment and Wages in Massachusetts Cities and Towns(selected years), Massachusetts Department of Employment and Training

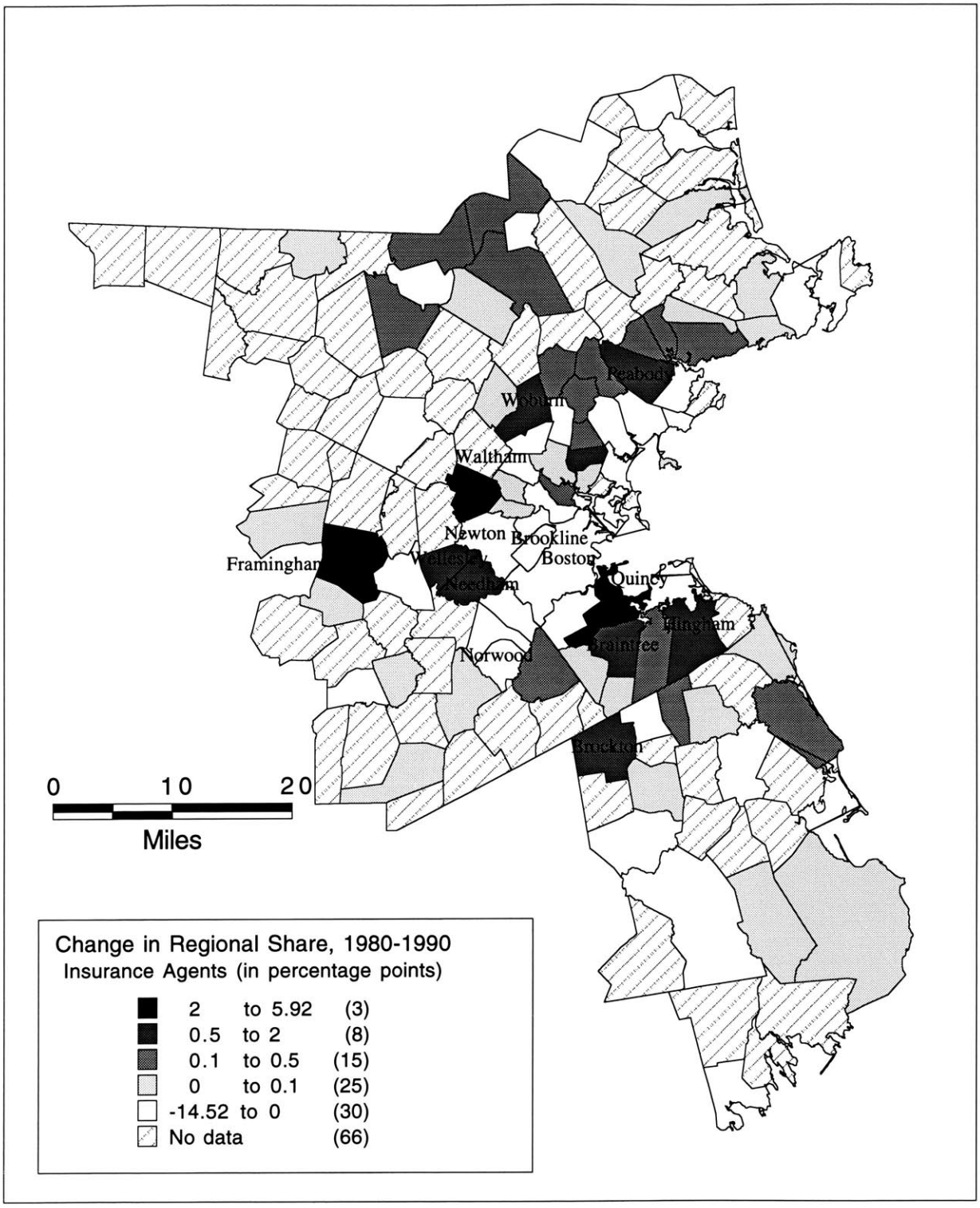

Figure 3.2 Change in Regional Share, Insurance Agents

Source: Employment and Wages in Massachusetts Cities and Towns (selected years), Massachusetts Department of Employment and Training

than 2 percentage points (5.9, 2.4 and 2.2 percentage points, respectively.) In 1980, they had relatively low shares between 0.85% to 1.27%. From Figure 3.2, we can also see that the municipalities whose shares increased between 0.5% to 2% were spread out in the R-128 Area (Needham, Worburn, Braintree, Wellesley, and Peabody) and the Outer Suburb (Brockton and Hingham). All of these changes in the distribution pattern support the high degree of dispersion of this industry.

Business Services

This industry is composed of a variety of services. Most of them, such as advertising, computer programming, and personnel supply services, mainly serve firm customers, but some of them, for instance, photocopying and services to dwellings, serve household customers as well.

Among the 147 municipalities, 144 (98%) in 1980 and all in 1990 included this industry. These percentages are highest among all the industries and give evidence to the high degree of dispersion in 1980 and 1990.

In 1980, Boston had the largest share (35.1%), and Cambridge (10.5%), Waltham (6.9%), Malden (3.6%), and Burlington (3.5%) followed (Table 3.3). Between 1980 and 1990, Boston's share dropped by 10.0 percentage points to 25.1%. Compared to other industries, Boston's shares in this industry in both 1980 and 1990 are the lowest. Cambridge and Waltham have extended their share by 2.7 and 0.2 percentage points, respectively, and narrowed the gap between Boston and themselves.

Other municipalities that increased their shares more than 1.0 percentage point were Braintree, Westwood, Somerville, Framingham, and Woburn. They spread out from the Inner Suburb to the Outer Suburb.

Table 3.3 Employment Data for Selected Municipalities: Business Services

		1980		1990		Change	
		Number	Share	Number	Share	Number	Share
5 Largest Municipalities in Employment in 1980	1 Boston	32018	35.1%	31202	25.1%	-816	-10.0 p.p.
	2 Cambridge	9558	10.5%	16367	13.2%	6809	2.7 p.p.
	3 Waltham	6305	6.9%	8877	7.1%	2572	0.2 p.p.
	4 Malden	3313	3.6%	1063	0.9%	-2250	-2.8 p.p.
	5 Burlington	3188	3.5%	3430	2.8%	242	-0.7 p.p.
5 Most Increased Municipalities in Share between 1980 and 1990	1 Cambridge	9558	10.5%	16367	13.2%	6809	2.7 p.p.
	2 Braintree	632	0.7%	2266	1.8%	1634	1.1 p.p.
	3 Westwood	461	0.5%	1971	1.6%	1510	1.1 p.p.
	4 Somerville	895	1.0%	2520	2.0%	1625	1.0 p.p.
	5 Framingham	1661	1.8%	3539	2.9%	1878	1.0 p.p.

p.p.: percentage points
Source: Author's tabulation from Employment and Wages in Massachusetts Cities and Towns(selected years), Massachusetts Department of Employment and Training

Social Services

This industry includes individual and family services, job training and vocational rehabilitation services, child day care services, and residential care. As these detailed categories indicate, this industry also relates to individual customers and therefore tends to be more dispersed.

Among the 147 municipalities, 128 (87%) in 1980 and 141 (96%) in 1990 included this industry. These percentages as well as the other two industries in this category are also relatively high.

Boston's share was 45.0% in 1980 and declined by 14.1 percentage points to 30.9% in 1990 (Table 3.4). Cambridge ranked second in 1980 with a share of 4.5% and increased its share slightly by 0.2 percentage points. However, Brockton, Watertown, and Lowell which had the third, fourth, and fifth largest shares in 1980, decreased their shares by 1.7, 1.9, and 0.4 percentage points, respectively.

Municipalities whose shares rose a great deal were mainly located in

the R-128 area and the Inner Suburb, such as Newton, Malden, Quincy, and Waltham (4.3, 3.3, 1.5, and 1.3 percentage points, respectively). However, in the Outer Suburb, some municipalities such as Lawrence, Plymouth, and Pembroke, also increased their share by 0.9, 0.6, and 0.3 percentage points, respectively.

Table 3.4 Employment Data for Selected Municipalities: Social Services

		1980		1990		Change	
		Number	Share	Number	Share	Number	Share
5 Largest Municipalities in Employment in 1980	1 Boston	11503	45.0%	13370	30.9%	1867	-14.1 p.p.
	2 Cambridge	1144	4.5%	2001	4.6%	857	0.1 p.p.
	3 Brockton	1093	4.3%	1110	2.6%	17	-1.7 p.p.
	4 Watertown	779	3.0%	517	1.2%	-262	-1.9 p.p.
	5 Lowell	691	2.7%	992	2.3%	301	-0.4 p.p.
5 Most Increased Municipalities in Share between 1980 and 1990	1 Newton	622	2.4%	2928	6.8%	2306	4.3 p.p.
	2 Malden	353	1.4%	2023	4.7%	1670	3.3 p.p.
	3 Quincy	679	2.7%	1810	4.2%	1131	1.5 p.p.
	4 Waltham	286	1.1%	1054	2.4%	768	1.3 p.p.
	5 Somerville	308	1.2%	1044	2.4%	736	1.2 p.p.

p.p.: percentage points
Source: Author's tabulation from Employment and Wages in Massachusetts Cities and Towns(selected years), Massachusetts Department of Employment and Training

3.2.2 Industries Relatively Dispersed in 1980 and Unchanged Over the Next Decade

Membership organizations and banking are included in this category and their common characteristics are summarized as follows.

- Their customers include both firms and households.
- The percentage of municipalities including these industries were around 85% in 1980 and around 90% in 1990 (slightly lower than in the first category.)
- Boston's employment share was around 43% in 1980 and around 35% in 1990 (slightly higher than in the first category.)

- There were no municipalities that increased their share more than 2 percentage points.

As well as the industries in the first category, these industries have a close relationship with customers, and this explains the high degree of dispersion in the early stage (1980). For them, however, it is also important to have a business relationship with government agencies (e.g., the Federal Reserve Bank for bank companies) or other firms (e.g., members of a business association for membership organizations). This kind of relationship is assumed to tie a certain part of these industries to the CBD, where these activities are most likely to take place. For example, a bank company locates many customer-serving branches and probably some back-support offices in suburbs, but their headquarters persist in locating in the CBD. This can be a reason why their degree of dispersion was unchanged after 1980. Below are the detailed characteristics by industries.

Membership Organizations

This industry is composed of organizations related to firms and also those related to households. The former includes business associations, professional membership organizations, and labor unions. The latter includes political organizations and religious organizations.

Among the 147 municipalities, 116 (79%) in 1980 and 124 (84%) in 1990 included this industry. These percentages are moderate compared to other industries.

Boston's share in 1980 was 42.1%, and Lynn, Framingham, Waltham and Lawrence followed it with shares between 3% and 4% (Table 3.5). As in the three industries previously mentioned, Boston's share in this industry also dropped, but only by 3.0 percentage points.

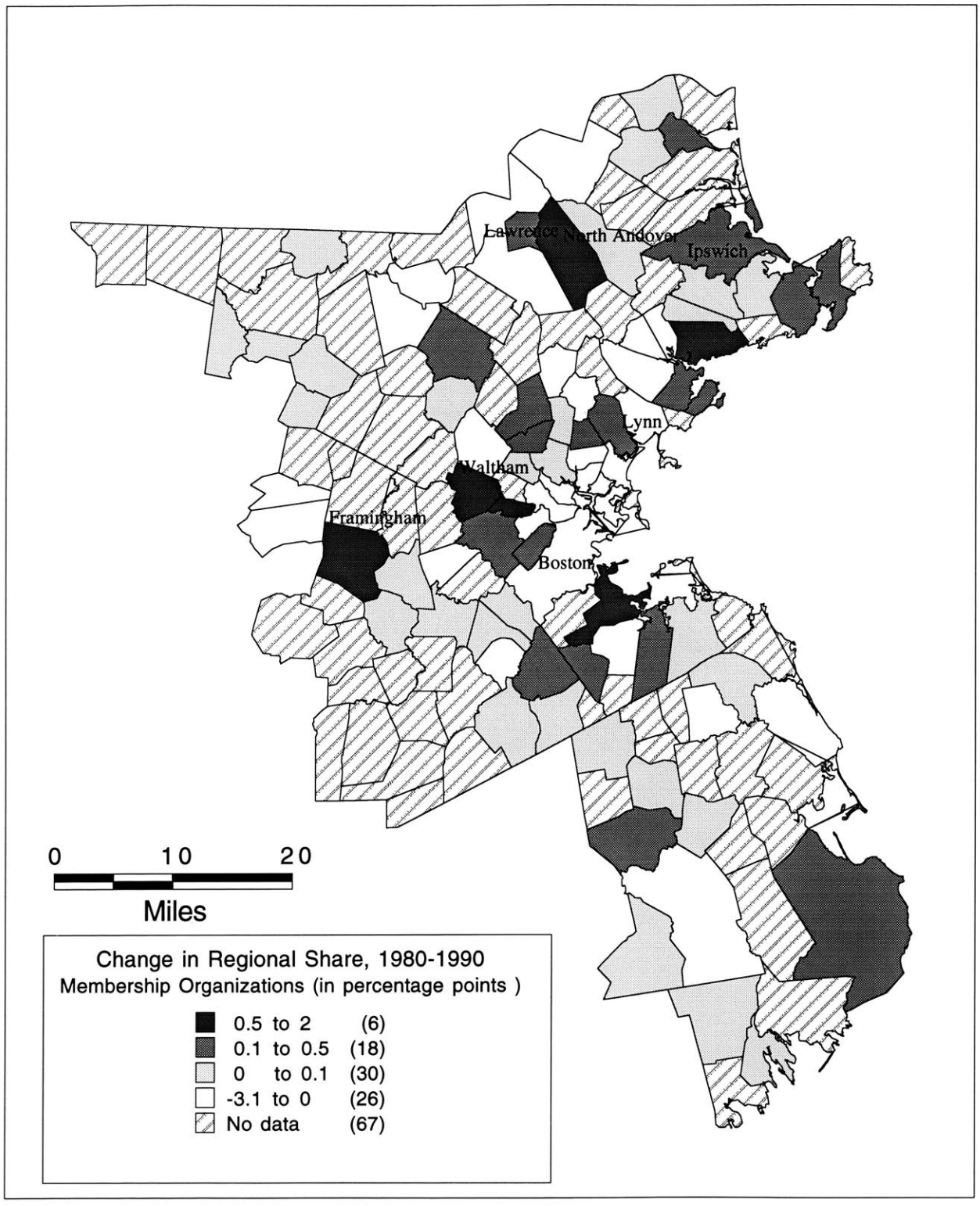

Figure 3.3 Change in Regional Share, Membership Organizations

Source: Employment and Wages in Massachusetts Cities and Towns (selected years), Massachusetts Department of Employment and Training

Figure 3.3 displays the changes in the regional share of employment in this industry between 1980 and 1990. From the figure, we can see that there are no municipalities that increased their shares more than 2 percentage points. Note that this industry's total employment growth ratio between 1980 and 1990 in the whole study area was the second lowest (Table 2.1). Framingham increased its share the most, but only by 1.6 percentage points from 3.2% to 4.8% in 1990. Some municipalities, such as North Andover and Ipswich, in the northern Outer Suburb increased their shares, but only by about 0.5 percentage points. These overall changes in the locational pattern suggest that this industry was at a relatively stable and constant growth stage.

Table 3.5 Employment Data for Selected Municipalities: Membership Org.

		1980		1990		Change	
		Number	Share	Number	Share	Number	Share
5 Largest Municipalities in Employment in 1980	1 Boston	5108	42.1%	5857	39.0%	749	-3.0 p.p.
	2 Lynn	464	3.8%	290	1.9%	-174	-1.9 p.p.
	3 Framingham	390	3.2%	721	4.8%	331	1.6 p.p.
	4 Waltham	366	3.0%	604	4.0%	238	1.0 p.p.
	5 Lawrence	361	3.0%	481	3.2%	120	0.2 p.p.
5 Most Increased Municipalities in Share between 1980 and 1990	1 Framingham	390	3.2%	721	4.8%	331	1.6 p.p.
	2 Quincy	207	1.7%	433	2.9%	226	1.2 p.p.
	3 Waltham	366	3.0%	604	4.0%	238	1.0 p.p.
	4 Beverly	84	0.7%	216	1.4%	132	0.7 p.p.
	5 Watertown	36	0.3%	151	1.0%	115	0.7 p.p.

p.p.: percentage points
Source: Author's tabulation from Employment and Wages in Massachusetts Cities and Towns(selected years), Massachusetts Department of Employment and Training

Banking

Among the 147 municipalities, 135 (92%) in 1980 and 143 (97%) in 1990 included this industry. These percentages are very high and suggest that

this industry was also much dispersed.

Boston's share dropped by 10.5 percentage points from 44.5% in 1980 to 34.1% in 1990, which is a moderate decline compared to other industries (Table 3.6). Other municipalities' change in share covered a very narrow range between 0.5% and -0.8%. Therefore, this industry also seemed to be in a stage of constant growth without changing its locational pattern, as far as we can judge from the limited available data. (Note that data for this industry are the sum of the data for two double-digit SIC categories, depository institutions and nondepository institutions, and if either of them is confidential, data for banking also become confidential. Therefore, we lose much information about this industry. The number of available cases, or municipalities, for this industry is only 33. This much loss in information might result in biased data analysis for this industry.)

Table 3.6 Employment Data for Selected Municipalities: Banking

		1980		1990		Change	
		Number	Share	Number	Share	Number	Share
5 Largest Municipalities in Employment in 1980	1 Boston	66513	57.2%	76437	48.0%	9924	-9.2 p.p.
	2 Quincy	4611	4.0%	11680	7.3%	7069	3.4 p.p.
	3 Cambridge	2549	2.2%	3398	2.1%	849	-0.1 p.p.
	4 Wellesley	2375	2.0%	2576	1.6%	201	-0.4 p.p.
	5 Newton	2303	2.0%	2544	1.6%	241	-0.4 p.p.
5 Most Increased Municipalities in Share between 1980 and 1990	1 Lowell	767	1.8%	1390	2.4%	623	0.5 p.p.
	2 Braintree	204	0.5%	497	0.8%	293	0.4 p.p.
	3 Waltham	615	1.5%	1052	1.8%	437	0.3 p.p.
	4 Woburn	242	0.6%	486	0.8%	244	0.2 p.p.
	5 Norwell	26	0.1%	133	0.2%	107	0.2 p.p.

p.p.: percentage points

Source: Author's tabulation from Employment and Wages in Massachusetts Cities and Towns(selected years), Massachusetts Department of Employment and Training

3.2.3 Industries Relatively Concentrated in 1980 and Dispersed Over the Next Decade

Only engineering services are in this category. They are distinguished from the previous two categories by these characteristics:

- Their customers are mainly firms.
- The percentage of municipalities including this industry was lower in 1980 (72%), but almost the same as the previous two categories in 1990 (93%).
- Boston's employment share was higher in 1980 (58%), but almost the same as the previous two categories in 1990 (34%).

Because their customers are mainly firms, which are more concentrated than households, they were also concentrated in 1980 in order to locate close to other firms. One possible explanation for the high degree of dispersion between 1980 and 1990 is that they followed their suburbanized customers. The other is that the information technology renovation changed the way of communications. Faxes, e-mail, and internet made face-to-face communication less important. Engineering services might have benefited from the new technology, have been freed from locating geographically close to their customers, and have become to enjoy better office environment in suburbs than in the crowded CBD. Below are detailed characteristics for this industry.

Engineering Services

Engineering services are composed of engineering, architectural, and surveying services, which are assumed to be mostly serving business entities.

Among the 147 municipalities, 106 (72%) in 1980 and 136 (93%) in 1990 included this industry. These percentage are moderate in 1980 and relatively high in 1990.

In 1980, Boston had the largest share of employment (57.8%), and Cambridge (13.1%), Waltham (7.3%), Wellesley (1.6%) and Newton (1.6%) followed. The total of these top five shares were 81.4%, which were the fourth largest share among all the industry, following Security brokers, Investment offices, and Insurance Carriers.

Between 1980 and 1990, Boston's employment decreased not only in share but also in number by about three thousand (Table 3.7). Its share dropped by as much as 23.8 percentage points to 34.0%. In 1980, other large concentrations, namely Cambridge and Waltham, also decreased their shares by 1.2 and 5.4 percentage points respectively.

The municipality that increased its share the most was Wakefield whose share was 0.1% in 1980 and 3.9% in 1990, followed by Woburn (from 0.1% to 1.9%), Norwood (from 0.3% to 1.2%), Brookline (from 0.6% to 1.4%), Framingham (from 0.4% to 1.2%), and Acton (from 0.1% to 0.8%). They are located in the R-128 and the Outer Suburb except for Brookline (Figure 3.4), and they had shares of less than 1% in 1980. All these changes show that this industry was much dispersed between 1980 and 1990.

Table 3.7 Employment Data for Selected Municipalities: Engineering Services

		1980		1990		Change	
		Number	Share	Number	Share	Number	Share
5 Largest Municipalities in Employment in 1980	1 Boston	11601	57.8%	8678	34.0%	-2923	-23.8 p.p.
	2 Cambridge	2639	13.1%	3049	11.9%	410	-1.2 p.p.
	3 Waltham	1471	7.3%	491	1.9%	-980	-5.4 p.p.
	4 Wellesley	315	1.6%	442	1.7%	127	0.2 p.p.
	5 Newton	312	1.6%	562	2.2%	250	0.6 p.p.
5 Most Increased Municipalities in Share between 1980 and 1990	1 Wakefield	20	0.1%	1000	3.9%	980	3.8 p.p.
	2 Woburn	20	0.1%	490	1.9%	470	1.8 p.p.
	3 Norwood	58	0.3%	294	1.2%	236	0.9 p.p.
	4 Brookline	118	0.6%	365	1.4%	247	0.8 p.p.
	5 Framingham	71	0.4%	295	1.2%	224	0.8 p.p.

p.p.: percentage points
Source: Author's tabulation from Employment and Wages in Massachusetts Cities and Towns(selected years), Massachusetts Department of Employment and Training

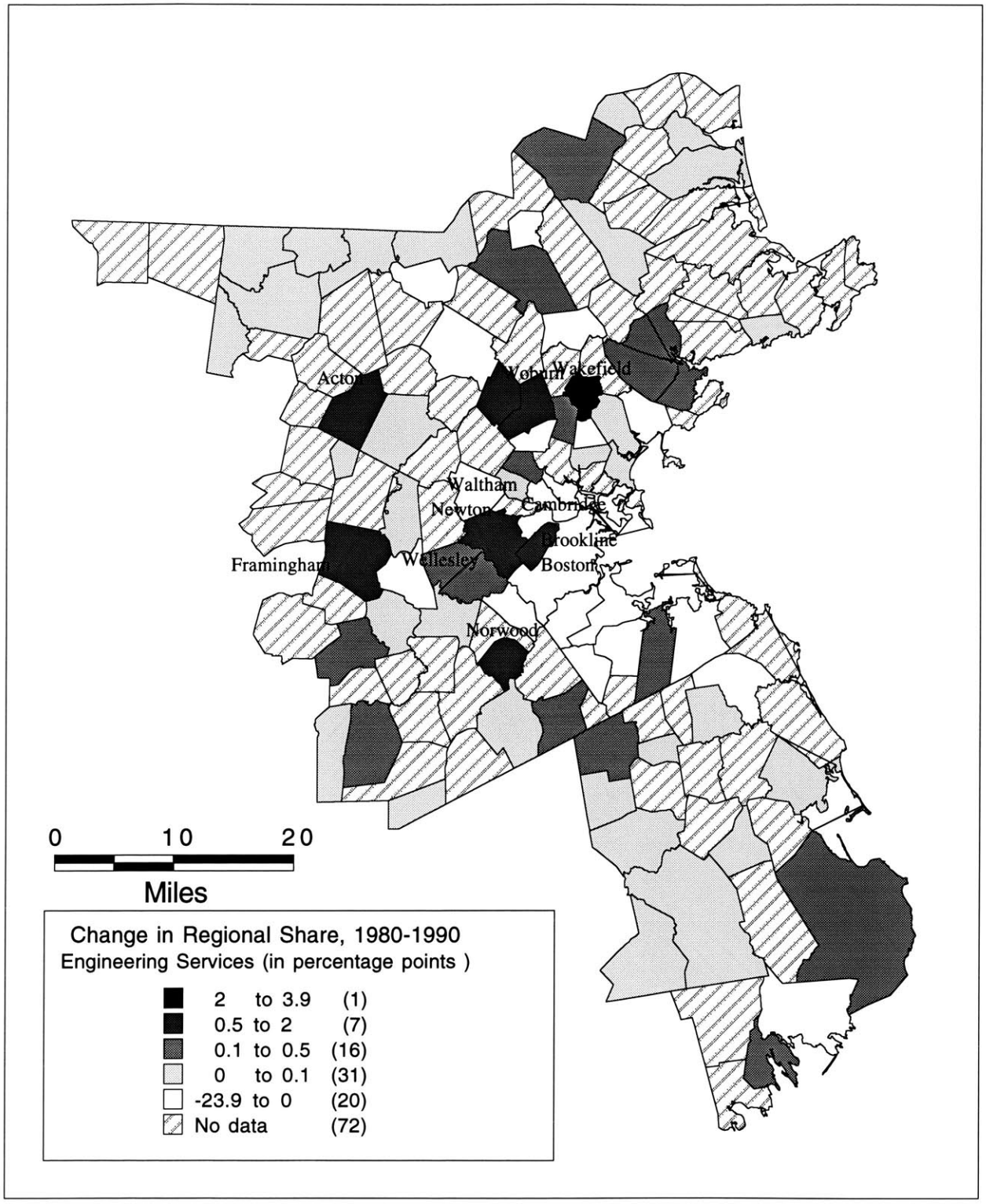

Figure 3.4 Change in regional Share, Engineering Services

Source: Employment and Wages in Massachusetts Cities and Towns (selected years), Massachusetts Department of Employment and Training

3.2.4 Industries Relatively Concentrated in 1980 and Unchanged Over the Next Decade

The common characteristics observed in the five industries in this category are summarized as follows.

- Their customers are mainly firms.
- The percentage of municipalities including these industries are relatively low (from 30% to 91% in 1980 and from 60% to 98% in 1990).
- Boston's employment share was more than 50% in 1980 and did not drop much between 1980 and 1990.
- There is only one municipality in one industry that increased its share more than 2 percentage points.

As well as the industries in the second category (dispersed in 1980 and unchanged over the next decade), these industries are assumed to benefit from concentrating in the CBD. For example, insurance agents and security brokers tend to have relationships with government agencies and headquarters of other big companies. Legal services tend to cluster around superior courts for obtaining valuable information. For these industries, it is critical to locate in the CBD where a lot of communication takes place and provides various business information. Moreover, for most of these industries, their customers are mainly firms, not households. In terms of the proximity to their customers, the CBD is still the best location for them. For these reasons, they tend to concentrate constantly. Below are the detailed characteristics by industry.

Legal Services

Among the 147 municipalities, 118 (80%) in 1980 and 130 (88%) included this industry. These percentages were moderate in both 1980 and 1990.

In 1980, Boston had the largest share of employment, as much as 73.6%, and all the other municipalities had shares of at most 1.6% each (Table 3.8). Thus, legal services was one of the industries with the most concentrated spatial pattern in the City of Boston.

Between 1980 and 1990, this characteristic did not change much. Boston's share slightly decreased (1.5 percentage points), but still contained 72.1% of the total employment in the whole area. Some suburban municipalities, such as Braintree, Wellesley, Newton, Andover, Lexington, Chelmsford, Salem, and Lynnfield, increased their shares, but at most by 0.6 percentage points (Figure 3.5). Judging from these facts, it can be said that legal services kept its concentrated spatial pattern.

Table 3.8 Employment Data for Selected Municipalities: Legal Services

		1980		1990		Change	
		Number	Share	Number	Share	Number	Share
5 Largest Municipalities in Employment in 1980	1 Boston	7605	73.6%	15941	72.1%	8336	-1.5 p.p
	2 Lowell	170	1.6%	329	1.5%	159	-0.2 p.p
	3 Brockton	159	1.5%	341	1.5%	182	0.0 p.p
	4 Cambridge	130	1.3%	299	1.4%	169	0.1 p.p
	5 Lawrence	110	1.1%	155	0.7%	45	-0.4 p.p
5 Most Increased Municipalities in Share between 1980 and 1990	1 Braintree	47	0.5%	241	1.1%	194	0.6 p.p
	2 Wellesley	38	0.4%	159	0.7%	121	0.4 p.p
	3 Newton	59	0.6%	199	0.9%	140	0.3 p.p
	4 Andover	28	0.3%	125	0.6%	97	0.3 p.p
	5 Lexington	24	0.2%	99	0.4%	75	0.2 p.p

p.p.: percentage points

Source: Author's tabulation from Employment and Wages in Massachusetts Cities and Towns(selected years), Massachusetts Department of Employment and Training

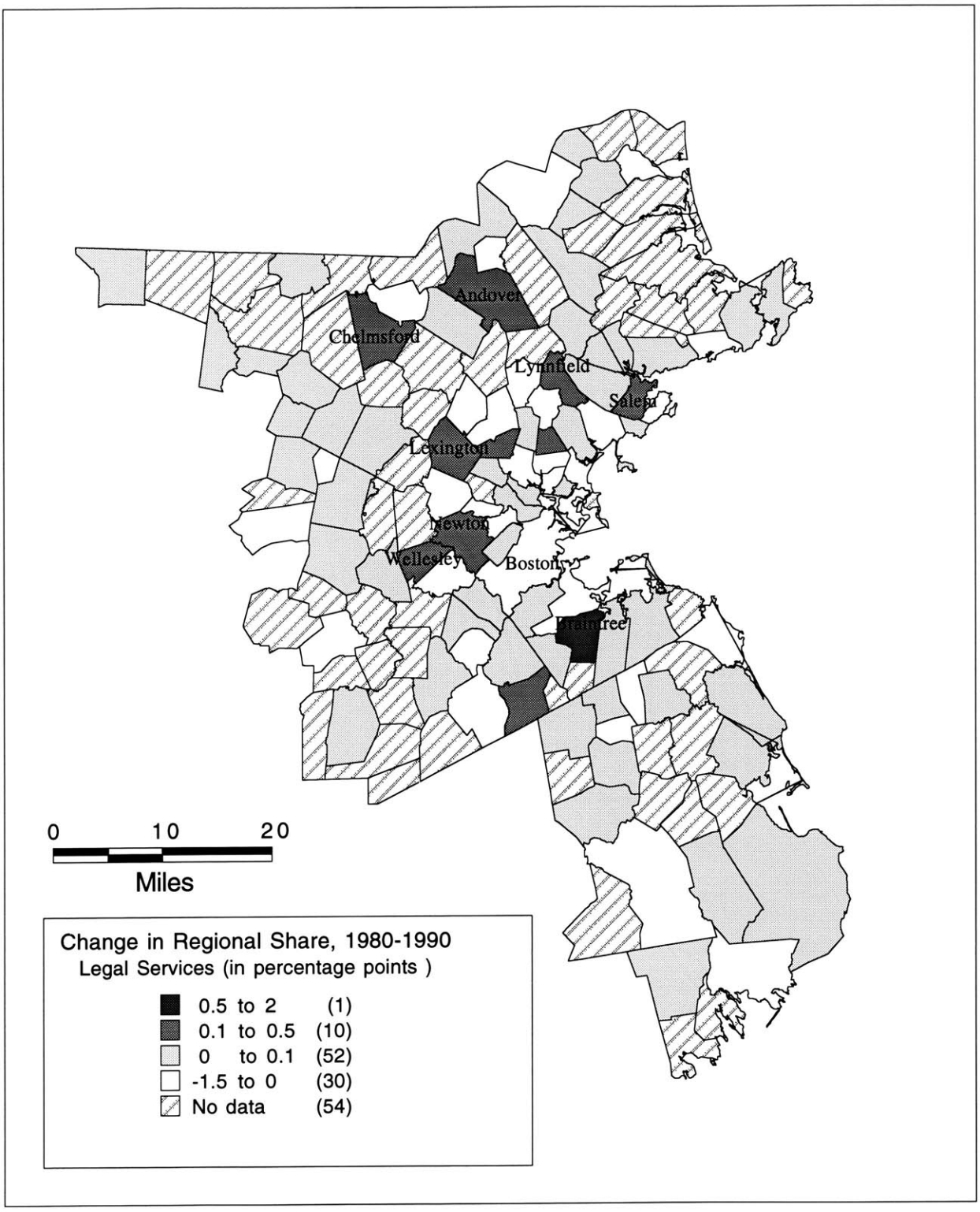

Figure 3.5 Change in Regional Share, Legal Services

Source: Employment and Wages in Massachusetts Cities and Towns (selected years), Massachusetts Department of Employment and Training

Real Estate

This industry includes real estate operators, owners and lessors of property, buyers, sellers, developers, agents, and brokers whose customers vary from firms to households.

Among the 147 municipalities, 134 (91%) in 1980 and 144 (98%) included this industry. These percentages were very high in both 1980 and 1990 and seem to be against the classification, "relatively concentrated in 1980." On the other hand, the relatively high share of Boston in 1990, 50.0%, is consistent with the classification (Table 3.9). Other concentrations in 1980 were Newton (4.9%), Braintree (4.4%), Brookline (3.5%), and Cambridge (3.2%).

This distribution pattern did not change much between 1980 and 1990. Boston's share decreased by only 6.4 percentage point to 43.6%. Quincy, Natick, and Burlington were the three municipalities whose shares increased the most over the decade, but their increases were only 1.6, 1.3, and 1.3 percentage points.

Table 3.9 Employment Data for Selected Municipalities: Real Estate

		1980		1990		Change	
		Number	Share	Number	Share	Number	Share
5 Largest Municipalities in Employment in 1980	1 Boston	7653	50.0%	10198	43.6%	2545	-6.4 p.p.
	2 Newton	754	4.9%	886	3.8%	132	-1.1 p.p.
	3 Braintree	672	4.4%	937	4.0%	265	-0.4 p.p.
	4 Brookline	533	3.5%	658	2.8%	125	-0.7 p.p.
	5 Cambridge	489	3.2%	727	3.1%	238	-0.1 p.p.
5 Most Increased Municipalities in Share between 1980 and 1990	1 Quincy	131	0.9%	573	2.4%	442	1.6 p.p.
	2 Natick	39	0.3%	364	1.6%	325	1.3 p.p.
	3 Burlington	66	0.4%	405	1.7%	339	1.3 p.p.
	4 Westwood	24	0.2%	267	1.1%	243	1.0 p.p.
	5 Waltham	271	1.8%	526	2.2%	255	0.5 p.p.

p.p.: percentage points

Source: Author's tabulation from Employment and Wages in Massachusetts Cities and Towns(selected years), Massachusetts Department of Employment and Training

Insurance Carriers

Insurance carriers are one of the industries whose spatial distribution are most concentrated in Boston. The share of Boston in 1980 was 72.4%, followed by Wellesley (4.4%), Quincy (3.0%), Waltham (1.4%), and Brockton (1.3%) (Table 3.10). Among the 147 municipalities, 66 (45%) in 1980 and 91 (62%) in 1990 included this industry. These percentages are the third lowest among all the industries in both years.

Between 1980 and 1990, Boston decreased its share by 13.2 percentage points, but still had 59.2% share in 1990. Wellesley also lost its share by 0.5 percentage points. However, Quincy, Waltham, and Brockton whose shares in 1980 were the second, third, and fourth highest increased their shares by 1.7, 1.0, and 0.7 percentage points, respectively (the first, fourth and sixth largest increases among all municipalities). It can be concluded from these results that there was little tendency of dispersion, because the change in the employment distribution was from Boston to the already existing concentrations in 1980 rather than to municipalities that had little employment then.

Table 3.10 Employment Data for Selected Municipalities: Insurance Carriers

		1980		1990		Change	
		Number	Share	Number	Share	Number	Share
5 Largest Municipalities in Employment in 1980	1 Boston	26985	72.4%	20910	59.2%	-6075	-13.2 p.p.
	2 Wellesley	1622	4.4%	1358	3.8%	-264	-0.5 p.p.
	3 Quincy	1100	3.0%	1651	4.7%	551	1.7 p.p.
	4 Waltham	517	1.4%	864	2.4%	347	1.1 p.p.
	5 Brockton	486	1.3%	711	2.0%	225	0.7 p.p.
5 Most Increased Municipalities in Share between 1980 and 1990	1 Quincy	1100	3.0%	1651	4.7%	551	1.7 p.p.
	2 Braintree	278	0.7%	810	2.3%	532	1.5 p.p.
	3 Peabody	125	0.3%	510	1.4%	385	1.1 p.p.
	4 Waltham	517	1.4%	864	2.4%	347	1.1 p.p.
	5 Framingham	138	0.4%	455	1.3%	317	0.9 p.p.

p.p.: percentage points

Source: Author's tabulation from Employment and Wages in Massachusetts Cities and Towns(selected years), Massachusetts Department of Employment and Training

Security Brokers

This industry also has a significant concentration in Boston. In 1980, Boston's share was as much as 88.8% (Table 3.11). Among the 147 municipalities, only 44 (30%) in 1980 and 89 (60%) in 1990 included this industry. During the decade, Boston's share increased to 90.6%. Other municipalities' share remained at almost the same level with changes between 0.7 and -0.4 percentage points.

Table 3.11 Employment Data for Selected Municipalities: Security Brokers

		1980		1990		Change	
		Number	Share	Number	Share	Number	Share
5 Largest Municipalities in Employment in 1980	1 Boston	7349	88.8%	18874	90.6%	11525	1.8 p.p.
	2 Wellesley	107	1.3%	188	0.9%	81	-0.4 p.p.
	3 Cambridge	35	0.4%	168	0.8%	133	0.4 p.p.
	4 Peabody	26	0.3%	26	0.1%	0	-0.2 p.p.
	5 Newton	15	0.2%	179	0.9%	164	0.7 p.p.
5 Most Increased Municipalities in Share between 1980 and 1990	1 Boston	7349	88.8%	18874	90.6%	11525	1.8 p.p.
	2 Newton	15	0.2%	179	0.9%	164	0.7 p.p.
	3 Braintree	0	0.0%	90	0.4%	90	0.4 p.p.
	4 Cambridge	35	0.4%	168	0.8%	133	0.4 p.p.
	5 Waltham	6	0.1%	51	0.2%	45	0.2 p.p.

p.p.: percentage points
Source: Author's tabulation from Employment and Wages in Massachusetts Cities and Towns(selected years), Massachusetts Department of Employment and Training

Accounting

Among the 147 municipalities, 98 (67%) in 1980 and 119 (81%) in 1990 included this industry. These percentages were relatively low in both years.

Boston's share in 1980 was the fourth largest, 63.5%, and Newton (2.7%), Lowell (2.2%), Canton (2.0%), and Brookline (1.6%) followed Boston (Table 3.12).

Between 1980 and 1990, Boston's share decreased by 11.1 percentage

points to 52.3%. On the other hand, some suburban municipalities in the R-128 Area and the Outer Suburb with small employment in 1980 increased their share, such as Waltham (from 1.2% to 4.0%), Burlington (from 0.8% to 2.3%), North Andover (from 0.3% to 1.4%), and Needham (from 0.2% to 1.3%). However, the degree of these observed dispersions was not very strong.

Table 3.12 Employment Data for Selected Municipalities: Accounting

		1980		1990		Change	
		Number	Share	Number	Share	Number	Share
5 Largest Municipalities in Employment in 1980	1 Boston	4698	63.5%	6508	52.3%	1810	-11.1 p.p.
	2 Newton	202	2.7%	382	3.1%	180	0.3 p.p.
	3 Lowell	165	2.2%	87	0.7%	-78	-1.5 p.p.
	4 Canton	147	2.0%	209	1.7%	62	-0.3 p.p.
	5 Brookline	120	1.6%	228	1.8%	108	0.2 p.p.
5 Most Increased Municipalities in Share between 1980 and 1990	1 Waltham	90	1.2%	503	4.0%	413	2.8 p.p.
	2 Burlington	54	0.7%	280	2.3%	226	1.5 p.p.
	3 North Andover	22	0.3%	176	1.4%	154	1.1 p.p.
	4 Needham	17	0.2%	160	1.3%	143	1.1 p.p.
	5 Quincy	39	0.5%	171	1.4%	132	0.8 p.p.

p.p.: percentage points
Source: Author's tabulation from Employment and Wages in Massachusetts Cities and Towns(selected years), Massachusetts Department of Employment and Training

3.2.5 Industries Relatively Concentrated in 1980 and More Concentrated Over the Next Decade

Only investment offices are in this category. This industry also tends to have much benefit from locating in the CBD, such as easy communication with other big firms and government agencies. Below are the detailed characteristics for this industry.

Investment Offices

This industry includes investment trusts, investment companies, and holding companies. As shown in Table 2.1 this is also a very small industry in terms of the amount of employment. Among the 147 municipalities, 49 (33%) in 1980 and 69 (47%) in 1990 included this industry. These percentages were very low in both years.

In 1980, Boston and Waltham were the two largest concentrations whose shares were 49.1% and 30.4%, respectively (Table 3.13). Between 1980 and 1990, however, Waltham lost most of its employment (from 686 to 71 in number and from 30.4% to 1.8% in share.) Consequently, Boston remained as the only concentration, although it also decreased its share by 10.0 percentage points. This change from a double concentration to a single one led this industry to the category "more concentrated over the decade."

Table 3.13 Employment Data for Selected Municipalities: Investment Offices

		1980		1990		Change	
		Number	Share	Number	Share	Number	Share
5 Largest Municipalities in Employment in 1980	1 Boston	1108	49.1%	1553	39.1%	445	-10.0 p.p.
	2 Waltham	686	30.4%	71	1.8%	-615	-28.6 p.p.
	3 Cambridge	97	4.3%	37	0.9%	-60	-3.4 p.p.
	4 Brockton	34	1.5%	14	0.4%	-20	-1.2 p.p.
	5 Lowell	31	1.4%	11	0.3%	-20	-1.1 p.p.
5 Most Increased Municipalities in Share between 1980 and 1990	1 Marlborough	0	0.0%	37	0.9%	37	0.9 p.p.
	2 Chelmsford	0	0.0%	9	0.2%	9	0.2 p.p.
	3 Belmont	0	0.0%	5	0.1%	5	0.1 p.p.
	4 Wenham	0	0.0%	4	0.1%	4	0.1 p.p.
	5 Burlington	0	0.0%	2	0.1%	2	0.1 p.p.

p.p.: percentage points

Source: Author's tabulation from Employment and Wages in Massachusetts Cities and Towns(selected years), Massachusetts Department of Employment and Training

3.3 Summary

This chapter discussed the locational differences between the industries, by focusing especially on the degree of dispersion. As a result of the analysis with the HHI, the industries were classified into five categories.

The first category is "relatively dispersed in 1980 and more over the next decade." Insurance agents, business services, and social services are in this category. Their customers include both firms and households which already highly dispersed. These industries also dispersed in order to follow their customers, rather than to concentrate and pursue agglomeration merits, which were not very important for them. As a consequence, they were included almost all the municipalities in the study area, and Boston's employment share was low (around 40% in 1980 and 25-30% in 1990). Moreover, there were some suburban municipalities that have increased their share significantly between 1980 and 1990.

The second is "dispersed in 1980 and unchanged over the decade," which includes membership organizations and banking. While they showed the dispersed locational patterns following their dispersed customers (both households and firms), a part of them persisted in concentrating in the CBD to obtain benefit from interactions with government agencies and other big firms, which also located in the CBD. Their high percentage of municipalities including these industries and low employment share of Boston were close to those of the industries in the first category, and showed the high degree of their dispersion. On the other hand, there were no municipalities that increased their share more than 2 percentage points.

The third is "concentrated in 1980 and dispersed over the decade." Only engineering services fall into this category. Their customers are mainly firms and this explains the concentrated pattern in 1980. The rapid

dispersion between 1980 and 1990 is represented by the large increase in the percentage of municipalities including this industry (from 72% in 1980 to 93% in 1990), and the large decrease in Boston's employment share (from 58% in 1980 to 34% in 1990). This dispersion might be attributed to their customers' dispersion or communication technology renovation, or both.

The fourth is "concentrated in 1980 and unchanged over the decade." Included in this category are legal services, real estate, insurance carriers, accounting and security brokers. They are likely to benefit from agglomeration merits: information sharing with other firms, communication with government agencies, and proximity to their customers which are mainly large firms and concentrated in the CBD. Therefore, they tend to concentrate in the CBD. For these industries, Boston's employment share ranged from 50% to 89% in 1980 and did not drop much between 1980 and 1990.

The last is "concentrated in 1980 and more over the decade," and only investment offices fall into this category. The firms in this industry also benefit from agglomeration merits, which entice them to concentrating in the CBD.

Chapter 4 Literature Review

Works relevant to the office growth model are derived mainly from the field of location choice analysis, which targets a wide range of industries including office industries. In addition, in the field of regional growth analysis, there are noteworthy studies that focus on the notion of convergence. In this chapter, I review some existing empirical studies from these two fields. After that, I clarify the relationship between the existing studies and this thesis.

4.1 Location Models for Office Industry

In the field of location choice analysis, economists and regional scientists have contributed to the empirical studies by building models and testing their hypotheses. Although their dependent and independent variables and model forms vary, most of their specifications are based on a discrete choice model.

The discrete choice model is used in the situation where a decision maker selects one choice out of a field of mutually exclusive choices (DiPasquale and Wheaton, 1996). The choice of a shopping center by customers is one of the examples. The choice of a travel mode among taxi, bus, privately-owned car, subway, etc. is another example. Also, this methodology has various kinds of applications in the location choice, such as a household's residential choice and a plant's site choice.

In this model, each choice has a set of attributes that determine the utility for the choice. The probability that particular choice i is selected is determined by the relative magnitude of the utility for the choice among all the possible choices. This probability is often expressed under the

logit model framework as follows:

$$P_i = \exp(\beta X_i) \,/\, \sum_j \exp(\beta X_j) \qquad i,j = 1, \ldots, n$$

where P_i = probability of selecting choice i;

X_i = vector of attributes of choice i;

β = parameters for X_i;

n = number of choices.

There are two types of methods to estimate the parameters ß. When individual choice data are used as a sample, the sample value P_i (dependent variable) takes a discrete value of either 0 or 1; that is, if the choice i is selected, the value of P_i is equal to 1, and otherwise 0. In this case, maximum likelihood estimation is used to obtain the estimates for ß. When individual data are aggregated by choice and used as a sample, the sample value of P_i takes any continuous value from 0 to 1. In this case, the standard regression analysis is usually employed to estimate the parameters ß.

The discrete choice model in the locational choice analysis is mainly applied to interregional choices. One typical example of these studies was done by Bartik (1985). Using individual locational data for new manufacturing plants within the United States between 1972 and 1978, he estimated a conditional logit model to explain their location choices on the state level. In other words, he focused on how the decision to locate a new plant was influenced by a state's characteristics, or attributes.

In the literature, there are a number of location models that explain location choices of office industries. In this section, I review some of the previous models, and summarize their findings about the attributes.

Erickson and Wasylenko (1980) developed a model of the site choice

decision of relocating firms which moved from the City of Milwaukee to suburban municipalities between 1964 and 1974. They obtained firm relocation data and aggregated them into the number of firms that moved to each municipality as a proportion of the total number of relocating firm by seven single-digit industries including FIRE. Therefore, their model is classified as an intrametropolitan location model based on aggregated data.

In their paper, firms are assumed to follow one of two criteria in their location decisions: cost minimization and profit maximization. Twelve explanatory variables were chosen to explain these criteria and tested using a logistic specification for the equations. The main results for the FIRE industry are as follows.

- Agglomeration effect measured as the ratio of employees in FIRE in each municipality to all non-central city employees in FIRE is one of the two most significant determinants of site selection.
- The other very significant determinant is proximity to an available work force measured by the number of residential employees in FIRE within a seven-mile radius of the municipality.
- Fiscal variables such as safety and service expenditures per capita, net effective property tax rate, and demand variables measured by population density and per capita income of each municipality are not statistically significant.

Wheaton (1986) examined population and office employment decentralization in America's 30 major metropolitan areas, using the discrete choice methodology. He tested this methodology by using aggregated data on the growth of office employment in 104 counties between 1967 and 1983. By the standard regression analysis, he estimated time-series equations for each

metropolitan area (intrametropolitan model), cross-section equations (intermetropolitan model), and annually pooled (cross-section and time-series) equations. His main findings are summarized as follows.

- With the exception of central counties, each county's population share in the metropolitan area, representing the potential work force in the county, is a strong determinant of office employment growth. This reveals that suburban office jobs follow suburban people.
- Office employment is attracted to counties with higher per-capita income (representing a greater concentration of white collar workers), and greater transportation infrastructures measured by highway miles within the county.
- County share of office employment in the metropolitan area is generally significant with an expected positive sign. This shows agglomeration merits that counties with larger shares have a stronger attraction for office firms.

Ihlanfeldt and Raper (1990) focused on new office firms and tested a model to explain their intrametropolitan location. According to them, new office firms are the best ones to analyze because they are consistent with the assumption of profit maximization, which underlies this kind of empirical modeling. They obtained data on 1,440 new office locations in the Atlanta Region from 1981 to 1983, calculated the density of new offices by census tracts, and used this aggregated data as a dependent variable. In order to avoid biased and inconsistent results from the ordinary least square (OLS) estimator due to the censored dependent variable, they employed the Tobit model to estimate parameters in the model.

They tested fifteen explanatory variables to explain density of two

types of offices, namely independent offices and branch offices. Their main results are as follows.

- Seven of the fifteen variables are significant at the 5% level with expected signs in both equations for independent and branch offices: proximity to total employment (proxy for land price), proximity to eating and drinking establishments (representing amenity), proximity to employment change in the last five years (representing proximity to demand of business establishment customers), dummy variable for regional shopping center in tract (representing amenity), dummy variable for the rail station of the rapid transit system (MARTA) in tract, proximity to managerial and professional workers (proxy for wage rates), and number of households in tract below the poverty level (also proxy for wage rates).
- Proximity to employment in business support services is significant in independent office equation, but not significant in branch office equation.
- Proximity to population change in the last five years weighted by per capita income (representing proximity to demand of residential customers) and property tax rate are not significant in either equation.
- Linear distance from CBD (proxy for land price) and dummy variable for selected freeways in tract are significant with positive signs in only the equation for branch offices. The positive signs suggest that new firms prefer locations with cheaper land costs and better transportation accessibility.

Shukla and Waddell (1991), based on the discrete choice analysis, developed a logit model to examine intrametropolitan location decisions of establishments in six single-digit SIC categories. They tabulated data on

numbers of establishments for 141 zip code zones by six industries in the Dallas-Fort Worth area. The dependent variable employed is each zip's share of establishments in the whole area in a single year. By using data in one year rather than data for changes between two or more different years, they focused on explaining the static locational pattern of each industry, rather than explaining the change in locational patterns. They tested twelve explanatory variables. The principal results from the analysis for the FIRE sector are as follows.

- Distance from CBD strongly affects locational decisions of FIRE firms. The coefficient is negative, which means that this industry is very centralized around the CBD.
- The FIRE industry also tends to locate in proximity to high income zones with low percent black resident populations. This may show the importance of both customer access and labor-market access.
- Proximity to employment in retail and services has a positive effect on the FIRE location. On the other hand, proximity to own-industry grouping--mining, transport/communication/utilities, and FIRE--has a negative effect, which is somewhat puzzling in terms of agglomeration merits.

Clapp, Pollakowski, and Lynford (1992) developed a multiple regression model to explain office space demand in eight submarkets in the Boston Area between 1980 and 1988. Because they used absorption data for office spaces, their model was different from ones based on the discrete choice analysis. Their main findings are as follows.

- Lagged employment growth in FIRE (representing expected demand for office space) was a strong determinant.

- Growth quotient that was designed to capture spatial concentrations by industry, or agglomerations, as a single variable is also strongly positive and significant in the demand equation, suggesting that agglomeration merits also affect office location choices.
- Lagged vacancy rate (proxy for rent) was not significant, contrary to the neoclassical theories.
- Distance to CBD and office worker density were also not significant.

Lastly, Xu (1996) used data of 429 office firms that moved into office buildings in ten submarkets in the Atlanta area between 1989 and 1993, and developed a conditional logit model to estimate each firm's individual choice within the metropolitan area by the maximum log-likelihood method. The main findings are as follows.

- Total net rentable area is significant with an expected positive sign, suggesting that economies of scale is a positive factor for attracting office firms.
- Vacancy rate (proxy for rental cost) is also significant with an expected positive sign, suggesting that lower rental cost attracts office firms.
- Better accessibility to its own industry labor is a positive factor.
- When the subcenter size is small, a higher concentration of its own industry is a positive factor. On the other hand, when the subcenter size is large, such concentration turns to a negative factor, suggesting that the economies of scale may stem from intra-industry activities when a subcenter is in the initial stage, and from inter-industry linkages as the subcenter becomes bigger.
- Distance from CBD has negative effect on the location choice. This may be attributed to the cost effect of the face-to-face contacts taking

place downtown.

- Average rent and mean travel time to work (proxy for wage cost) have positive effect on the location choice, which is contrary to the theory.

As previously stated, there are a number of location models employing various dependent and explanatory variables. The explanatory variables appeared in these six studies, in other words, spatial attributes which affect firms' locational choices, are classified into six categories: agglomeration, labor accessibility, demand (customer accessibility), land or floor cost, transportation, and others (Table 4.1).

Agglomeration is mainly measured by the office employment share of each zone (geographical unit for analysis) in the whole area, and most of the studies show that this has a significant effect on locational choices. Labor accessibility is mainly measured by the proximity to office workers, but sometimes data on income are used as its proxy. This attribute is also significant in most of the studies.

Demand, or customer accessibility, is not incorporated in many models, and even if incorporated, it is generally insignificant. Except in one study, land or floor cost, measured by the vacancy rate, distance from CBD, etc., is also insignificant. One possible explanation for this is that some uncontrolled factors that attract office firms may be capitalized in higher land or floor cost.

Transportation, mostly measured by highway accessibility, displays somewhat ambiguous results. Three studies out of five show its significance, while two show the opposite. Because the highway accessibility measures the degree of convenience in terms of freight transportation better than in terms of person transportation, one study adds the accessibility to subway.

Table 4.1 Summary of the Attributes in Existing Locational Models

	Agglomeration	Labor Accessibility	Demand
Erickson and Wasylenko	*: Share of FIRE employment	*: # of FIRE employment within 7 miles	-: Population density -: Per capita income
Wheaton	*: Share of office employment	*: Share of population *: Per capita income	
Ihlanfeldt and Raper		*: Proximity to managerial and professional workers	*: Proximity to employment change -: Proximity to population change
Shukla and Waddell	-: Proximity to industry group [1]	*: Proximity to high income population	
Clapp, Pollakowski, and Lynford	*: Growth quotient	-: Office worker density	
Xu	*: Total rentable area *: Self Industry share [2]	*: Proximiy to own industry worker -: Wage cost	

	Land/Floor cost	Transportation	Others
Erickson and Wasylenko	-: Ratio of vacant land -: CBD distance (positive)	-: Highway dummy	-: Fiscal expenditures -: Tax rate
Wheaton		*: Highway miles	
Ihlanfeldt and Raper	*: Proximity to total employment *: CBD distance [3]	*: MARTA dummy *: Highway dummy [4]	*: Amenity *: Proximity to support services [4] -: Tax rate
Shukla and Waddell		*: Highway dummy	*: CBD distance (negative) *: Proximity to retail/services
Clapp, Pollakowski, and Lynford	-: Vacancy rate		*: Lagged employment growth -: CBD distance
Xu	-: Vacancy rate	-: # of highways	*: CBD distance (negative)

*: Statistically significant
-: Statistically insignificant
1: Mining, transportation, comunications, and utilities, and FIRE
2: Significant only when submarket size is small
3: Significant only in branch office equation
4: Significant only in independent office equation

One interesting comparison is made from results on distance from CBD. Two studies show its insignificance, and three show its significance. Interestingly enough, one of these three has a positive sign suggesting that firms prefer cheaper land or floor, whereas the remaining two studies have a negative sign suggesting a strongly centralized location pattern.

In summary, according to the studies discussed, agglomeration and labor accessibility are two major attributes for firms' location decisions, while demand and land or floor cost are, although they are theoretically recognized as determinants of location choices, mostly found to be insignificant. Transportation falls into a gray zone.

4.2 Regional Growth Models with the Notion of Convergence

For many years, numerous researchers in economics have studied regional growth models. Regional growth is measured by a number of indicators: population, income, sales of product, value-added, etc. Employment is, of course, one of the important measures and has been analyzed as an object of empirical studies. Among the studies, those focusing on the notion of convergence, or mean reversion, are worth reviewing here because the convergence is closely related to the dispersion of the office location.

The notion of convergence emerged from theories of international and interregional trade (Rees and Stafford, 1986) and has long been known as a stylized fact. This notion can be summarized this way: under the assumption of free mobility of capital and labor, differences in regional economy (income inequality for instance) eventually disappears and an equilibrium is reached where per capita income is equalized. In other words, poor regions grow faster than rich ones. This is also recognized as another expression of the diminishing returns to scale.

Barro and Sala-i-Martin (1991) used per capita personal income data for U.S. states from 1880 to 1988 and presented the empirical evidence on the convergence of income across the country. According to their analysis, the gap between the typical poor and rich state diminishes at roughly 2% a year.

One can apply the convergence notion to employment growth models in the following manner; regions that have larger amount of employment grow slower than regions with smaller amount of employment. Practically, this hypothesis is tested by including past (base year's) employment level in explanatory variables of the model that explains the growth of employment from the base year to a current year.

Glaeser, Kallal, Scheinkman, and Shleifer (1992) analyzed data on the employment growth of large industries in 170 U.S. cities between 1956 and 1987. In a multiple regression model to explain the logarithm of employment growth rate between 1956 and 1987, they included the logarithm of the industry's employment in 1956 as one of the explanatory variables.

They obtained a negative estimate of the coefficient on the past employment level, and consequently concluded that high initial employment in an industry in a city leaded to slower growth of employment in that industry.

After controlling for this convergence effect, they also tested some of the externality theories. First, they tested the theory that the concentration of an industry in a city helps knowledge spillovers between firms, and therefore, the growth of that industry in the city. They included a specialization index in the model and showed that, contrary to the theory, industries that were more heavily concentrated in the city grew slower. Second, they tested the theory that local competition fosters the pursuit and

rapid adoption of innovation. The result of the analysis reveals that industries grow faster in cities in which firms in those industries are smaller than the national average. This is consistent with the theory. Lastly, they examined the theory that variety and diversity of industries promote innovation and growth because of the knowledge spillovers from outside the industry. The results show that an industry in a city grows faster when the rest of the city is less specialized. This is also favorable to the theory.

Henderson, Kuncoro, and Turner (1995) applied this convergence notion to employment data for eight manufacturing industries in 224 metropolitan areas. Five of them are classified as traditional industries, and three as high-tech industries. They explained the logarithm of each industry's employment in 1987 (EMP87) with a multiple regression model including the logarithm of the industry's employment in 1970 (EMP70), that is:

$$Ln(EMP87) = a + b*Ln(EMP70) + ...$$

Note that this equation can be transformed into one with an employment growth rate as a dependent variable, that is:

$$Ln(EMP87/EMP70) = a - (1-b)*Ln(EMP70) + ...$$

If the value of (1-b) is positive, it shows that the convergence takes place. Using the estimate value of the coefficient b, the annual rate of convergence, r, is obtained as a solution to

$$1 - b = 1 - \exp(-rT), \quad \text{which is solved as}$$

$$r = -(1/T) * Ln(b), \quad \text{where } T = \text{number of years.}$$

They analyze the annual rates of convergence for their traditional industries to be around 4% when other conditions are controlled, and around 1% otherwise.

They incorporated other explanatory variables that represented specialization and diversity to test the intra-industry externality associated with the industry's concentration, and the inter-industry externality associated with diversity of local total employment. They concluded that for the traditional industries, there was evidence of the former externality but none for the latter. On the other hand, for the high-tech industries, there was evidence of both externalities. These findings are consistent with notions of urban specialization and product cycles: new industries prosper in large and diverse cities, but with maturity, production decentralizes to smaller and more specialized cities. However, their results differ from those in Glaeser et al. (1992), and they attributed it to the difference in samples; their samples were eight manufacturing industries, while Glaeser et al. used a variety of industries that were ranked as the six largest industries in a city. This comparison suggests that these externalities affect different industries in different directions and extents.

These studies with the notion of convergence and the following analysis about externalities are mainly applied to interregional comparisons. This notion has been applied to neither the office employment growth nor the intraregional comparisons, but it can obviously be applied to it. This kind of analysis is useful especially when one analyzes the historical change in the office locational pattern focusing on the trend of concentration versus dispersion.

4.3 Relationship between the Existing Literature and This Thesis

As previous discussion has revealed, a number of locational models have dealt

with office employment, and some of them intend to explain intrametropolitan locational choices, but the factors that influence choices have not been fully clarified. Also, their analyses stay at the aggregated (single-digit SIC) industry level. There are some studies that compare a locational model for aggregated office industry with models for other industries, but few studies focus on the difference between disaggregated office industries. This thesis explores these points, and intends to develop intrametropolitan growth model by industry.

Moreover, this thesis tries to build another model that incorporates the notion of convergence, which has seldom been applied to intrametropolitan office employment growth. The application of the notion of convergence to the disaggregated office industries in order to measure their decentralization within the region is expected to reveal additional characteristics for each industry.

The comparison between these two types of models is another interesting issue. When the location model and the regional growth model are applied to the office employment growth, a fundamental difference lies in how these two models interpret the source of the growth. The location model based on the discrete choice model intends to measure the possibility that a firm selects one particular location among a certain number of locations (a mutually exclusive choice). Therefore, in the locational model, the growth is considered as a consequence of firms' movements. A relocation is a typical example of the location choices that are dealt with in the location model. A birth of a new firm is also regarded as a movement from no place. Even a firm's expansion within the same site is interpreted that the firm has made the decision that they select the current site as the best location to accommodate a new demand for its office space among all the possible

locations.

On the other hand, the regional growth model does not have an explicit recognition of firms' movements. According to the regional growth model with the notion of convergence, the growth from a base year to a current year is proportional to the employment level in the base year, because the employment in the base year is included as a explanatory variable in the log-linear model specification. This implies that the regional growth model regards the growth as a consequence of an internal growth. This is a very different view of the growth from the location model. This thesis also examines how these two different underlying theories work in explaining the office employment growth.

Chapter 5 Intrametropolitan Office Employment Growth Models

Following the review of the existing studies, this chapter discusses the specification and the test of the models that explain office employment growth between 1980 and 1990 in each municipality in the study area. First, two kinds of models, the logit model and the convergence model, are introduced. Then, explanatory variables are given in detail. Finally, the results of the estimation, first by the logit model, then by the convergence model, are discussed. Different results for different industries are interpreted as the locational characteristics for each industry, and they are related to the results in the earlier chapters.

5.1 Model Framework

The first model is the logit framework based on the discrete choice analysis. As mentioned in Chapter 4, the application of this framework to a location model is expressed as follows:

$$P_i = \exp(\beta X_i) \,/\, \sum_j \exp(\beta X_j) \qquad i,j = 1, \ldots, n$$

where P_i = probability of locating in region i;

X_i = vector of attributes of region i;

β = parameters for X_i;

n = number of regions.

The denominator of the right-hand side takes the same value across all the regions, therefore it can be regarded as a constant. Then, if we take the natural log (Ln) of both sides, it is converted into the linear equation as follows:

$$\mathrm{Ln}(P_i) = a + \beta X_i \qquad i = 1, \ldots, n$$

where a = constant.

In this thesis, for P_i, aggregated data by municipality is used rather than individual data. Thus, P_i, the probability of a firm in each industry k (subscript omitted) locating in municipality i, is approximated by the municipality's share of the employment change in industry k between 1980 and 1990 in the sample, that is:

$$P_i = (EMP90_i - EMP80_i) \;/\; \sum_j (EMP90_j - EMP80_j) \qquad i,j = 1, \ldots, n$$

where $EMP90_i$ = employment in 1990 in municipality i

$EMP80_i$ = employment in 1980 in municipality i.

Note that this employment change is the net result of births, growth and decline in existing establishments, deaths, and relocations (Wheat, 1986).

Thus, the final form of the equation is

$$Ln[(EMP90_i - EMP80_i) \;/\; \sum_j (EMP90_j - EMP80_j)] = a + \beta X_i \qquad i = 1, \ldots, n$$

and the parameters a and ß will be estimated by the ordinary least square (OLS) method. Throughout the rest of the thesis, this model is mentioned as the logit model.

One problem associated with this model is the incapability of dealing with a zero or negative growth, because the logarithm of zero and negative values are not defined. Therefore, we are going to lose the cases with the zero or negative growth, in addition to the ones with confidential data.

The other model follows the regional growth model with the convergence term. As shown in the previous chapter, this model is expressed as:

$$Ln(EMP90_i) = a + c*Ln(EMP80_i) + \beta X_i \qquad i = 1, \ldots, n$$

or

$$Ln(EMP90_i/EMP80_i) = a + b*Ln(EMP80_i) + \beta X_i \qquad i = 1, \ldots, n$$

where $b = c-1$.

Because this thesis focuses on the growth, the latter expression is selected

as the second model. While the logit model deals with the employment growth in absolute number, this model deals with the growth rate. The parameters a, b, and ß will be estimated by the OLS method. Throughout the rest of the thesis, this model is referred to as the convergence model.

Unlike the logit model, the convergence model can handle the zero or negative growth in number, because the zero growth in number means that the growth rate (EMP90/EMP80) is equal to 1, and the negative growth, between 0 and 1. However, this model can't be applied to the cases whose EMP90 and/or EMP80 are equal to zero. Therefore, this model also loses some cases which are different from the logit model.

5.2 Explanatory Variables

Following the literature, explanatory variables to be incorporated in each of the two models are selected so that they cover the five main categories that are assumed to affect the growth of employment on the office industry: agglomeration, labor accessibility, customer accessibility, land or floor cost, and transportation. Nine explanatory variables are prepared and tested. A list of the variables including names, definitions, and data sources is provided in Table 5.1. Below is the detailed information for each of the explanatory variables.

Specialization Index (SPEC)

This is the one of the measures used to test the influence of agglomeration, or more precisely, industrial composition in the municipality. The value of this variable in municipality i for industry k is defined as the ratio of the industry's employment in the municipality to the total employment in the municipality, and it is expressed as follows:

$$SPEC_{ik} = EMP80_{ik} / TEMP80_i \qquad i = 1, \ldots, n$$

where $EMP80_{ik}$ = industry k's employment in 1980 in municipality i;

$TEMP80_i$ = total employment in 1980 in municipality i

(excluding government employment).

If the firms in an industry tend to benefit from the concentration of the industry, this variable has a positive effect on the growth of the industry. On the other hand, if the firms tend to benefit from inter-industry linkages, this variable has a negative effect, because a smaller value of this index means less concentration in all the other industries. Thus, no sign for the coefficient on this variable is hypothesized.

Localization Index (LOCAL)

This is the other measure used to test the influence of agglomeration. The value of this variable in municipality i for industry k is defined as the ratio of the industry's employment in the municipality to the industry's total employment in all the municipalities, and it is expressed as follows:

$$LOCAL_{ik} = EMP80_{ik} / \sum_j (EMP80_{jk}) \qquad i, j = 1, \ldots, n.$$

Because the denominator of the right-hand side is constant across municipalities, this variable is essentially the same as the level of the industry's employment in 1980, and also the same as the convergence term in the convergence model. Therefore, this variable is incorporated in only the logit model.

The inclusion of SPEC with this variable means that the industrial composition is already controlled. Under the control, a smaller value of this variable means less concentration of both the industry and other industries. Therefore, this variable measures the degree of overall industrial concentration, and a positive sign is expected for this variable.

Highway Accessibility (HIGHWAY)

This variable is adopted in order to represent each municipality's degree of transportation convenience. Many past studies incorporate this attribute in the model as a dummy variable. However, taking account of the observation in Chapter 3 that major office employment centers in the study area tend to develop near the intersection of circumferential and radial highways, the number of highways crossing the municipality's boundary is counted and used as an explanatory variable. Here, highways mean controlled access highways, namely, I-90, I-93, I-95, I-195, I-290, I-495, US-1, US-3, ST-2, ST-3, ST-24, ST-128, and ST-140. The expected sign for this variable is positive.

Proximity to Office Workers (EPTA)

This is one of the two variables that is intended to represent labor accessibility. The data of the office workers living in each municipality, i.e., residence location basis, are approximated by the sum of workers in four occupational categories in the 1980 Population and Housing Census: 1) executive, administrative and managerial occupations, 2) professional specialty occupations, 3) technicians and related support occupations, and 4) administrative support occupations, including clerical.

Obviously, firms draw their workers not only from the municipality where they are located but also from further away municipalities, so this variable must be a summation of the municipality itself and some other municipalities around it. However, the answer to "from how far away should municipalities be included?" is unknown and probably different among industries, or even among firms. Therefore I have prepared summations under

two different kinds of methods and tested them to see which one yields the best result.

The first method is the simple summation of the municipalities within a certain mile radius from each municipality. The radii are set at 1, 3, 5, 7, 10, and 13 miles. Each variable will be referred to as EPTA(r=1), EPTA(r=3), and so on. The case of r=1 is equivalent to using only a municipality's data (no summation). The second method sums up all the municipalities in the study area taking the distance into account. More specifically, it is expressed as:

$$EPTA(a=A)_i = \sum_j [\ (EPTA_j) \ / \ (d_{ij})^A\ ] \qquad i, j = 1, \ldots, n$$

where $EPTA_j$ = sum of the four occupations in municipality j;

d_{ij} = distance between municipality i and j.

In the equation, "A" is a constant what is called the "distance exponent," and in this analysis, it is set at 0.5, 1, 2, and 3. Each variable will be referred to as EPTA(a=0.5). Also, the summations in the first method will be referred to as the radius type summations, and those in the second, as the gravity type summations. Therefore, six radius type and four gravity type summations are prepared and tested to identify which one performs the best in the models. The expected sign for this variable is positive.

In order to calculate these summations, we have to know the distance matrix between any two of the municipalities. The coordinates of the geometric centroid for each municipality are obtained from the Geographic Information System (GIS). These data yield the straight line distance matrix used in these summations (see Appendix B for detailed calculation). In the gravity type summations, the distance from a municipality to itself, i.e., d_{ii}, is defined as two thirds of the radius of a circle with the same area as the municipality.

Proximity to College Graduates (COL)

This is the other variable that represents the degree of labor accessibility. The data of college graduates for each municipality (residence location basis) are taken from the 1980 Population and Housing Census. The same summations as EPTA are done with this variable. A positive sign is expected.

Proximity to Population (POP)

This variable is used to measure the degree of accessibility to household customers. The data are also taken from the 1980 Population and Housing Census, and the same summation process is made. A positive sign is expected.

Proximity to Total Employment (EMPW)

This variable is used to measure the degree of accessibility to firm (business entity) customers. The total employment data for each municipality (workplace basis), in other words, the data of the number of workers working in the municipality, are taken from the Employment and Wages in Massachusetts Cities and Towns in 1980. The same summations are done with this variable. The expected sign is positive.

Distance from the CBD (BOSDIST)

Two different hypotheses are possible for this variable. The first one is that this variable represents the level of land/floor cost, because generally speaking the land/floor cost decreases as the distance from the CBD increases. Firms are assumed to prefer cheaper land/floor, therefore the

expected sign is positive.

The alternative hypothesis is that this variable represents the monocentric structure of the whole area. Under this hypothesis, a firm's utility decreases as the distance from the CBD increases. This utility is illustrated by the travel cost to the CBD where many business meetings take place. In this case, the expected sign is negative.

This variable is defined as the distance between each municipality's geometric centroid and the City Hall of Boston. The actual calculation is done by the GIS.

Property Tax Rate (TAX)

In addition to the variables that represent the five main attribute categories, the tax rate for commercial property in each municipality in the fiscal year 1981 is also tested as one of the explanatory variables. Firms are assumed to prefer a lower tax rate, therefore the expected sign is negative. The data source is the Massachusetts Department of Revenue.

Table 5.1 Explanatory Variables

Name	Definition	Expected Sign	Data Source
SPEC	Ratio of self industry's employment in the municipality to the total employment in the municipality	+/-	1980 Employment and Wages in Massachusetts Cities and Towns
LOCAL	Ratio of self industry's employment in the municipality to the industry's total employment in all the municipalities	+	1980 Employment and Wages in Massachusetts Cities and Towns
HIGHWAY	Number of limited access highways that cross the municipality's boundary	+	Gousha Massachusetts Roadmap
EPTA	Summation of the number of workers in executive, administrative, and managerial occupations, professional specialty occupations, technicians and related support occupations, and administrative support occupations including clerical	+	1980 Population and Housing Census
COL	Summation of the number of college graduates	+	1980 Population and Housing Census
POP	Summation of the population	+	1980 Population and Housing Census
EMPW	Summation of the number of workers working in the municipality	+	1980 Population and Housing Census
BOSDIST	Distance from the City Hall of Boston to the municipality's geometric centroid	+/-	Geographic Information System
TAX	Tax rate for commercial property in the fiscal year 1981	-	Massachusetts Department of Revenue

5.3 Logit Model Specification

5.3.1 Estimation for the FIRE and Service Sectors

Before applying the model to the disaggregated industries, the data of total employment for the FIRE sector (single-digit SIC) are used as a dependent variable to identify the best set of explanatory variables and obtain "benchmark" results. The reason the sum of the employment data for each office industry defined in Chapter 2 is not used is that the summation yields much loss in cases due to the existence of confidential data in each industry. If the summation is done, the numbers of applicable cases are reduced to 33 in the logit model and 36 in the convergence model. The data of total employment for the service sector (also single-digit SIC) are used as another dependent variable. Although the whole service sector includes industries other than the office industries, such as personal, health, and educational services, the results of the estimation can be used for a rough comparison with the results in the FIRE sector before proceeding to the estimation for more disaggregated industries.

Results for the FIRE Sector

First, seven explanatory variables out of the nine were incorporated into the model, that is, one from EPTA and COL (the two "labor accessibility" variables) and one from POP and EMPW (the two "customer accessibility" variables) were omitted. However, a very high correlation between these four variables caused a multicollinearity problem. With these four, the labor accessibility and the customer accessibility are not well distinguished. Therefore, only one variable among these four is used in the equation. The variable can be interpreted as the measure of both labor and customer accessibility.

Throughout many trials of regression, the coefficients on TAX are always positive, which is the unexpected sign, and not statistically significant. Thus, TAX is omitted. For firms in the FIRE sector, the rate of property tax has little effect on their location decision. These results reduce the total number of explanatory variables in the model from nine to five.

For "accessibility" variables (EPTA, COL, POP, and EMPW), 40 choices are possible, that is, 6 radius type (r=1, 3, 5, 7, 10, and 13) and 4 gravity type (a=0.5, 1, 2, and 3) summations for each of 4 variables. The comparisons of the estimation results among these 40 cases are summarized as follows.

- In general, in terms of the value of R-square, the radius type summations yield better results than the gravity type ones.
- Among the four variables (EPTA, COL, POP, and EMPW), POP yields the best result, but the differences between the four are small.
- Among the six radius type summations for POP, POP(r=1) yields the largest R-square and POP(r=5) yields the second largest R-square. However, these two cases have opposite signs for the coefficients on LOCAL: negative in the case of POP(r=1) and positive in the case of POP(r=5).

The main results of the estimation including the exploration about the "accessibility" variables are presented in Table 5.2. First of all, the comparison between POP(r=1) and POP(r=5) draws an interesting finding. POP (r=1) is equivalent to a municipality's population. Therefore, to include POP(r=1) in a model means to control for the size of municipalities. On the other hand, LOCAL is equivalent to the level of the FIRE employment in each municipality in 1980. Therefore, the negative sign on LOCAL indicates that if we control for the municipality size, higher level of the FIRE employment

Table 5.2 Estimation of FIRE Employment Growth by LOGIT Model

Explanatory Variables	Model 1 POP(r=1)	Model 2 POP(r=3)	Model 3 POP(r=5)	Model 4 POP(r=7)	Model 5 POP(r=10)	Model 6 POP(r=13)	Model 7 EPTA(r=5)	Model 8 COL(r=5)	Model 9 EMPW(r=5)
HIGHWAY	0.366	0.481	0.495	0.495	0.469	0.478	0.489	0.484	0.490
	(4.27)**	(5.50)**	(5.69)**	(5.49)**	(5.21)**	(5.19)**	(5.57)**	(5.43)**	(5.62)**
BOSDIST	-0.045	-0.047	-0.038	-0.055	-0.034	-0.049	-0.040	-0.049	-0.046
	(-3.54)**	(-3.16)**	(-2.33)**	(-2.91)**	(-1.55)	(-1.82)*	(-2.40)**	(-2.92)**	(-3.10)**
SPEC	1.991	3.067	1.697	2.501	2.197	2.174	1.709	1.577	1.068
	(0.52)	(0.74)	(0.41)	(0.59)	(0.52)	(0.50)	(0.410)	(0.37)	(0.26)
LOCAL	-29.710	-1.713	1.729	3.999	3.937	4.528	2.028	2.703	0.582
	(-4.17)**	(-0.54)	(0.68)	(1.59)	(1.60)	(1.83)*	(0.79)	(1.05)	(0.21)
POP(r=1)	3.71E-05								
	(5.07)**								
POP(r=3)		7.58E-06							
		(2.99)**							
POP(r=5)			3.19E-06						
			(3.16)**						
POP(r=7)				7.96E-07					
				(1.26)					
POP(r=10)					9.35E-07				
					(2.08)**				
POP(r=13)						4.12E-07			
						(1.00)			
EPTA(r=5)							1.09E-05		
							(2.84)**		
COL(r=5)								1.48E-05	
								(2.15)**	
EMPW(r=5)									5.48E-06
									(3.03)**
Intercept	-6.780	-6.566	-6.813	-6.302	-6.913	-6.498	-6.711	-6.435	-6.480
	(-17.5)**	(-14.8)**	(-14.1)**	(-11.2)**	(-10.5)**	(-7.9)**	(-13.8)**	(-13.5)**	(-15.3)**
Number of Cases	116	116	116	116	116	116	116	116	116
Adjusted R square	0.517	0.449	0.454	0.413	0.427	0.410	0.445	0.429	0.450

** Significant at the 5% level
* Significant at the 10% level
t-statistics are in parentheses

in 1980 results in smaller growth in number. This suggests decentralization of the FIRE employment, or convergence.

When we use POP(r=5), it no longer controls for the municipality size. It measures the level of population concentration around each municipality. In this case, LOCAL, instead of POP(r=1), accounts for the size of each municipality, and therefore, its coefficient becomes positive (although it is not significant).

Looking at other results in Model 3 in Table 5.2, the coefficients on HIGHWAY and POP(r=5) are statistically significant with the expected positive signs. These results suggest that better accessibility to highways, labor, and customers is an important determinant on location choices for the firms in the FIRE sector. The coefficient on BOSDIST is also significant with a negative sign, suggesting that the firms in the FIRE sector prefer to be close to the CBD in spite of higher land/floor cost. On the other hand, the coefficients on SPEC and LOCAL are not statistically significant. Therefore, the evidence for agglomeration merits is not found through this analysis.

Results for the Service Sector

The estimation results for the service sector using the same variables as in the case of FIRE are presented in Table 5.3. In this case, again, the coefficient on LOCAL is negative when POP(r=1) is included (Model 1), indicating the decentralization of the service employment. Looking at Model 2-Model 9, major differences from the FIRE case are that 1) the coefficients on LOCAL turn significant with the expected positive signs, and 2) the coefficients on SPEC turn negative although they are insignificant. These results suggest that, for the firms in the service sector, the agglomeration merits come not from the service industries themselves but from the

Table 5.3 Estimation of Service Employment Growth by LOGIT Model

Explanatory Variables	Model 1 POP(r=1)	Model 2 POP(r=3)	Model 3 POP(r=5)	Model 4 POP(r=7)	Model 5 POP(r=10)	Model 6 POP(r=13)	Model 7 EPTA(r=5)	Model 8 COL(r=5)	Model 9 EMPW(r=5)
HIGHWAY	0.302	0.363	0.374	0.370	0.357	0.369	0.370	0.366	0.368
	(4.16)**	(5.01)**	(5.26)**	(5.12)**	(4.92)**	(5.00)**	(5.20)**	(5.14)**	(5.18)**
BOSDIST	-0.047	-0.052	-0.040	-0.048	-0.038	-0.057	-0.039	-0.041	-0.044
	(-4.62)**	(-4.40)**	(-3.08)**	(-3.32)**	(-2.18)**	(-2.73)**	(-3.00)**	(-3.26)**	(-3.78)**
SPEC	-0.067	-0.359	-0.612	-0.417	-0.519	-0.282	-0.704	-0.802	-0.665
	(-0.09)	(-0.45)	(-0.77)	(-0.52)	(-0.64)	(-0.34)	(-0.88)	(-0.99)	(-0.84)
LOCAL	-18.540	6.937	7.224	9.660	9.671	10.375	7.258	7.457	5.996
	(-2.04)**	(1.74)*	(2.32)**	(3.29)**	(3.37)**	(3.62)**	(2.33)**	(2.42)**	(1.81)*
POP(r=1)	2.11E-05								
	(3.34)**								
POP(r=3)		2.84E-06							
		(1.24)							
POP(r=5)			1.90E-06						
			(2.32)**						
POP(r=7)				5.35E-07					
				(1.03)					
POP(r=10)					5.56E-07				
					(1.53)				
POP(r=13)						4.56E-08			
						(0.14)			
EPTA(r=5)							7.20E-06		
							(2.33)**		
COL(r=5)								1.21E-05	
								(2.31)**	
EMPW(r=5)									3.40E-06
									(2.45)**
Intercept	-5.899	-5.617	-5.954	-5.710	-6.019	-5.473	-5.931	-5.847	-5.772
	(-16.7)**	(-14.9)**	(-14.7)**	(-12.7)**	(-11.5)**	(-8.47)**	(-14.8)**	(-15.3)**	(-16.0)**
Number of Cases	135	135	135	135	135	135	135	135	135
Adjusted R square	0.454	0.414	0.431	0.412	0.418	0.407	0.431	0.431	0.433

** Significant at the 5% level
* Significant at the 10% level
t-statistics are in parentheses

concentration of overall industries, or the size of the municipality where they locate. This result seems consistent with the industrial composition of the service sector which has a stronger linkage with local customers than that of the FIRE sector. Other results are almost the same as the FIRE case.

Results When Boston is Excluded

In the study area, Boston has such a large concentration in office employment that it might be appropriate to interpret the whole urban structure as "Boston versus other (suburban) municipalities." Therefore, it is interesting to see how the results will change if the Boston data are excluded from the sample. The results for the FIRE sector are presented in Table 5.4.

The major differences in the results from ones when Boston is included are that 1) the coefficient on LOCAL turns positive in Model 1, 2) the coefficients on LOCAL turn strongly significant with the expected positive signs in Model 2-Model 9, and 3) the coefficients on SPEC turn negative although they are insignificant. The first difference shows that there is no evidence of the decentralization of the FIRE employment when Boston is excluded from the sample. The other two differences are the same as in the case of the service sector. For the firms in the municipalities other than Boston, there exist the agglomeration merits which come mainly from the concentration of other industries. One possible explanation for this is that the industrial composition within the FIRE sector is different between Boston and the other municipalities. If these municipalities are more specialized in the industries that have relatively strong relationships with other industries as their customer, these results will be the case.

Table 5.4 Estimation of FIRE Employment Growth by LOGIT Model Excluding Boston

Explanatory Variables	Model 1 POP(r=1)	Model 2 POP(r=3)	Model 3 POP(r=5)	Model 4 POP(r=7)	Model 5 POP(r=10)	Model 6 POP(r=13)	Model 7 EPTA(r=5)	Model 8 COL(r=5)	Model 9 EMPW(r=5)
HIGHWAY	0.346	0.386	0.399	0.391	0.382	0.386	0.387	0.389	0.383
	(4.16)**	(4.72)**	(4.69)**	(4.64)**	(4.55)**	(4.54)**	(4.69)**	(4.63)**	(4.60)**
BOSDIST	-0.042	-0.033	-0.046	-0.049	-0.034	-0.045	-0.036	-0.048	-0.039
	(-3.42)**	(-2.43)**	(-2.99)**	(-2.89)**	(-1.67)*	(-1.87)*	(-2.50)**	(-3.33)**	(-2.83)**
SPEC	-4.408	-6.502	-6.830	-7.346	-7.193	-7.489	-6.598	-7.246	-5.679
	(-1.02)	(-1.54)	(-1.55)	(-1.69)*	(-1.67)*	(-1.73)*	(-1.55)	(-1.67)*	(-1.30)
LOCAL	66.710	118.060	120.609	130.066	124.789	130.284	119.117	127.668	112.804
	(1.97)*	(4.84)**	(4.05)**	(5.14)**	(4.97)**	(5.24)**	(4.79)**	(4.99)**	(4.26)**
POP(r=1)	2.31E-05								
	(2.70)**								
POP(r=3)		6.02E-06							
		(2.59)**							
POP(r=5)			7.29E-07						
			(0.65)						
POP(r=7)				1.41E-07					
				(0.24)					
POP(r=10)					4.81E-07				
					(1.15)				
POP(r=13)						1.23E-07			
						(0.33)			
EPTA(r=5)							1.95E-05		
							(2.05)**		
COL(r=5)								9.96E-06	
								(0.53)	
EMPW(r=5)									1.18E-05
									(1.75)*
Intercept	-6.525	-6.582	-6.184	-6.053	-6.541	-6.177	-6.488	-6.093	-6.388
	(-17.0)**	(-16.3)**	(-12.9)**	(-11.9)**	(-10.8)**	(-8.30)**	(-15.6)**	(-14.6)**	(-15.6)**
Number of Cases	115	115	115	115	115	115	115	115	115
Adjusted R square	0.518	0.515	0.488	0.486	0.492	0.486	0.505	0.487	0.500

** Significant at the 5% level
* Significant at the 10% level
t-statistics are in parentheses

5.3.2 Estimation for the Disaggregated Office Industries

The next step is to apply the model to the disaggregated office industries. The employment data for the disaggregated industries contain more confidential data than the data for single-digit industries. The seven industries that hold more than 50 cases are selected as dependent variables. Banking, security brokers, insurance carriers, investment offices, and membership organizations are omitted from the estimation due to too much loss in their cases. For some of the seven industries, the employment growth in absolute number in Boston is negative. In such cases, Boston is omitted from the sample because the logarithm of negative values is not defined. To make a comparison across the seven industries, the Boston data are excluded from the sample in all the industries.

The structure of the explanatory variables is the same as in the case of FIRE. Using POP among four "accessibility variables," the best radius for each industry was searched for. The results are shown in Table 5.5.

For three industries, i.e., insurance agents, real estate, and business services, the best radius for POP is 1, and the coefficients on POP(r=1) is statistically significant. For these industries, the level of the population in the municipality is an important determinant in location decisions. Considering that the characteristics of these industries are that their business activities are relatively neighborhood customer-oriented, POP(r=1) is thought to represent the accessibility to their nearby customers. Two of these three, namely insurance agents and business services, and social service whose coefficient on POP is also significant, are the three industries that are classified into the "relatively dispersed in 1980 and more dispersed over the next decade" category in Chapter 3. The results of the model estimation suggest that their dispersions took place following the

Table 5.5 Estimation of Disaggregated Office Industry Employment Growth by LOGIT Model, Excluding Boston

Explanatory Variables	Insurance Agents	Real Estate	Business Services	Social Services	Legal Services	Engineering Services	Accounting
Best Radius for POP	1	1	1	10	13	13	13
HIGHWAY	0.260	0.360	0.320	0.191	0.164	0.434	0.213
	(2.50)**	(3.05)**	(3.09)**	(1.58)	(2.48)**	(3.03)**	(1.53)
BOSDIST	-0.058	-0.012	-0.042	0.045	-0.042	0.039	0.028
	(-3.41)**	(-0.53)	(-2.46)**	(1.30)	(-1.83)*	(0.89)	(0.77)
SPEC	8.680	-24.252	1.079	5.972	20.202	11.785	-146.044
	(0.28)	(-1.02)	(0.18)	(0.27)	(0.45)	(0.40)	(-1.97)**
LOCAL	8.598	41.843	18.261	61.853	171.697	21.960	128.087
	(0.29)	(1.72)*	(1.35)	(2.95)**	(6.89)**	(1.81)*	(3.12)**
POP(r=1)	2.11E-05	1.76E-05	2.21E-05				
	(2.48)**	(2.06)**	(2.90)**				
POP(r=10)				1.85E-06			
				(2.92)**			
POP(r=13)					-2.57E-07	1.08E-06	8.01E-07
					(-0.84)	(1.68)*	(1.53)
Intercept	-5.385	-6.710	-5.902	-8.195	-6.006	-7.625	-7.123
	(-11.8)**	(-12.6)**	(-11.5)**	(-8.24)**	(-8.93)**	(-5.61)**	(-6.32)**
Number of Cases	58	67	78	58	75	51	51
Adjusted R square	0.415	0.275	0.441	0.347	0.487	0.392	0.301

** Significant at the 5% level
* Significant at the 10% level
t-statistics are in parentheses

suburbanization of the population.

On the other hand, the best radius for legal services, engineering services, and accounting is 13, and the coefficients on POP(r=13) are not significant at the 5% level. Therefore, for these industries, the accessibility to customers and labor is not very important. In Chapter 3, these industries are classified into the "relatively concentrated in 1980" categories. They did not disperse because they did not need to chase the suburbanized customers and labor. If there is a possible interpretation of the POP(r=13) for these industries, it might represent the accessibility to labor rather than to customers, because these industries are relatively professional services and tend to hire workers from wider areas.

Effects by other attributes for each industry are summarized as follows. Insurance agents and business services tend to prefer better accessibility to highways and proximity to the CBD. The agglomeration merits are not important for them. Real estate and engineering services are attracted by better accessibility to highways, but not by the proximity to the CBD. The agglomeration merit from the concentration of overall industries is somewhat important for them. For social services, the agglomeration merit from the concentration of overall industries is of sole importance. For accounting, the agglomeration merit comes strongly from inter-industry linkage. Lastly, legal services are attracted by highway accessibility, and the proximity to the CBD to some extent. They are also benefited by the agglomeration merit from the concentration of overall industries.

5.4 Convergence Model Specification

5.4.1 Estimation for the FIRE and Service Sectors

Before applying the model to disaggregated industries, the data of total employment for the FIRE sector and the service sector (single-digit SIC) are used as dependent variables as in the logit model specification.

Results for the FIRE Sector

For the same reason as in the case of the logit model, only one variable among EPTA, COL, POP, and EMPW is used in the model. The variable can be interpreted as the measure of both labor and customer accessibility. Also, TAX is omitted because of an unexpected sign and insignificance. Thus, the explanatory variables in the equation are: 1) the natural logarithm of FIRE employment in 1980 (Ln(FIRE80)), 2) HIGHWAY, 3) BOSDIST, 4) SPEC, and 5) one of the "accessibility" variables (EPTA, COL, POP, or EMPW).

For "accessibility" variables, 40 choices are possible. The comparisons of the estimation results between these 40 cases are summarized as follows.

- In general, in terms of the value of R-square, the radius type summations yield better results than the gravity type ones.
- Among the radius type summations, r=3 is the best for all the four variables.
- Among the four variables with r=3, POP yields the best result, but the differences between the four are small.

As a result, explanatory variables of POP(r=3), HIGHWAY, BOSDIST, SPEC, and Ln(FIRE80) are determined to be the best set to explain the employment growth rate for the FIRE sector. The estimation results including exploration about the best "accessibility" variable are given in Table 5.6.

Table 5.6 Estimation of FIRE Employment Growth Rate by COVERGENCE Model

Explanatory Variables	Model 1 POP(r=1)	Model 2 POP(r=3) Best Set	Model 3 POP(r=5)	Model 4 POP(r=7)	Model 5 POP(r=10)	Model 6 POP(r=13)	Model 7 EPTA(r=3)	Model 8 COL(r=3)	Model 9 EMPW(r=3)
Ln(FIRE80)	-0.115	-0.123	-0.101	-0.088	-0.093	-0.089	-0.122	-0.110	-0.113
	(-2.69)**	(-2.88)**	(-2.37)**	(-2.19)**	(-2.29)**	(-2.28)**	(-2.87)**	(-2.59)**	(-2.70)**
HIGHWAY	0.111	0.116	0.114	0.109	0.111	0.114	0.115	0.113	0.112
	(3.08)**	(3.22)**	(3.10)**	(3.01)**	(3.07)**	(3.14)**	(3.20)**	(3.12)**	(3.10)**
BOSDIST	-0.006	-0.003	-0.005	-0.008	-0.006	-0.013	-0.003	-0.004	-0.005
	(-1.17)	(-0.63)	(-0.79)	(-1.23)	(-0.78)	(-1.30)	(-0.51)	(-0.73)	(-0.96)
SPEC	-6.167	-5.876	-5.987	-6.025	-6.007	-5.907	-5.924	-6.038	-6.057
	(-3.88)**	(-3.73)**	(-3.76)**	(-3.79)**	(-3.77)**	(-3.71)**	(-3.76)**	(-3.81)**	(-3.83)**
POP(r=1)	1.22E-06								
	(1.21)								
POP(r=3)		1.26E-06							
		(1.63)							
POP(r=5)			1.56E-07						
			(0.44)						
POP(r=7)				-1.09E-07					
				(-0.50)					
POP(r=10)					-2.57E-09				
					(-0.02)				
POP(r=13)						-1.18E-07			
						(-0.80)			
EPTA(r=3)							5.19E-06		
							(1.61)		
COL(r=3)								6.22E-06	
								(0.96)	
EMPW(r=3)									1.59E-06
									(1.25)
Intercept	1.302	1.242	1.205	1.274	1.226	1.420	1.228	1.224	1.272
	(5.74)**	(5.74)**	(5.42)**	(5.29)**	(4.62)**	(4.31)**	(5.67)**	(5.62)**	(5.76)**
Number of Cases	130	130	130	130	130	130	130	130	130
Adjusted R square	0.238	0.245	0.230	0.231	0.229	0.233	0.245	0.235	0.239

** Significant at the 5% level
* Significant at the 10% level
t-statistics are in parentheses

First we take notice of the coefficient of Ln(FIRE80), the convergence term. In any model, it is statistically significant with the expected negative sign. This result suggests that the convergence in the FIRE employment growth is certainly taking place. That is, the higher the level of concentration in the FIRE employment in 1980 is, the lower the growth rate of the FIRE employment between 1980 and 1990 is. Using the formula in Section 4.2 and the coefficient value in Model 2 (the best set), the annual rate of the convergence is calculated as about 1.3%.

The coefficient on SPEC is statistically significant with a negative sign. That is, the degree of specialization in FIRE in a municipality has a negative impact on the growth rate of the FIRE employment in the municipality. Under the control of the level of concentration in FIRE in 1980, the degree of specialization in FIRE means less concentration in other industries. From this result, it is also interpreted that the agglomeration merit for the firms in the FIRE sector comes from inter-industry linkage but not from intra-industry linkage.

Looking at the other results in Model 2 in Table 5.6, the coefficient on HIGHWAY is statistically significant with the expected positive sign. The accessibility to highways is an important determinant on the growth rate as well as on the growth in absolute number. On the other hand, the coefficient of BOSDIST is no longer statistically significant. The distance from the CBD has an explanatory power when it is applied to the growth in absolute number, but no power when applied to the growth rate. In the logit model, BOSDIST explains the centered distribution pattern of the growth in number, which is with the peak at the CBD and gradually decreasing outward. However, such centered pattern does not exist in the distribution pattern of the growth rate, and therefore, BOSDIST is not significant in the convergence model.

Similarly, POP(r=3) is not significant in the convergence model. This is because the scale factor incorporated in POP is not influential on the growth rate, although it is influential on the growth in number.

Results for the Service Sector

The estimation results for the service sector using the same variables as the case of FIRE are presented in Table 5.7. In this case, EMPW(r=5) gives the best result instead of POP(r=3). The coefficient on Ln(SERV80), the convergence term, is also negative and statistically significant. The annual rate of the convergence (in Model 9, the best set) is about 2.5%, which is greater than in the FIRE case. For the industries in the service sector, convergence is taking place more rapidly than in the FIRE. In other points, the results are almost the same as in the FIRE case. The coefficient on SPEC is negative and significant, suggesting the existence of the agglomeration merit from inter-industry concentration. The accessibility to highways is also an important determinant for the service firms, but the distance from the CBD is not. When using r=5, the coefficients of "accessibility" variables turns significant, which suggests that, for the service firms, the accessibility to customers and labor is more important than for the FIRE firms.

Results When Boston is Excluded

The estimation results for the FIRE sector when Boston is excluded are presented in Table 5.8. Unlike in the case of the Logit model specification, the results are almost the same as the results when Boston is included (Table 5.6). The reason for the same results is that the value of the dependent variable for Boston is not extreme in this specification, because it is the

Table 5.7 Estimation of Service Employment Growth Rate by CONVERGENCE Model

Explanatory Variables	Model 1 POP(r=1)	Model 2 POP(r=3)	Model 3 POP(r=5)	Model 4 POP(r=7)	Model 5 POP(r=10)	Model 6 POP(r=13)	Model 7 EPTA(r=5)	Model 8 COL(r=5)	Model 9 EMPW(r=5) Best Set
LN(SERV80)	-0.231	-0.220	-0.225	-0.205	-0.209	-0.201	-0.225	-0.223	-0.226
	(-6.56)**	(-6.39)**	(-6.73)**	(-6.25)**	(-6.39)**	(-6.15)**	(-6.78)**	(-6.76)**	(-6.84)**
HIGHWAY	0.064	0.068	0.075	0.069	0.064	0.063	0.073	0.070	0.071
	(2.04)**	(2.15)**	(2.37)**	(2.16)**	(2.01)**	(1.96)*	(2.31)**	(2.23)**	(2.26)**
BOSDIST	-0.006	-0.003	0.001	-0.001	0.004	0.001	0.002	0.001	-0.001
	(-1.18)	(-0.60)	(0.22)	(-0.10)	(0.59)	(0.14)	(0.34)	(0.23)	(-0.11)
SPEC	-0.934	-0.987	-1.062	-1.031	-1.064	-1.043	-1.113	-1.168	-1.100
	(-2.71)**	(-2.85)**	(-3.10)**	(-2.94)**	(-3.05)**	(-2.93)**	(-3.24)**	(-3.36)**	(-3.22)**
POP(r=1)	1.94E-06								
	(2.24)**								
POP(r=3)		1.23E-06							
		(1.80)*							
POP(r=5)			8.00E-07						
			(2.62)**						
POP(r=7)				2.52E-07					
				(1.31)					
POP(r=10)					2.67E-07				
					(1.89)*				
POP(r=13)						1.25E-07			
						(0.95)			
EPTA(r=5)							3.17E-06		
							(2.76)**		
COL(r=5)								5.41E-06	
								(2.77)**	
EMPW(r=5)									1.41E-06
									(2.90)**
Intercept	2.353	2.227	2.127	2.084	1.961	2.000	2.126	2.150	2.218
	(9.37)**	(9.15)**	(8.83)**	(8.06)**	(7.20)**	(6.25)**	(8.85)**	(8.98)**	(9.30)**
Number of Cases	139	139	139	139	139	139	139	139	139
Adjusted R square	0.429	0.422	0.437	0.415	0.423	0.412	0.440	0.440	0.443

** Significant at the 5% level
* Significant at the 10% level
t-statistics are in parentheses

Table 5.8 Estimation of FIRE Employment Growth Rate by CONVERGENCE Model Excluding Boston

Explanatory Variables	Model 1 POP(r=1)	Model 2 POP(r=3) Best Set	Model 3 POP(r=5)	Model 4 POP(r=7)	Model 5 POP(r=10)	Model 6 POP(r=13)	Model 7 EPTA(r=3)	Model 8 COL(r=3)	Model 9 EMPW(r=3)
Ln(FIRE80)	-0.118	-0.122	-0.103	-0.094	-0.099	-0.096	-0.121	-0.106	-0.113
	(-2.03)**	(-2.80)**	(-2.42)**	(-2.31)**	(-2.41)**	(-2.41)**	(-2.79)**	(-2.47)**	(-2.42)**
HIGHWAY	0.111	0.115	0.110	0.107	0.109	0.112	0.114	0.110	0.112
	(3.04)**	(3.16)**	(3.00)**	(2.93)**	(3.01)**	(3.08)**	(3.14)**	(3.03)**	(3.06)**
BOSDIST	-0.006	-0.004	-0.006	-0.009	-0.007	-0.013	-0.003	-0.005	-0.005
	(-1.16)	(-0.64)	(-0.91)	(-1.30)	(-0.82)	(-1.27)	(-0.54)	(-0.89)	(-0.90)
SPEC	-6.122	-5.933	-6.339	-6.404	-6.367	-6.259	-5.999	-6.293	-6.066
	(-3.57)**	(-3.59)**	(-3.90)**	(-3.95)**	(-3.92)**	(-3.86)**	(-3.65)**	(-3.86)**	(-3.54)**
POP(r=1)	1.45E-06								
	(0.42)								
POP(r=3)		1.19E-06							
		(1.16)							
POP(r=5)			6.81E-08						
			(0.19)						
POP(r=7)				-1.35E-07					
				(-0.62)					
POP(r=10)					-1.14E-08				
					(-0.07)				
POP(r=13)						-1.13E-07			
						(-0.76)			
EPTA(r=3)							4.75E-06		
							(1.14)		
COL(r=3)								2.91E-06	
								(0.36)	
EMPW(r=3)									1.55E-06
									(0.52)
Intercept	1.308	1.247	1.259	1.334	1.279	1.456	1.236	1.258	1.272
	(5.44)**	(5.63)**	(5.53)**	(5.43)**	(4.75)**	(4.40)**	(5.55)**	(5.63)**	(5.73)**
Number of Cases	129	129	129	129	129	129	129	129	129
Adjusted R square	0.234	0.241	0.233	0.235	0.233	0.237	0.241	0.234	0.235

** Significant at the 5% level
* Significant at the 10% level
t-statistics are in parentheses

growth rate of employment. In the Logit model specification, the dependent variable is measured in absolute number and its value for Boston is extreme, and therefore it affects the results.

5.4.2 Estimation for the Disaggregated Office Industries

The seven industries that are the same as in the logit model are selected as dependent variables. To make results comparable with those from the logit model, the Boston data are excluded from the sample. The structure of the explanatory variables are the same as in the FIRE and service cases. This time, however, the search for the best radius for "accessibility" variables are not conducted, because the coefficients on those variables are not statistically significant with any radius in the FIRE case. The radius for them is set at 3. The results are presented in Table 5.9.

Table 5.9 arranges industries from left to right in order of the value of the coefficient on the convergence term. Engineering services, business services, and insurance agents are the three industries that are estimated to converge most rapidly. Their annual convergence rates are 3.4%, 2.9%, and 2.1%, respectively. These industries are classified into the "dispersed between 1980 and 1990" categories in Chapter 3. The results of the HHI analysis and the convergence model are consistent. Legal services and real estate present a moderate rate of convergence. Their annual convergence rates are 1.8% and 1.5%, respectively. On the other hand, the coefficients of the convergence term for accounting and social services are not statistically significant. For these industries, no evidence of the convergence is found.

The coefficients on SPEC are negative for all industries, and statistically significant except for engineering services and legal services.

The degree of the specialization in the industry itself in a municipality has negative impact on the growth rate of the industry's employment in the municipality for most of the industries, suggesting that the agglomeration merits come from inter-industry linkage but not from intra-industry.

For all the industries except social services, the coefficient on HIGHWAY is statistically significant with the expected positive sign. These industries grow rapidly in the municipalities where the highway system is more convenient to use. On the other hand, the coefficients on BOSDIST and POP(r=5) are not statistically significant for all the industries. The distance from the CBD and the accessibility to customers and labor do not affect the growth rate in any of the industries.

Table 5.9 Estimation of Disaggregated Office Industry Employment Growth Rate by CONVERGENCE Model, Excluding Boston

Explanatory Variables	Engineering Services	Business Services	Insurance Agents	Legal Services	Real Estate	Social Services	Accounting
LN(EMP80)	-0.291	-0.255	-0.190	-0.164	-0.139	-0.082	-0.073
	(-2.44)**	(-3.60)**	(-2.22)**	(-2.85)**	(-1.77)*	(-0.90)	(-0.63)
HIGHWAY	0.241	0.135	0.139	0.104	0.133	0.010	0.171
	(2.09)**	(2.18)**	(2.32)**	(2.64)**	(2.14)**	(0.13)	(2.21)**
BOSDIST	-0.023	-0.016	-0.016	-0.008	-0.004	0.000	-0.017
	(-1.26)	(-1.45)	(-1.54)	(-1.03)	(-0.35)	(0.01)	(-1.26)
SPEC	-16.043	-7.620	-23.510	-48.753	-29.130	-26.135	-106.522
	(-1.24)	(-3.11)**	(-2.27)**	(-1.67)	(-2.80)**	(-2.62)**	(-2.43)**
POP(r=3)	3.35E-08	7.57E-07	-3.58E-07	-7.45E-07	7.30E-07	3.06E-06	-2.29E-06
	(0.01)	(0.48)	(-0.24)	(-0.74)	(0.46)	(1.69)*	(-1.17)
Intercept	1.748	2.394	1.520	1.517	0.992	1.229	1.405
	(2.78)**	(6.09)**	(3.79)**	(7.01)**	(2.79)**	(2.96)**	(3.51)**
Number of Cases	50	94	69	74	85	57	51
Adjusted R square	0.253	0.400	0.273	0.258	0.167	0.229	0.241

** Significant at the 5% level
* Significant at the 10% level
t-statistics are in parentheses

5.5 Summary

The two types of models, the logit model and the convergence model, are empirically tested in this chapter in order to examine the determinants of the employment growth of the office industries. Principal findings are summarized as follows.

First of all, determinants are different between the two models. Each model handles the different dependent variables; the logit model explains the growth in absolute number, and the convergence model explains the growth rate. Consequently, the significant explanatory variables also differ between them even if their results are compared for the single-digit industry, i.e., the FIRE or the service sector.

The accessibility to labor and customer (POP) and the distance from the CBD (BOSDIST) are significant determinants in the logit model, but insignificant in the convergence model. They have a positive effect on the growth in number, but have no influence on the growth rate. On the other hand, the accessibility to highways (HIGHWAY) has a positive effect on both.

The results for agglomeration merits are somewhat complicated. There are no evidence of the agglomeration merit from the specialization (intra-industry linkage). The concentration of overall industries (inter-industry linkage) has positive effect in both the logit and convergence models, except for the logit model that explains the FIRE growth including Boston. This result suggests a different industrial composition in the FIRE sector between Boston and the other municipalities.

Secondly, the determinants for each disaggregated industry are further different. For instance, the accessibility to highways has a positive effect

on almost all the industries, but no effect on social services in either model. In the logit model, the distance from the CBD has a negative effect on insurance agents and business services, but no effect on the other five industries. In the convergence model, the specialization in the industry itself has a negative effect on most of the industries, but no effect on legal services and engineering services. These differences reflect each industry's characteristics in location decisions.

Also in the logit model, the best radii for the summation of labor and customers to represent accessibility to those are different among the industries. For insurance agents, real estate, and business services, it is 1 mile, which represents strong linkage to the nearby market. For legal services, engineering services, and accounting, it is 13 miles, suggesting little linkage to the nearby market.

Lastly, the convergence certainly exists in the office employment growth. Using the convergence model, the existence of convergence in the office employment growth is confirmed in the FIRE and the service employment, as well as in most of the disaggregated industries. The annual rate of convergence are 1.3% for the FIRE sector and 2.5% for the service sector. Among the disaggregated industries, engineering services, business services, and insurance agents show rapid convergence (3.4%, 2.9%, and 2.1%, respectively). Legal services and real estate show moderate convergence (1.8% and 1.5%, respectively). Accounting and social services have no evidence of convergence. This convergence is also shown by the logit model when it includes the size control variable, i.e., POP(r=1).

Chapter 6 Conclusion

Between 1980 and 1990, employment in the office industries in the Boston area increased by 42.3%, or 119,404 in number. In the same period, jobs in the manufacturing industry in this area decreased by 83,860. The increase in the employment of the office industries more than offsets the decrease. These changes clearly show the essential and leading role the office industries play in the regional economic growth.

More importantly, the spatial distribution pattern of the industries dramatically changed from the traditional monocentric pattern to a polycentric one. Under the circumstances, it is becoming more and more important for policy makers in municipalities, especially in suburbs, to attract the office industries as a central figure of their economic development. For private developers, it is also important to predict the office space demand of these industries and provide the right project in the right place. In order to accomplish these difficult tasks, it is necessary to understand the locational characteristics of the office industries.

This thesis has analyzed the change in the locational patterns of the office industries in three ways. The main analysis is the empirical testing of the intrametropolitan office employment growth models (Chapter 5). Two types of models were tested; one is the logit model which explains the growth level in number, and the other is the convergence model which explains the growth rate. These two models were estimated by using the data for the aggregated (single-digit SIC) level of industries as well as for the disaggregated (double- or triple-digit SIC) level of industries, and drew different results about influential explanatory variables.

The results from the aggregated data provide the general findings on the determinants of the office employment growth. The logit model shows that the accessibility to labor and customers, proximity to the CBD, and accessibility to highways have positive effects on employment growth level. The specialization in the industry itself is not significant.

The results from the convergence model are somewhat different. The accessibility to highways still has positive effect, but the accessibility to labor and customers and the proximity to the CBD are no longer influential. The specialization has a negative effect, showing that a municipality specialized in the office industries grows slower than other municipalities. This suggests that the agglomeration merit comes from inter-industry linkage rather than from intra-industry. These differences can be attributed to the different dependent variables: the growth in absolute number in the logit model, and the growth rate in the convergence model.

The convergence model also reveals the existence of convergence of the employment growth in the office industries. In the logit model, this convergence is presented when the population size of each municipality, i.e., POP(r=1), is included in the model. This result may suggest that because the logit model deals with the "level" of the growth, a variable to control for the size of each municipality should be included in the model.

The empirical test of the models with the data for the disaggregated industries revealed several interesting characteristics for each industry. The results are combined with those from two other analyses: the analysis using the Herfindahl and Hirschmann Index (HHI) and the examination of actual spatial distribution changes (Chapter 3).

Insurance agents and business services are classified as "relatively

dispersed in 1980 and more dispersed between 1980 and 1990," by the HHI analysis. Boston's share of employment in these industries dropped more than 10 percentage points over the decade, and some suburban municipalities increased their shares considerably. The logit model shows that their growth in number is partly explained by the population within a one-mile radius. Thus, their outstanding dispersion took place as they followed the suburbanized population as their customers and labor. This is consistent with the characteristics of these industries that they tend to have close relationships with their customers rather than to have agglomeration merits from linkages with other firms. The convergence model also shows their rapid convergence.

Real estate is classified as "relatively concentrated in 1980 an unchanged over the decade" by the HHI analysis, but the results from the model analysis are close to the aforementioned two industries. Its growth in number is positively affected by the population within a one-mile radius. It converges with a moderate rate. The results from the HHI analysis are mainly attributed to the relatively high employment shares of Boston. On the other hand, the models exclude the Boston data and show its dispersion following the population. Therefore, one can infer that this industry is divided into two types of establishments: establishments such as headquarters which tend to concentrate in the CBD and benefit from agglomeration merits, and establishments such as branches which tend to disperse in the whole area and have more relationship with local labor and customers.

Engineering services, legal services, and accounting are classified as "relatively concentrated in 1980" by the HHI analysis. The logit model shows that the accessibility to labor and customers is not a significant determinant of the growth of these industries. Because they are not

influenced by the location of local labor and customers, they tend to concentrate, rather than disperse. On the other hand, the characteristics of their business suggest that they tend to benefit from concentrating in the CBD where a lot of communication with other big companies or government agencies provides useful business synergy.

Although these three industries were relatively concentrated in 1980, the HHI analysis presents different results for the change between 1980 and 1990 among them; engineering services dispersed over the decade whereas the other two were unchanged. This is consistent with the results in the convergence model; engineering services converged most rapidly whereas legal services converged with a moderate rate, and accounting had no evidence of convergence. According to the model analysis, engineering services tended to disperse to the municipalities where the concentration of the industry was small and the highway accessibility was convenient.

Social services are classified as "dispersed in 1980 and more over the decade" by the HHI analysis, but have no evidence of convergence, which is a somewhat puzzling result.

This thesis intended to construct intrametropolitan office employment growth models, which, in the literature, have not well developed yet. The thesis revealed the clear evidences of the trend of dispersion, or convergence, the negative effect of the specialization, and the positive effect of the accessibility to highways. However, many other factors that determine office firms' locational decisions remains unclear. They are left to future studies.

Also, the considerable differences in the results of the two different types of models have not been explored sufficiently in this thesis, in terms

of the reasons for the differences as well as the evaluation of the two models. As I mentioned in Section 4.3, the two models have different theoretical views about the growth. In order to make the reasons for the different results clearer, the theoretical background has to be thoroughly examined and developed.

As for the evaluation of the two models, we cannot simply compare the goodness-of-fit of the two models, because they have different dependent variables. One method to make the two models comparable is to employ the same dependent variable in both models. In this thesis, the dependent variable in the convergence model was Ln(EMP90/EMP80). If we employ Ln(EMP90/EMP80-1) instead of Ln(EMP90/EMP80) as a dependent variable, the whole model equation is expressed and transformed as follows.

$$\text{Ln(EMP90/EMP80-1)} = a + b*\text{Ln(EMP80)} + \beta x$$

$$\text{Ln[(EMP90-EMP80)/EMP80]} = a + b*\text{Ln(EMP80)} + \beta x$$

$$\text{Ln(EMP90-EMP80)} = a + (b+1)*\text{Ln(EMP80)} + \beta x$$

The left-hand side of the last equation is essentially equivalent to the dependent variable employed in the logit model in this thesis. Therefore, the comparison becomes valid by using Ln(EMP90/EMP80-1) as a dependent variable in the convergence model. Such a comparison and evaluation of these two models are one possible path to future studies.

Finally, I would like to suggest some policy implications drawn from the findings. First, even for the municipalities that currently have little concentration of office industries, there is considerable possibility to increase the office employment, because there exists the convergence of the office employment growth rate and no agglomeration merit from intra-industry linkage. The critical condition is, however, the transportation convenience

represented by the highway accessibility.

Second, it will not work well to promote specialization in any of the office industries, because there is no agglomeration merit from intra-industry linkage. On the other hand, the overall industrial concentration positively affects the employment growth of most office industries. Therefore, the promotion of other industries might result in synergistic effects on the office industries.

Lastly, the different locational characteristics between industries should be taken into consideration when the target of economic development or office development projects is identified. For example, some industries have a strong relationship with the local labor and customer market, while others have a weak one. These two groups must have a different preference for their location. The site conditions have to satisfy the criteria for the targeting industries.

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Appendix A. Cities and Towns in the Study Area

ESSEX COUNTY	MIDDLESEX COUNTY		NORFOLK COUNTY	PLYMOUTH COUNTY	SUFFOLK COUNTY
Amesbury	Acton		Avon	Abington	Boston
Andover	Arlington	Pepperell	Bellingham	Bridgewater	Chelsea
Beverly	Ashby	Reading	Braintree	Brockton	Revere
Boxford	Ashland	Sherborn	Brookline	Carver	Winthrop
Danvers	Ayer	Shirley	Canton	Duxbury	
Essex	Bedford	Somerville	Cohasset	East Bridgewater	
Georgetown	Belmont	Stoneham	Dedham	Halifax	
Gloucester	Billerica	Stow	Dover	Hanover	
Groveland	Boxborough	Sudbury	Foxborough	Hanson	
Hamilton	Burlington	Tewksbury	Franklin	Hingham	
Haverhill	Cambridge	Townsend	Holbrook	Hull	
Ipswich	Carlisle	Tyngsborough	Medfield	Kingston	
Lawrence	Chelmsford	Wakefield	Medway	Lakeville	
Lynn	Concord	Waltham	Millis	Marion	
Lynnfield	Dracut	Watertown	Milton	Marshfield	
Manchester	Dunstable	Wayland	Needham	Mattapoisett	
Marblehead	Everett	Westford	Norfolk	Middleborough	
Merrimac	Framingham	Weston	Norwood	Norwell	
Methuen	Groton	Wilmington	Plainville	Pembroke	
Middleton	Holliston	Winchester	Quincy	Plymouth	
Nahant	Hopkinton	Woburn	Randolph	Plympton	
Newbury	Hudson		Sharon	Rochester	
Newburyport	Lexington		Stoughton	Rockland	
North Andover	Lincoln		Walpole	Scituate	
Peabody	Littleton		Wellesley	Wareham	
Rockport	Lowell		Westwood	West Bridgewater	
Rowley	Malden		Weymouth	Whitman	
Salem	Marlborough		Wrentham		
Salisbury	Maynard				
Saugus	Medford				
Swampscott	Melrose				
Topsfield	Natick				
Wenham	Newton				
West Newbury	North Reading				

Appendix B. Calculation for the Distance between Two Points

The X and Y coordinates obtained from the Geographic Information System are the longitude for X and the latitude for Y. They are usually expressed in degrees, minutes, and seconds. In this case, first, this expression should be converted into a decimal number as follows:

A degrees B minutes C seconds = (A + B/60 + C/3600) degrees.

Next, in order to calculate a distance between two points using X and Y coordinates expressed in decimal numbers, we have to know the actual distance corresponding to one degree of longitude and latitude.

The distance for one degree of latitude, for example the distance between (40°N, 70°W) and (41°N, 70°W), is always the same anywhere on the earth. It is approximately 69 miles. On the other hand, the distance for one degree of longitude in not always the same. As approaching to the Equator, it becomes longer, and as approaching to the Poles, it becomes shorter. However, in the study area, this difference is quite small. At the northernmost point in the area (about 42°55'N), the distance for one degree of longitude is shorter by only 2% than that at the southernmost point (about 41°45'N). Therefore, in this study area, the distance for one degree of longitude is assumed to be the same, and the distance around Boston, which is almost the center between the northernmost and the southernmost points, is used. The distance is approximately 50 miles.

Given these distances, the distance between two points whose coordinates in decimal numbers are (X1, Y1) and (X2, Y2) is calculated as follows:

$$SQRT[\{ (X1-X2)*50 \}^2 + \{ (Y1-Y2)*69 \}^2].$$