Dispersed Concentration of High-tech Jobs in the New Economy: The Paradox of New Information and Communication Technologies

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Submitted to the Department of Urban Studies and Planning in Partial Fulfillment of the Requirements for the Degree of Doctorate in Philosophy of Urban and Regional Studies

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Abstract

More high-tech firms are conducting their business over long distances due to the use of new information and communication technologies (ICT). However, regional scientists articulate that geographic proximity is still important, at least, to the high-tech industry and the knowledge-related business activities. My research offers a ground work for understanding the paradox – more dispersed high-tech business practices and higher geographic concentration of high-tech jobs in the new economy than before. Drawing from diverse regional and economic literatures, I suggest a paradox of new information communication technology regarding the location pattern of high knowledge-generating jobs. From this perspective, I found a dispersed concentration pattern of high knowledge-generating jobs due to less transitory tacit knowledge than codified knowledge and implicit communication; and business organization change.

Both my longitudinal empirical analysis and interviews suggest that the jobs in the *high knowledge-generating production* industries in the United States became further concentrated during the 1990s. During the same period, the jobs in the *high knowledge-generating customer-oriented* industries dispersed. In the former industries, producers are the major knowledge generators, while in the latter industries, tacit knowledge is derived mostly from the interaction between firms and customers. In consequence, the jobs in the former industries tend to agglomerate with each other, but the jobs in the latter industries tend to disperse in order to be close to customers.

Furthermore, five out of the six high-knowledge generating production industries show a "winner-takes-all" kind of *spatial* monopolization of jobs. For example, in the computer industry, the ratio of the job share of Silicon Valley, the top share holder, and the job share of the Boston metro area, the second highest job share holder, increased from 1.6 in 1990 to 2.9 in 2000.

However, this finding fails to explain the phenomenon of R&D units of advanced multinational high-tech production firms locating in remote developing and middle-income countries. To answer this puzzle, I identify their actual activities and compare multinational and local R&D operations in Korea. Interviews reveal that they are closer to being customer-relations intensive units, although the R&D units of the multinational firms in Korea are labeled "R&D." They are conduits of outreach to local customers, which conduct (1) the flexible customization of their products to meet local customers' demands and (2) customer management and marketing in the highly competitive global market.

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Chapter 1

Introduction

According to Malmberg (1996), for more than a century, many geographers and economists have developed theories relating to the spatial agglomeration of economic activity in response to three empirical observations: (1) a large portion of world output is produced in a limited number of highly concentrated core regions; (2) firms in similar or related industries tend to be co-located in particular places; (3) both of these patterns seem to be sustainable over time.

As more high-tech firms are currently conducting their business over long distances than a couple of decades ago mostly due to the use of new information and communication technologies (ICT),Cairncross (1997, 2001), among others, asserts a "death of distance" in businesses and jobs. This new business practice over distance, which is derived by the new ICT, raises a question about the geographic agglomeration pattern of economic activity and its sustainability in the new economy.

I hypothesize that geographic concentration level of, at least, knowledge-related jobs may not decrease due to tacit knowledge and implicit communication; and business organization change. Some regional scientists' empirical studies find that high-tech industries and jobs are still highly concentrated (Audretsch and Feldman, 1996, among others). Regional scientists maintain that geographic proximity is still important, at least, to the high-tech industry and other knowledge-related business activities. However, the mechanism of recent geographic concentration is still unclear.

Although these empirical studies show high geographic concentration of high-tech industries and jobs, they tend to rely on either cross-sectional comparative analysis between high-tech industries and mature industries or some anecdotes and cases. Consequently, there is a lack of systematic longitudinal empirical studies on the geographic concentration pattern. Moreover, theory to explain the current geographic concentration pattern in the new economy needs further development beyond existing location theories.

My study offers the ground work for understanding the paradox – more dispersed high-tech business practices and a greater geographic concentration of high-tech jobs in the new economy – by taking both tacit knowledge and business organization change into account.

The purpose of my research is three-fold. First is to conduct a longitudinal empirical analysis of the geographic concentration pattern of knowledge-related business activities to confirm whether or not geographic concentration increases over time. There has been a lack of systematic longitudinal empirical analysis on job concentration pattern mainly due to the data availability and compatibility over time. My research fills the gap in existing literature. The second purpose is to bridge economics, business, and regional science theories to give a better understanding of the job-location pattern in the new economy. Although these theories are concerned with jobs, industries, and locational pattern, there is a need to bridge the two different perspectives – firm-oriented perspective and region-oriented perspective. The third purpose of the study is to draw regional economic development policy implications in the new economy. Job availability of a region has been one of the most critical issues in the regional economic development field. As the new economy emerges, the geography of job location seems to be affected. This research helps us to develop better regional economic development strategies by providing a comprehensive understanding of the job location behavior in the new economy.

1.1 Two Anecdotes: Millennial Net, Inc. in Boston, MA and Semiconductor Manufacturing in Austin-Dallas, TX

Two MIT graduates established the company Millennial Net in Cambridge, MA, in 2000 as they were graduating.[1] Until then, wireless sensors used Radio Frequency Identification (RFID) technology, which can only handle unilateral communication and requires pre-configuration. Millennial Net made a breakthrough in that its products can communicate bilaterally and automatically build an ad-hoc network connection among them. Their two-way, self-governing wireless sensor network devices are still a globally unique technology. (personal interview, founder of Millennial Net, May 3, 2005) From the start of their business, Millennial Net has focused on this new wireless sensor networking technology, but it has had no in-house production. This is a drastic paradigm shift from the earlier generation firms, such as Digital Equipment Corporation (DEC) and Wang Laboratories, which did all jobs from R&D to final production in-house.

For production, Millennial Net works with their partners around the world, which include radio/chip providers Chipcon, RF Monolithics, and Freescale; technology providers Kele, Sensirion, and TCS/Basys; and a family of development partners.

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[1] Millennial Net, Inc. settled in Burlington, MA, which is a part of Route 128, in 2004 as it grew to over 20 full-time employees.

Interestingly, all the partners are scattered in different places. For example, Chipcon is a Norwegian firm and has a branch in Nashua, NH. RF Monolithics is located in Dallas, TX and Freescale Semiconductor Inc. is located in Austin, TX.

However, as I discuss later in detail, we also observe that semiconductor manufacturing jobs are concentrated in the Dallas and Austin, TX, metropolitan areas. Freescale Semiconductor Inc., which is a partner of Millennial Net's semiconductor manufacturing, is located in Austin, TX. It is one of the largest semiconductor manufacturing firms in the World. Freescale's manufacturing expertise concentrates in two areas – die manufacturing, and packaging and testing.[2] It has shipped more than 16 billion semiconductors, which can be found in everyday name brands: Motorola cell phones, Sony electronics, Whirlpool appliances, Logitech keyboards and mice, Lifefitness cardiovascular and strength training equipment, Cisco routers, Apple laptops, Bose Acoustic Wave radios, Trane heating and cooling equipment, Mercedes, BMW, Ford, Hyundai and General Motors vehicles. Freescale is the world's top supplier of the semiconductors being used in automotives, so many automotive firms rely on Freescale's semiconductor parts.

As illustrated in the Millennial Net, on the one hand, various necessary business activities of a firm – such as research and development (R&D), production, and marketing – tend to disperse, even beyond an individual firm's boundary, in order to create a finished product. On the other hand, we also observe the geographic concentration of certain business activities (e.g., semiconductor manufacturing in the above case). For example, another of the largest semiconductor manufacturers, Solectron, also has its biggest semiconductor manufacturing establishment with more than 1,000

[2] Source: Information from the Freescale Website: http://www.freescale.com/ (Accessed on Jan 14, 2006)

employees, in Austin, TX.[3] In addition, Samsung Electronics opened its semiconductor manufacturing unit with over 1,000 employees in Austin, TX, too. Austin and Dallas, TX, have increased their job share in semiconductor manufacturing during the 1990s.[4] The region became the top job share-holder in the semiconductor manufacturing industry (NAICS 3344) in 2000.[5]

These cases – Millennial Net for an individual firm's business practice and Austin-Dallas, TX, for a geographic concentration of semiconductor manufacturing – illustrate and reflect the use of new information and communication technologies (ICT), which change business practices and the economic environment. "Even in smaller companies, a growing number of people now operate in teams spread across continents [due to the use of the new ICT]." (BusinessWeek, December 19, 2005, p.74) Negroponte (1995), among others, asserted that the post-information age would remove the limitations of geography. He argued that digital living will include less and less dependence upon being in a specific place. His notion is true at an individual firm level. This individual firm's more dispersed business activities might lead us to presume the decrease of the importance of geographic proximity and hence more geographic dispersion of business activities, and support a controversial prophecy of a "death of geography." (Martin, 1996)

However, as illustrated in the semiconductor manufacturing in the Austin-Dallas, TX, case, the geographically aggregated number of high-tech jobs can increase, while the

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[3] Source: Solectron Website and ReferenceUSA (2005)
[4] Source: U.S. Bureau of Labor Statistics. Author's calculation.
[5] The focus of my study is on business activities. As I discuss later, 4-digit NAICS level establishment data can be interpreted as business activities. For example, Solectron's Texas branch's primary use is classified as semiconductor manufacturing, while its Michigan branch's primary use is classified as design and engineering. (Source: Solectron Annual Report, 2005 and ReferenceUSA, 2005)

individual firm's business practices are dispersing as more firms – which need semiconductors – purchase semiconductors from the semiconductor manufacturing firms in Austin-Dallas, TX. Then, the geographic concentration by business activities – when we aggregate the number of individual firm's jobs at a metropolitan area level by business activity – can increase. For example, we can observe that large computer firms, such as IBM, Oracle, and Sun Microsystems, set up R&D units in the Boston metropolitan area without relocating the whole firm in order to tap into the knowledge workers in Boston. That is to say, the firms need a computer-related, state-of-the-art technology, so the firms set up their sub units in the Boston metropolitan area or make partnerships with firms in the Boston metropolitan area. From the location perspective, this trend can increase the geographic concentration of knowledge-related jobs in the computer-related R&D in Boston.

If this is the case, geography does matter, and the individual firm's dispersed business practices may, paradoxically, increase the aggregated spatial concentration of jobs in certain business activities. I discuss the empirical research finding in Chapter 3.

1.2 Underlying the Economy-wide Labor-Market Change in the New Economy: Comparative Advantage of Computer vs. Human Beings[6]

Before discussing the job-location pattern, I introduce the economy-wide labor-market change in the new economy, which gives background context for us to understand the new job-location pattern.

Levy and Murnane (2004) investigated the impact of computers on jobs in four dimensions: (1) Employment (e.g., possibility of mass layoffs); (2) mix of jobs (e.g.,

[6] This section is primarily based upon the Levy and Murnane's (2004) comprehensive study on the effect of the use of the new ICT on the job market in the new economy.

growing/declining job areas); (3) wages (e.g., especially income inequality); and (4) worker skills (e.g., the skills that the new economy will value).

They found that the computer is a complementary technology for those who deal with expert thinking and complex communication, while the computer substitutes for rule-based jobs, such as mid-level administrative and clerical jobs.[7] These labor-market changes are mainly the result of the comparative advantage of human beings versus computers. Historical data and cases confirm the job bifurcation: high-skill jobs and low-skill jobs combined with a "hollowing out" of mid-skill jobs; even within a job category, there are increasingly more skilled job requirements as well as "deskilled" job requirements. According to Levy (1998), the income disparity between jobs has also increased recently due to the use of the new ICT.

1.3 Location Issue Revisited: Do All Places Experience the Same Labor-Market Change?

In this study, as regional scientists has been doing since a century ago, I explore the regional question, "What is where, and why – and so what?" (Hoover and Giarratani, 1999) As new information and communication technology (ICT) emerges, it affects work, society, community, and everyday life (Castells, 2000; Florida, 2002; Levy and Murnane, 2004). I focus in depth on the location issue, specifically the agglomeration issue among the various potential questions derived by the emergence of the new ICT and new economy.

In other words, although those labor-market changes can be a universal trend, different places may experience labor-market changes. For example, I conduct a brief

[7] A by-product of this restructuring is the increase in the number of human-labor based service jobs, which still cannot be substituted by machines.

comparison of the job-mix change in two different locations – Connecticut and Iowa – in order to check if new economic changes have something to do with location.

As seen in Figure 1-1, Connecticut shows a different job-market change from 1970 to 2000 than Iowa. [8] In 1970, both states had a similar job mix, with their proportion of blue-collar workers being approximately 36 percent (the U.S. average was 37 percent). By 2000, Connecticut's blue-collar job share dropped by 16 percentage points to 20 percent, while Iowa's blue-collar job share dropped by 7 percentage points to 28 percent (the U.S. average dropped by 13 percentage points to 24 percent). In 1970, both states' proportion of managerial jobs was approximately 10 percent (the U.S. average was 9 percent). By 2000, Connecticut's increased by 7 percentage points to 16 percent, while Iowa's managerial job share increased by only 1 percentage point to 11 percent (the U.S. average increased by 4 percentage points to 13 percent). Although the job mix in Connecticut and Iowa were comparable in 1970, their job mix in 2000 is substantially different from each other. Although the general trend of both states conforms to Levy and Murnane's findings, the degree of change experienced varies substantially by location.

Place <Figure 1-1> here.

An analyst can view these different experiences of job-market change in different places either as a cross-sectional spatial difference or as a lagging spatial pattern of a longitudinal industry life-cycle evolutionary process. It is too early to make a final judgment in the middle of the restructuring process. The nature of job-location patterns in

[8] These figures are produced based upon Levy and Murnane's (2004) idea.

the new economy remains, to a great extent, unknown within the theory and practice of regional economic development. (Alonso, 1990; Barnes 2004)

1.4 Research Questions

In this research, I seek to understand the knowledge-related job location pattern in the new economy. In particular, I have two main related locational questions. One is: What are the impacts of the new information and communication technology on job concentration? The other is: What is the behavior of multinational firm R&D in foreign countries?

I hypothesize that the use of the new ICT increases the value of proximity for knowledge-related jobs. Furthermore, the use of the new ICT increases the possibility of emergence of a dominant location for a knowledge-related production activity.

A firm's use of the new ICT lowers its barriers to business interaction with distant locations, but it also heightens the value of timing and less transitory tacit knowledge for business success. We will observe more concentration when the latter offsets the former. Second, although an increase in dispersion can happen with the use of the new ICT at the individual firm level, the aggregated geographic concentration can still be high or higher than before due to the industry organizational restructuring induced by the use of the new ICT. I discuss this issue in detail in Chapter 3.

A second set of location questions actually arose from an anomaly to the findings of my first job-concentration question. As I discuss in more depth later, my interviews and empirical study suggest that jobs in the knowledge-creative business activities in the high-tech production industries tend to agglomerate geographically. However, this fails to explain why R&D units of advanced multinational firms locate in remote developing and middle-income countries. Why do advanced multinational firms set up R&D units in distant foreign countries? What do the multinational R&D units in remote places actually do? Is it a kind of outsourcing? To answer these questions, I identify their actual activities and compare multinational and local R&D.

Outsourcing has become commonplace in the new economy. Outsourcing usually results in the substitution of domestic high-cost workers with foreign low-cost workers in order for multi-national firms to cut costs by locating an establishment in a low-wage developing country. This kind of functional separation is not an entirely new business practice. For example, the "back-office" – dispatching routine and administrative office jobs to suburban areas – began to be popular on Wall Street in the 1980s (BusinessWeek, November 2, 1985).[9]

The firms' goal to maximize their profits and minimize their costs has not changed. What has changed is the availability of the new ICT, which enables firms to (1) send their separable subunits to the most desirable place regardless of distance and (2) collaborate with other business entities more easily regardless of distance. As a business model of dispersed units of the firm becomes profitable, firms increasingly adopt this organizational change in their operations.

However, according to Piore (2004), R&D outsourcing might be different from manufacturing or back-office outsourcing, because of the type of knowledge R&D uses. R&D is known to require advanced technology and accumulated knowledge and experience. Moreover, locating R&D in remote places causes the problem of integration

[9] Nowadays government organizations adopt outsourcing, too. For example, New York City conducts its parking-ticket processing in Ghana (New York Times, July 22, 2002, p. A4).

and coordination with other divisions of the firm.[10] I further discuss these R&D-related issues in Chapter 4.

In Chapter 5, I reaffirm the central theme of the dissertation research and the findings and draw some policy implications. Then, I conclude with issues for future research.

[10] In addition, advanced firms often want to keep their R&D within their home country because of intellectual property right considerations (Fan, 2003).

Chapter 2
Literature Review

Answering the job-location question in the new economy becomes an inherently complex process. The complexity comes from multi-fold and multi-route impacts of the new ICT on job markets and job location. ICT changes the economic meaning of distance and proximity. In addition to the direct impact of ICT on the communication cost over distance, ICT concurrently affects organization, supply-chain management, business strategy, the importance of speed, and the degree of competition. ICT's multi-fold and multi-route impacts compound the complexity required to understand today's industry location. These changes call for new explanations of industrial location. (Alonso, 1990; Barnes 2004)

Correspondingly, analysts in various academic fields – regional science, economics, business, geography, planning, public policy, and so forth – are conducting research to understand the impact of new ICT on their concerns. I argue that all the changes caused by the use of the new ICT – including distant collaboration and reorganization, as I discuss in detail later in this chapter, closely relate to each other and have been collectively shaping the geography of jobs in the new economy.

In this regard, I synthesize various perspectives to explain the current job-location pattern. By taking a relatively holistic approach, I can help readers understand the actual outcome because the new ICT brings about these various kinds of impacts concurrently. In the following, first, I summarize various conventional location theories. Second, I discuss recent changes in the new economy, which affect the location pattern. Finally, based on the literature, I discuss potential factors that increase the geographic agglomeration of high knowledge-generating jobs.

2.1 Conventional Theories to explain Location Patterns

I identify four kinds of conventional theories regarding industry location and geographic concentration of industry. First, in general, "location theory" refers to the transportation cost-based location theory. The basic idea is that firms tend to locate where the transportation cost of goods and services is minimum. As I discuss in the next section, this theory is limited in explaining the location pattern of current knowledge-intensive industry. Second, scholars, mainly from economics, adopt externalities, i.e., agglomeration economies, and economies of scale to explain the geographic agglomeration pattern. These theories stem from Marshall's specialization and Jacob's urban-economies tradition. Still, many scholars are investigating the mechanism of these two processes.

Third, the spatial-competition process is another strand to explain individual location behavior and collective location pattern. Competition is surrounding the environment outside an individual firm's boundary. This idea broadens the scope of the location-behavior study to a market beyond an individual firm's endogenous factors. Fourth, industry life cycle theory enables us to view a location pattern as a longitudinal process. This theory shows that a location pattern can change over time due to the changing nature of the supply system and market. I discuss these four conventional location relevant theories in detail in the following sections.

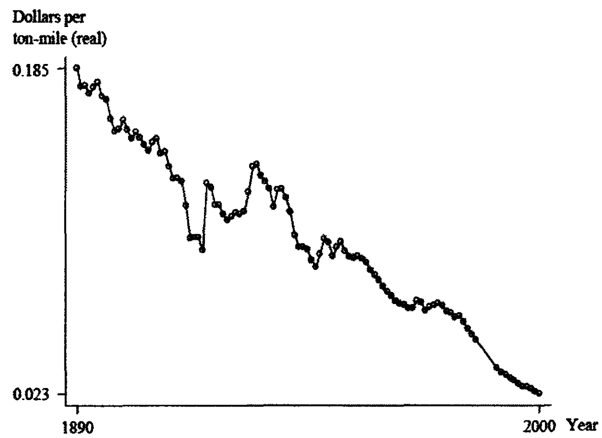
2.1.1 Transportation Cost Minimization – Supply Side and Demand Side

Classic Supply-side Industrial Location Theory: Classic industrial-location theories came into the world at the beginning of the last century when today's mass-production manufacturing emerged. Classic industrial-location theories are mediated by distance, which is a simplified proxy measure of transaction costs. Weber (1929) was a pioneer of industrial location theory. He formulated the classic supply-side industrial location theory. His contention was that firms tend to locate where transportation cost is minimized. Then, he formulated cost minimization as a function of the weight of inputs, outputs, and distances between the firm and its suppliers, and between the firm and its consumers. In his model, for example, firms with commodities that lose mass during production and therefore are transported less expensively from the production site to the market are located closer to the raw-material site than those firms with goods that gain weight during production.

Classic industrial location theories are based on the importance of the transportation costs between a firm and its suppliers and markets. Distance is a friction to overcome. This model worked well when transportation was relatively costly, goods transported were mainly heavy agricultural and minind products, and only a handful of suppliers and markets were considered.

However, business circumstances have changed. Transportation costs have significantly decreased. Glaeser and Kohlhase (2003) calculated that railroad transportation costs decreased by 88 percent from 18.5 cents per ton-mile in 1890 to 2.3 cents per ton-mile in 2000. (Figure 2-1) Supply-chain analysts show that conventional transportation cost is not usually an important location factor for most firms today. (Polenske, 2003)[11]

Figure 2-1. The Cost of Railroad Transportation over Time



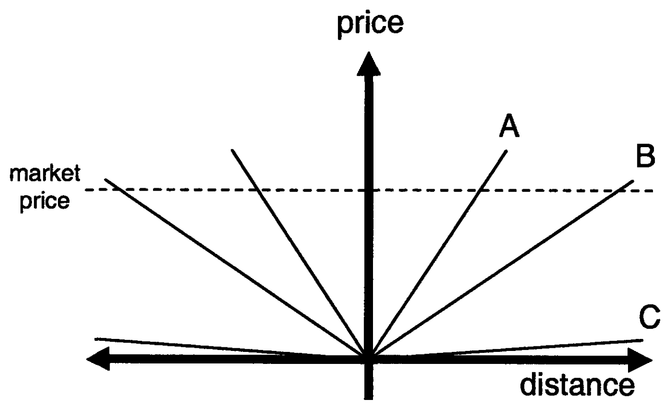
Source: Glaeser and Kohlhase, 2003

In Figure 2-2, line A conceptually shows the threshold that a firm can reach, at which the production cost exceeds the market price. As transportation costs decrease, a firm can send its products farther away from the firm's location (Line B in Figure 2-2). In theory, there could be a transportation-cost rate that allows a firm to reach every corner of the globe (line C in Figure 2-2). This means, from the location perspective, that the firm has full freedom in location choice with respect to transportation cost. From the location

[11] The weight-to-value ratio of high-tech products, such as semiconductors and software, tends to be much lower than traditional manufacturing goods. This "weightless" economy also decreases the importance of transportation cost. Moreover, as we move further to a service and information economy, the "weight" of a dollar of GDP must have declined significantly.

perspective, this implies emergence of a monopoly and complete geographic concentration.[12]

Figure 2-2. Transportation cost and location freedom



Source: Author

In addition, the linkages between economic activities have become increasingly tangled as society becomes increasingly specialized and the division of labor becomes ever more highly advanced. For example, Ford Motor Company currently has about 2,500 suppliers around the world (USA Today, 2005) and the linkages have multiple tiers. (Table 2-1)

The markets for goods and services are also spread around the world. In consequence, a firm is tied to thousands of different suppliers and markets. Although the conventional supply-side location theories hold conceptually, they have serious limitations in explaining more recent location patterns.

[12] This perfect geographic concentration driven by a monopoly can hardly happen under a perfectly competitive market because, as the transportation cost decreases, the market price may decrease too and create another set of thresholds.

Table 2-1. Automobile Industry Assembly System

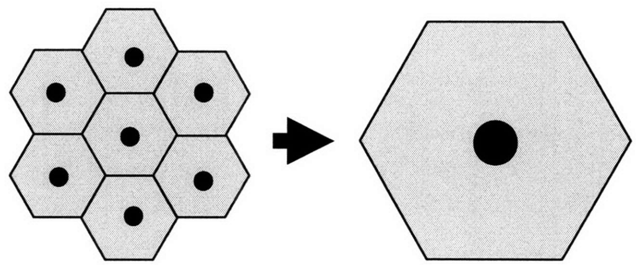
Assembly	Vehicle		
↑ First Tier	Body (e.g., seats, consoles, suspensions)	Power (e.g., engines, transmissions)	Chassis (e.g., steering, brakes)
↑ Second Tier	Components (e.g., air bags, pistons, gauges, valves)		
↑ Third Tier	Piece parts (e.g., castings, stampings, moldings)		
↑ Fourth Tier	Raw materials		

Source: Adopted from Rassameethes (2000)

Classic Demand-side Location Theory: Classic demand-side industrial location theories show a similar story. Christaller (1933) and Lösch (1939) developed a beehive-like hexagonal spatial pattern, one version of a central-place location theory that is based upon transportation cost just as the classic supply-side location theories are. Firms can deliver their product only up to a certain distance, a so-called threshold. Beyond the threshold, firms lose profit due to the transportation-cost burden. This theory suggests a high concentration for high-ranked businesses, which have high thresholds, such as a jewelry shop, and more dispersion for low-ranked businesses, which have a low threshold, such as a grocery store.

If the threshold of an industry gets larger, the industry tends to be located in a smaller number of core locations and eventually fulfills demand from the entire area. Like supply-side location theory, the central-place theory suggests that the number of centers decline as transportation costs decrease. Interestingly, *ceteris paribus*, the outcome of this process is greater concentration, as illustrated by the Central Place theory. In Figure 2-4, for example, we need seven establishments to support the demand of the entire region mainly due to the transportation-cost restriction. When the transportation cost drops drastically enough for an establishment to deliver its goods and services to every corner of the region, we would observe only a big establishment, instead of seven establishments. From the geographic concentration pattern, that means theoretically an absolute geographic concentration.

Figure 2-3. Classic Demand-side Central Place Theory

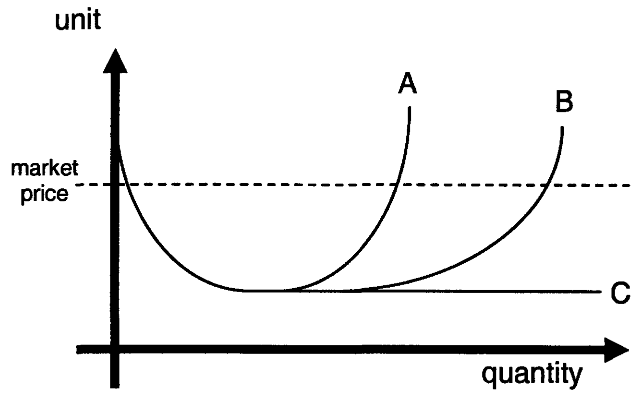


Source: Author

2.1.2 Agglomeration Economies, Economies of Scale, and Increasing Returns

If the production cost falls as the quantity increases, there exist economies of scale. Economies of scale imply the emergence of a big business unit. This – possible emergence of a big business unit – is one of the most common economic explanations for geographic concentration. The benefit of the large size of an individual establishment is expressed in the concept of "economies of scale." Returns-to-scale are initially increasing as volume of production increases at least up to a certain scale. In particular, high-fixed-cost and low-operating-cost firms tend to yield a smaller number of bigger firms than firms with low fixed cost and high operating costs. This increasing returns tends to amplify the concentration pattern.[13] If this is the case, concentration occurs at both the individual firm level and the geographic level. That is to say, more economies-of-scale or increasing returns usually means more geographical concentration.

Figure 2-4. Increasing Returns-to-Scale



Source: Author

Increasing returns also exist at a spatial level, beyond an individual firm's boundary. This regional level benefit of "being there" is a type of positive externality.[14] (Gertler, 1995) Specialization and its externalities are well captured by Marshall (1920), Arrow (1962), and Romer (1986). According to Marshall, the externalities of specialization come from (1) specialized supply, (2) labor pooling, and (3) knowledge spillovers. Specialization gives an individual firm extra benefits, which, in turn, increase the firm's gain from "being there." This location premium can pull firms to concentrate at specific locations. Paradoxically, the use of the new ICT bears the potential for both (1) individual firm's organizational freedom over distance and (2) the increasing possibility

[13] For more discussion of increasing returns, refer to Romer (1986).
[14] Polenske (2003) discusses the diseconomies of agglomeration – congestion cost.

of geographic agglomeration at the same time by making both curves flatter in Figures 2-3 and 2-4.

Note that increasingly frictionless transportation costs, combined with increasing returns-to-scale (line C in Figure 2-3), imply the increasing possibility of a spatial monopoly (Castells, 2000).[15]

Agglomeration economies are one kind of external economies, so that firms can achieve greater output when they operate in the context of a local economy where they can draw on large pools of labor, materials, and services. Agglomeration economies are of two types: Localization economies – those relating to the agglomeration of firms of the same industry in one area; and urbanization economies – those relating to the agglomeration of various industries in one location (Equation 2-1). If agglomeration economies exist, dG/dN is greater than 0; if diseconomies of agglomeration exist, dG/dN is less than 0.

$$Q = G(N) * f(K,L,D) \qquad (2\text{-}1)$$

where, N = size of industry or city

The theory of localization economies asserts that the size of the industry in a region seems to offer a positive benefit to individual firms in the region. The source of localization economies includes (1) firm-specific business savings due to scale economies

[15] Hereafter, I use the term "spatial monopoly" to depict the hyper concentration of a business activity in one location without one big firm. In other words, spatial monopoly distinguishes itself from conventional economic "monopoly" in terms of absence of one dominant firm. Instead, the notion of spatial monopoly articulates the dominance of one place with multiple business units of a kind.

in intermediate inputs, (2) unique skilled labor markets, (3) incubation of industry-specific knowledge, and (4) informal communication.

While Marshall's externalities and knowledge spillovers focused on specialization of these firms, Jacobs (1969) emphasized diversity, which is the source of urbanization economies. Notably, Jacobs viewed diversity as being of much greater importance than specialization with respect to innovations, new ideas, and new ways of working. This capability of generating and disseminating innovation and knowledge is at the core of the competitive advantage of a city. Henderson and Cockburn (1993) confirmed that, at a firm level, diversity showed significant importance for knowledge creation whereas specialization did not.

The sources of urban economies include (1) better business services, (2) economies of scale in input supply for all industries, (3) local labor-market efficiencies, (4) complementary businesses, and (5) economies from interaction.

Jacobs (1969, pp. 51) argued that diversity is the fundamental power of a city, saying that, "[O]ne kind of work leads to another." In her examples, she emphasized the role of place. "In this process, it does not matter who carries out the new work, as long as somebody does [in the place]." For example, 3M (Minnesota Mining & Manufacturing Co.) was selling sand and gravel. Construction workers used sand for grinding and polishing. 3M then started to produce sandpaper by adhering sand on a sheet of paper. Sandpaper became popular among construction workers. For better sandpaper, 3M developed better glues, which are chemical products. 3M could then successfully develop diverse glues, one of which created today's sticky pad.

Another recent example is the artificial intelligence robots of MIT. According to Ferrell (1995), today's robotics is inspired by the movement of insects. Insect research and robotics are previously unrelated knowledge fields, but there is a growing interest in using insect locomotion schemes to control walking robots. Insect locomotion schemes require relatively little computational power, which is essential to build real-time walking machines.

2.1.3 Profit Maximization – Competitiveness, Spatial Competition, and Comparative Advantage

Profit maximization offers us a broader perspective to understand location behavior because firms eventually pursue profit. In other words, firms can locate where the apparent cost seems high if, and only if, the return would be even higher than the cost increase.

Roughly speaking, the cost-minimization location theorists, such as Weber, view a firm as an isolated entity and the agglomeration-based location theorists, such as Marshall, assume that multiple firms are mutually beneficial to each other. On the contrary, competition is another dimension of business – market.

Competition is the act of striving against another entity for the purpose of achieving dominance or attaining a reward or goal, or out of an imperative such as survival. Seen as the pillar of capitalism in that it may stimulate innovation, encourage efficiency, or drive down prices, competition is stressed by neoclassical theorists to be the foundation upon which capitalism is justified. According to microeconomic theory, no system of resource allocation is more efficient than pure competition. Competition, according to the theory, causes commercial firms to develop new products, services, and technologies. (Schumpeter, 1942 [1975]). This gives consumers greater selection and better products than without competition. The greater selection typically causes lower prices for the products compared to what the price would be if there were no competition (monopoly) or little competition (oligopoly).[16]

There are three types of competition. The most narrow form is direct competition (also called category competition or brand competition), where products that perform the same function compete against each other. The next form is substitute competition, where products that are close substitutes for one another compete. The broadest form of competition is typically called budget competition.[17] Porter (1985) argues that firms need to achieve a competitive advantage against their rivals for survival.

For competitiveness advantage, knowledge is a key ingredient for high-tech firms, and leads high-tech firms to form a geographic cluster (Breschi and Lissoni, 2001; Mowery and Ziedonis, 2001; Amsden 2001).

In addition, Hotelling demonstrated spatial competition in his seminal work, *Stability in Competition* (1929). In his model, firms were assumed to be able to choose to locate anywhere. Paradoxically, his result suggested that all firms' profit maximization behavior leads each firm to locate at essentially the same location as everyone else due to competition. Hence, his model results in high geographic concentration.

Besides, comparative advantage can be used to explain geographic concentration especially a global division of labor such that a country focuses on producing, for example, corn and another country focuses on producing wine. Comparative advantage

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[16] Competition may also lead to wasted (duplicated) effort and to increased costs (and prices) in some circumstances.

[17] Included in the budget competition is anything on which consumers might want to spend their available money. For example, a family that has $50,000 available may choose to spend it on many different items, which can all be seen as competing with each other for the family's available money.

theory implies regional specialization and free trade to maximize the output and benefit. However, comparative advantage does not tell us what will happen; instead the theory tells us what can happen. As the importance of the location-specific, natural-resource endowments in modern industry also decrease, the probability of concentration due to the location-based comparative advantage seems to decrease.

2.1.4 Industry Life Cycle and Location

Yet, an analyst may need to view the business spatial pattern in the context of a longitudinal evolutionary process, instead of a cross-sectional static pattern.

Vernon (1963) looked at New York City in the late 1950s and examines a number of its disadvantages, such as, no natural resource advantage, high relative wages, costly commuting expenses, and declining importance of ports. However, certain types of companies continue to locate there.

He found that those companies tended to be ones with low overhead, which need limited space. In addition, they tend to face an uncertain future, and survival requires ability to adapt quickly. Thus, they continue to rely upon face-to-face contact, and other forms of communication are poor substitutes.

According to him, as time changes, some firms may move because advantages can erode. As technologies mature, some activities get exported to lower-cost production areas (i.e., outsourcing). As industry grows, the activities increasingly are pulled to lower- cost regions (i.e., labor migration occurs).

Vernon's findings imply that the requirements for the emerging industry may differ from those for the maturing industry. Hence, the location behavior changes as industry matures.

However, location is not always static, either. In particular, once a place establishes momentum of, for example, a certain knowledge domain, the location tends to become "sticky." This place, in turn, has substantial influence on the followers' location. (Krugman, 1991 and 1995; Markusen, 1996) Many entrepreneurial activities, for example, happen to occur in the places where entrepreneurs have personal connections or preferences. (Roberts, 1991; Rosegrant and Lampe, 1992; Saxenian, 1994) Once a place gains momentum for several firms in an industry, such as Microsoft and the software industry in the Seattle area, it tends to become a magnet for followers in the same industry. A traditional example is the cluster of firms in the auto industry in the Detroit area. (Krugman, 1995) As a product becomes standardized, however, the degree of concentration may decrease due to the pressure of cost minimization and the "congestion effect" (Polenske, 2003). From the location perspective, the concentration level of a newly emerging industry is high at the initial phase mainly due to the existence of only a few establishments. Later, more establishments and more jobs in the industry appear in the market. Because of the longitudinal evolutionary process of an emerging and then maturing industry, the concentration pattern needs to be examined over time.

Industry life-cycle theory articulates the progress of industry development and its implications for the location pattern (Vernon, 1966).[18] According to Williamson (1975), there are three distinguishable stages; the early exploratory stage, the intermediate development stage and the mature stage. In addition, Klepper and Miller (1995) identified and closely examined the stage of "shakeout" and found that shakeouts are distinguished

[18] I use industry life cycle (Williamson, 1975) and product life cycle (Vernon, 1966) interchangeably.

by rates of entry into the market falling off sharply, but rates of exit remain steady or rise over time. (Table 2-3)[19]

The implication of the industry life-cycle theory on location patterns is that the earlier the stage that an industry is in, the more the firms tend to agglomerate because geographic proximity matters the most at the early stage of the industry life-cycle when "tacit knowledge" is important (Audretsch and Feldman, 1996).[20] As products mature and standardize, the business activities, especially manufacturing, tend to diffuse.

Table 2-2. An Industry Life-Cycle

	Exploratory Stage	Intermediate Development	Shakeout	Mature
Production Volume	Low	Rapidly Increasing	Declining	Stagnate or Declining
Uncertainty	High	Medium	Medium	Low
Entry	Emerging	Expanding	Sharp Declining	Low
Exit	N/A	Low	Low-Medium	Low-Medium

Source: Author. Reconstructed from Williamson (1975) and Klepper and Miller (1995)

However, as I will discuss later in the modularization and functional separation section in this study, today's diffusion pattern comes with organization change, so that the business movement can occur at the business activity level, instead of the firm level, due to the new information and communication technology. In other words, I argue that the location decision is made by business activities, instead of whole firms, in the new economy.

[19] This kind of fluctuation can be explained by the myopic behavior of firms.
[20] More detailed discussion about "tacit" knowledge follows in the next section.

2.2 Recent Changes in the New Economy

As new information and communication technologies (ICT) emerge and more firms utilize the new technology in their business, the way of doing business seems to be changing. To maximize the utility of the new ICT, firms tend to reshape their organizations. New business practices and increasing market competition tend to increase drastically the relative value of tacit knowledge, at least, in the knowledge-intensive industries. In consequence, location choice behavior seems to be changing accordingly.

In the following, first, I summarize what places offer to firms to help sort out the location factors and relative importance of each factor for various business kinds. Second, I discuss the current organizational change, which, I argue, greatly affects the current locational pattern. As I discuss later, modularization is one critical phenomenon to explain current geographic concentration. Third, I focus on the tacit knowledge and its importance for knowledge-intensive industries. I empirically examine the location pattern of knowledge-intensive industries in detail in Chapter 3.

2.2.1 What Places offer to Firms: Emerging Importance of a Pool of Knowledge Workers and Well-informed Customers in the New Economy

Before discussing recent changes in the new economy, I summarize what geographic places offer to firms. Places offer to firms a bundle of tangible and non-tangible characteristics. Labor, for example, varies considerably place-to-place. Analysts can capture these variations by calculating the costs of the wage-and-benefits packages and even hiring and training costs. At the same time, labor characteristics differ from location-to-location in terms of level of unionization, skills, attitudes, willingness to work, gender, and ethnicity. The importance of each locational characteristic varies from business-to-business. The relative importance has also changed as the new ICT emerges. Firms choose places based upon the features of location as a bundle.[21] Hayter (1997) summarized the location characteristics as follows. (Table 2-3)

Table 2-3. A Typology of Location Characteristics

Location Factor	Tangible Features	Non-Tangible Features
Transportation	freight rates	reliability, frequency, damage, availability
Materials	production costs, transportation costs	security, quality
Markets	transportation costs, servicing costs	personal contact, tastes, rivals
Labor	wages, non-wage benefits, hiring costs	attitude, unionization, skill, type, turnover, availability
External Economies (Localization and Urbanization)		externalities (positive and negative) labor skills, information sharing, common services, reputation
Energy	Costs	reliability, diversity
Community Infrastructure (SOC, EOC)	capital cost, taxes	quality, diversity
Finance	cost of borrowing	Availability
Land/Buildings	costs, rent, size	shape, access, services, lay-out, age
Amenity		worker preferences, local attitudes
Government Policy	incentives, penalties, taxes	attitude, stability, business climate
Local Customer**		Taste, market testing, innovation source

* Notes: SOC: Social overhead capital; EOC: Economic overhead capital
** Local customer is added by author.
*** Source: Hayter (1997) p.84; Modified by Author.

[21] According to Machlup (1967), there are three types of firms regarding decision making – marginalist, behavioral, and managerial. Although firm decision theory is related to the job-location pattern, the firm decision theory is beyond the scope of this research. For more information on this topic, refer to Machlup (1967).

Notice that firms tend to view specialized business activities as units of location choice. Firms function to coordinate various business activities. Firms assemble materials and services in order to add value by the application of factors of production (labor, capital, location, etc.) and then to ensure the distribution of the output.

Not all functions of a firm are located in one place. IBM's global organization case is palpable. The number of employees focused on business rather than pure technology has leaped from 3,500 in mid-2002 to more than 50,000 today – out of a total of 330,000. And they are growing at more than 10,000 a year. They are scattered all over the world. Meanwhile, IBM has 6,000 employees working for a customer-relation division, mainly customer-call centers, in India. (BusinessWeek, April 18, 2005) Because of increasing location freedom induced by the new ICT, firms become able to choose best location in the world for their each sub business unit.

Furthermore, this trend fueled emergence of highly specialized firms, such as semiconductor manufacturing firms and semiconductor design firms, which used to be part of a firm. Emergence of specialized semiconductor manufacturing firms is an example. Moreover, further sub-specialized firms are created, which conduct only wafer design, wafer fab, or packaging.

Given the business reorganization, for example, the monetary cost seems to be the most important concern in manufacturing activities. Even in a mature industry, such as clothing, however, design activity may still require a location of skilled labor and/or well-informed customers. For call centers, I argue that the importance of transportation costs, which play a significant role in the early industrial location theories, becomes virtually irrelevant.

2.2.2 Organizational Changes in the New Economy: Modularization and Functional Separation

Firms are not static. Firms utilize the new information and communication technology by reorganizing themselves, and often times the reorganization creates needs for additional new information and communication technology (Zuboff, 1988; Fountain, 2001). Recently, product/production modularization and functional separation over distance have become prominent. This organizational change is one of the instruments to the paradox of individual firm's dispersion and geographic job concentration.

The use of the new ICT causes business organization to maximize the utility of the new technology. A significant component of the value of information technology is its ability to enable complementary organizational innovation, such as business processes and work practices.[22] (Brynjolfsson and Hitt, 2000; Levy and Murnane, 2004)

> Firms adopt computers to gain a particular competitive advantage. Realizing computers' potential requires *reorganizing* work. As computers proliferate in the workplace, the jobs they create, destroy, and change are the byproduct of this work reorganization. (Levy and Murnane, 2004, p. 34, italics added by author)

This organizational change adds to the complexity required to understand job location patterns in the new economy. Organizational change is shaped by organizational culture and power relations; performance pressures and external market; and regulatory

[22] Brynjolfsson and Hitt (2000) also argue that the organizational innovations, in turn, lead to productivity increases by reducing costs and, more importantly, by enabling firms to increases output quality in the form of new products or in improvements in intangible aspects of exiting products like convenience, timeliness, quality, and variety.

conditions (Schrock, 2005).[23] To respond to current business climate changes and to take advantage of the new ICT, two prominent organizational changes have emerged; functional separation and modularization.

For Chandler (1990), a business historian, the rise of the modern multi-unit firm was an epochal event in the history of the modern world in the twentieth century. Modern economic growth is based upon high volume production technology, which takes advantage of economies of scale and scope. A geographically dispersed multi-unit organization emerged to overcome the limitations of a single-unit organization, which was restricted in realizing economies of scale and scope.[24] The emergence of the multi-unit firm was aided by significant technological developments, which lowered the costs of coordinating and monitoring multi-unit firms. Numerous advances in ICT and innovations in management and accounting techniques significantly lowered the costs of operating geographically dispersed units. (Kim, 1998)

With the advent of new ICT, this organizational change accelerated both at an individual firm level and at an industry and economy level. Gangnes and Assche (2004) pointed out the trend towards modularization. Sturgeon (2002) identified the adoption of ICT as an important driver for the most recent wave of product modularization and organizational change in the electronic industry. Modules are independent from one another. Changes can now be made to one module independently from other modules, as long as the changes are compatible with the codified interfaces that govern the operability

[23] Firms are known not likely to perceive accurately what is happening, and they interpret what they perceive through the cognitive frameworks of managers. As a result, the response of an individual firm may vary. (This discussion deserves a separate study. Refer to Schrock, 2005 and his references)
[24] According to Kim (1998), multi-unit firms also necessitated innovations in management structure. He argues that whereas activities of single–unit firms were coordinated and monitored by the market mechanism, those of modern multi-unit firms were coordinated and monitored by middle managers.

of the system. In Figure 2-5, each firm, such as IBM, Microsoft, and Solectron, primarily focuses on its modules and also cooperates with other firms. Modularity also bestows greater flexibility on a system by enabling firms to mix and match compatible components to produce heterogeneous final products (Schilling, 2000)

Place <Figure 2-5> here.

However, modularization requires standard-setting, which is a counter force to dispersion. For example, Gordon (2001) found that Silicon Valley is the key location for the standard-setting activity in the electronics industry, which sometimes runs into resistance because standard-setting often times requires revealing tacit knowledge. As an industry becomes increasingly modular, the standard-setting activity becomes more important. Hence, "being in Silicon Valley is a huge advantage" (Sturgeon, 2003).

Therefore, original equipment manufacturers continue to keep their highest value added modules in developed countries, while they move low value-added modules to developing countries because of a comparative cost advantage.[25] (Luethje, 2002) This change in the international division of labor helps explain agglomeration and dispersion trends of the jobs in the United States.

Consequently, functional separation and modularization lead to a horizontal industry life-cycle process and a new spatial division of labor within firms and between firms. If, for example, a firm can locate R&D anywhere, it would locate R&D at the

[25] Multinational firms are also concerned with the lack of property rights in developing countries. (Fan, 2003)

source of competitive knowledge.[26] On the contrary, if a firm can locate its customer-contact units anywhere, the firm would put the units close to customers. Therefore, the concentration and dispersion of jobs depends on the needs of each business activity. In general, tacit knowledge-oriented production activities may concentrate more at the aggregated spatial level, whereas customer-oriented activities may follow the spatial pattern of customers, which is typically rather dispersed.

2.2.3 Increasing Importance of Tacit Knowledge: Knowledge Creation and Distribution, and Bounded Rationality

As the importance of knowledge increases, a strand of literature accounting for knowledge is being re-discovered in the context of economic development and spatial economics. Polanyi (1974 [1962], p. 53) proposed the duality of knowledge and introduced "tacit" knowledge in his path-breaking book, *Personal Knowledge*.

> An art which cannot be specified in detail cannot be transmitted by prescription, since no prescription for it exists. It can be passed on only by example from master to apprentice. This restricts the range of diffusion to that of personal contacts, and we find accordingly that craftsmanship tends to survive in closely circumscribed local traditions. Indeed, the diffusion of crafts from one country to another can often be traced to the migration of groups of craftsmen, … .

Polanyi (1962) said that the knowledge used as a *tool* to handle or improve what is in focus is tacit knowledge. He argues that even scientific knowledge is not purely

[26] R&D or any business activity can be located even in expensive places as long as the return is greater than the cost. Because breakthrough innovations can yield monopolistic market power, at least for a certain period of time, which allows for firms to be able to set price, location costs tend to be a lower priority for the state-of-the-art oriented business activities.

objective, especially when the knowledge is created and utilized. Similarly, Wiener (1948) viewed information as feedback (Johns, 2004).[27] Levy and Murnane also assess the importance of the human-cognitive processing of information, which is used "to decide what to do next or update their picture of the world" (Levy and Murnane, 2004, p. 5).[28]

The key issue is that tacit knowledge cannot be easily transferred. Marshall (1961 [1920], p. 271) described a way of conveying tacit knowledge as follows.

> The mysteries of the trade become no mysteries; but are as it were in the air, and children learn many of them unconsciously. Good work is rightly appreciated, inventions and improvements ... have their merits promptly discussed: if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of further new ideas.

The best way to convey such knowledge is "learning by doing." Learners learn through demonstration and practice, such as in the classic master-apprentice relationship in which observation, imitation, correction and repetition are used in the learning process. (Polanyi, 1962; Arrow, 1962; Lundvall, 1994)

To compete effectively, it is not enough to look at trade journals or computer screens, to communicate via telephone conferences or to monitor plants in remote locations via modern communication means (Graham, 1996). Being where your partners and competitors are is still an important asset. Socializing with them allows the opportunity to ask for advice or for a specific bit of information that has not been formalized (Desrochers, 2001, p. 34).

[27] Wiener (1948) articulated that to practice science is to distingush signals from noises.

[28] Although tacit knowledge requires cognitive processing first, not all cognitive processing is necessarily tacit. Some cognitive processing can be written in a rule-based algorithm, and can be controlled by machines with little intervention of people.

> Could this device be modified to do this? How does it react under such and such condition? Have you ever tried something like this? Do you know somebody who could do that? Did you ever do business with them? What is going on over there? What kind of technologies are they using? Why are they no longer doing business with them? Why did he quit his job? etc.

In this regard, geographic proximity and/or language community becomes more important in tacit knowledge-related activities. According to Piore (2004), for example, off-shoring of R&D is an organic growth process in which personal contacts are important; especially to start the process, build language community, and communicate effectively. Saxenian (1994) discovered that the languages are substantially different between Silicon Valley workers and Boston Route 128 counterparts even in the same electronics industry.

Along the same lines, Saxenian also found that the region's social and professional networks were not simply conduits for the dissemination of technical and market information. They also functioned as efficient job-search networks (Saxenian, 1994, p. 34).

> "In this [computer] business [in Silicon Valley] there's really a network. You just don't hire people out of the blue. In general, it's people you know, or you know someone who knows them." (Gregory 1984; requoted from Saxenian, 1994, p. 34)

Finding knowledge workers is an extreme example of dealing with invisible knowledge, because employers look for a knowledge factor that is inside the head of knowledge workers.

Interestingly, the informal weak-tie network was equally important when the new information and communication technology did not exist, and the importance seems never to disappear. Granovetter (1974) found that professionals rely primarily on their set of personal contacts to get information about job-change opportunities rather than more formal or impersonal routes. According to him, in the majority of cases, people hear about new jobs through their personal contacts. Simply speaking, no matter how great the net advantage of a new opportunity, the person cannot take advantage of it unless they know about it. He concluded that managerial workers with more social contacts are more likely to find their next job through personal contacts.

Lester and Piore (2004) argue that there are two dominant approaches for knowledge creation; the analytical approach and the interpretive approach. The former approach is that of the engineers and is dominantly analytical and focused on problem solving. Engineers define the problem, break it into constituent parts, find solutions for the pieces of the problem, and then assemble them into something whole that solves the defined problem. Precision and the elimination of ambiguity are central to this approach.

The second approach they call "interpretive." Here the emphasis is on a constant process, whereby communication may be less precise, but more open-ended and fluid, leading to more creative ideas. In this view, it is recognized that creativity is a social process, a so-called "cocktail party." People from a diverse group engage in open-ended communication. People with different backgrounds co-mingle and move about, talking to others openly, without a preset agenda. The thrust is the discovery of new directions, new languages, new perspectives. Lester and Piore (2004) argue that both approaches are essential in knowledge creation.

Von Hippel (1988) investigated two major classes of process equipment used by the electronics industry and found that the innovators are most often users. The user-innovation relationship is critical in the high-tech industries, especially at the specific marketable product development stages. As illustrated below, a high-tech firm needs to specify a set of product configuration out of general technologies in order to make a product or provide a service.

The difficulty of transferring tacit knowledge, especially in the initial stage of communication, arises from the fact that the participants themselves are not fully conscious of every detail of what they do or that the language they are using is not well enough developed to transfer clear explication. (Polanyi, 1966)

Today, codified knowledge may travel the world with gradually less friction thanks to improvements in ICT. Such reductions in the friction of space have sometimes led to the assumption that knowledge, once codified, is almost instantly available to all firms at zero cost regardless of their location. However, in reality, there are usually substantial, sometimes even prohibitive costs associated with identifying, assessing, assimilating, and applying codified knowledge already in existence and use. Attaining knowledge existing at new locations requires decisions and investments (Leamer and Storper, 2001).[29]

In the high knowledge-generating customer-oriented industries, the incentive to locate jobs close to customers is highlighted by the following example. Approximately 52 percent of the nation's total procurement in homeland security products and services in 2004 was captured in the Washington, DC metropolitan statistical area (MSA) (Mayer,

[29] According to Almeida and Kogut's (1997), in their patent-citation study, they found that small firms tend to explore new technology areas and make more use of local patents than large firms do.

2005). The firms and branches located in the DC area are typically involved from the beginning to the end of a federal government project. (Markusen, Hall, Campbell, and Deitrick, 1991) In sum, firms, if they need, can have their relevant work units close to both suppliers and customers due to the use of the new ICT.

Analysts note that some competitive knowledge does not require close interactions or intensive input-output relations involving substantial physical transactions, but does require geographic proximity. According to Porter (1998), for example, strong competition and rivalry between firms on the horizontal dimension of a spatial cluster is an important incentive for innovation and product differentiation. The respective firms benefit from their co-location through which they are well informed about the characteristics of their competitors' products, and about the quality and cost of the production factors they use. He suggested this competitive advantage of proximity arising out of continuous monitoring and comparing, which is one kind of tacit knowledge essential to business.

As the same time, information generation, acquiring, communicating and processing are costly (Stiglitz, 1985). Along the same lines, Amsden (2001) pointed out that the neoclassical economic assumptions – knowledge is ubiquitous and free and, furthermore, every economic actor has the same knowledge – are unrealistic. Stiglitz and Amsden's imperfect and costly information problem becomes more prominent in the new knowledge economy.

Amsden (2001) continued to suggest three domains of necessary knowledge for a business: (1) production knowledge to transform inputs into outputs; (2) project-execution knowledge to expand capacity, marketing, etc; and (3) innovation knowledge to design entirely new products and processes. Each category of knowledge consists of codified and tacit knowledge. Knowledge in every domain is required for a successful business operation. Amsden's (2001) notion expands the scope of knowledge from product knowledge to a broader context including project execution, process, and client interactions.

Bounded Rationality: Location is ultimately a part of a strategic decision made by individual firms, which base upon available knowledge and information.[30] Rational decision-making, especially in this kind of incomplete decision-making situation, tends to be bounded. Simon (1955, p. 99) alluded to this quasi-rational behavior in his article about the limitations of rational decision-making.

> This [rational decision-making] man is assumed to have knowledge of the relevant aspects of his environment which, if not absolutely complete, is at least impressively clear and voluminous. He is assumed also to have a well-organized and stable system of preferences, and a skill in computation that enables him to calculate, for the alternative courses of action that are available to him, which of these will permit him to reach the highest attainable point on this preference scale.

Simon pointed out that traditional economic theory presupposes a rational economic man. Alternatively, he tried to construct "rational choices" that are more closely based upon the actual human decision-making processes. He proposed a satisfying pay-off model by which people choose a "good enough" option, rather than the traditional neoclassical economic maximizing model.

In particular, this issue is important for high-tech firms, which deal with unprecedented products or services. Both firms and customers do not know exactly what

[30] The very origin of high-tech entrepreneurial firms often times happen "by accident" at the entrepreneurs' personally related places. (Krugman, 1995; Rosegrant and Lampe, 1992; Roberts, 1991)

the new products or services can or cannot do. Both firms and customers undergo a significant mutual-learning process. Firms learn what customers want and educate customers about what the products and service can do for customers. Likewise, customers learn what the products and services are and ask for certain kinds of functions or customization.

2.3 Potential Forces to Increase the Geographic Agglomeration of High Knowledge-Generating Jobs

> Previous rounds of infrastructure improvement always have had a double effect, permitting dispersion of certain routine activities but also increasing the *complexity* and the *time dependence* of productive activity, and thus making agglomeration more important. We argue that the Internet will produce more of the same – forces of deagglomeration, but offsetting and possibly stronger tendencies toward agglomeration. (Leamer and Storper, 2001, p.1, italics added by author)

With the new ICT, more dispersion of some business activities is relatively intuitive to us, because this dispersion is related to efforts of cost reduction. In addition, Polenske (2003) pointed the need to operate with local, national, and global supply chains in which they can disperse production and distribution centers throughout the world.

Increasing concentration of some business activities can be counter-intuitive, at first glance, because more concentration tends to increase cost. Polenske (2003) also discussed the "congestion cost" of being together. For example, the computer and semiconductor industry remain concentrated in Silicon Valley and Boston Route 128 where business costs are high.

Economies of scale that enables emergence of large establishments can explain high geographic concentration because economies of scale may compensate the diseconomy of concentration through the increase in efficiency of production as the number of goods being produced increases.

Alternatively, analysts, such as Audretsch and Feldman weigh more on external economies of scale, or agglomeration economies, to explain the current job-concentration pattern. Agglomeration economies are of two types – localization economies and urbanization economies. Localization economies are benefits created external to an individual business unit from the agglomeration of business activities of the same kind in one geographic area; and urbanization economies are benefits created external to an individual business unit from the agglomeration of various kinds of business activities in one geographic area.

I argue that all of these external economies stem from accumulated knowledge capacity in a region including potential workers who possess the knowledge and specialized services. In this section, I synthesize existing literature around knowledge and knowledge transfer (or, communication) to understand geographic concentration in the new knowledge economy. I focus on what information and knowledge is and what information and knowledge means to the economy. Communication includes internal linkages (e.g., intra-firm communication), supply-chain linkages (e.g., inter-firm communication for a production), and broader linkages including marketing and market research (e.g., communication between customers, workers, institutions, and society).

In the rest of this section, I enlist potential forces of increasing geographic concentration of business activities.

2.3.1 Rising Competition

As Hotelling demonstrated this issue in his seminal work, *Stability in Competition* (1929), competition, ceteris paribus, can increase concentration even though firms can choose any location. In his model, firms' profit-maximization behavior leads all of them to locate at essentially the same location as everyone else due to competition. Paradoxically, it is the firms' location freedom that enables the spatial monopolization. Spatial dispersion of economic entities is presumed as an individual economic entity's location choice becomes freer. (Negroponte, 1995; Martin 1996; Cairncross, 1997, 2001) However, even though every individual business entity has more locational freedom, certain business activities can still spatially concentrate due to other factors such as competition for the most profitable optimum location.

2.3.2 Speed Economy - the relative value of time

As competition becomes fiercer in the new economy, the use of the new ICT has increased the importance of speed – knowledge-generation speed, idea-to-product speed (commercialization), and product-to-market speed (Fine, 1998).[31] Hence, the relative value of time has become more valuable than ever. Even though the transaction time

[31] According to an R&D Director of Motorola; "A prototype cell phone development took about three months a decade ago and it was fine. Now, Motorola works with a Japanese firm on prototype cell phone development. It takes about two to three weeks. But, a couple of weeks are not short enough to compete with Samsung. Samsung Electronics placed a prototype manufacturing unit in its R&D center, and it can produce a cell phone prototype in-house in three days. Samsung's R&D-to-product-to-market speed is stunning" (personal interview, Motorola R&D in Korea, June 10, 2003)

decreases, the importance of time can still increase if the unit value of time increases at a faster rate than the amount of time decreases.

In consequence, I maintain that the increasing importance of time may lead to a related importance of proximity for faster transactions. The increasing importance of speed, which is driven by the use of the new ICT, therefore, can act to increase geographic concentration of knowledge-related jobs in the fiercely competitive global market in spite of the decreasing amount of time required for business interactions.

As ICT reduces the time to market for a developed product, it becomes increasingly valuable to be the first to market while the value of being later to market falls. This raises the value of being able to develop products fast, which leads to the concentration of development activities. In other words, shortening the time it takes to get to market raises the cost of time in development.

2.3.3 Increasing Importance of Tacit Knowledge

Recently, the studies of the forms of knowledge are being rediscovered, as knowledge becomes increasingly important in economics and business (Gertler, 2004). Polanyi (1962) pointed out the two forms of knowledge and introduced the concept of "tacit" knowledge to complement "codified" knowledge. He defined tacit knowledge as a kind of knowledge used as a tool to handle or improve what is in focus. The relevant question is not whether some knowledge is in principle codifiable or necessarily tacit. Instead, some knowledge remains, in fact, tacit if the willingness to codify it is low or the cost of codifications is high. The relative significance of the tacit dimension will depend, therefore, on a combination of cost and context (Morgan, 2004).

According to Leamer and Storper (2001), although codified knowledge may instantly travel the world with gradually less friction thanks to improvements in ICT, it does not necessarily mean that all firms make use of the knowledge at zero cost regardless of their location.[32] This codified knowledge is useless to a firm until the firm absorbs the knowledge. There are usually substantial, sometimes even prohibitive costs associated with identifying, assessing, assimilating, and applying codified knowledge already in existence and use. Attaining knowledge existing elsewhere requires decisions and investments. That is, knowledge is a product of codified knowledge and tacit knowledge.

Even in cases where codified knowledge is almost omnipresent, it becomes valuable only if it is appreciated with tacit knowledge, which is less transferable (Leamer and Storper, 2001). Because of the critical role of less transferable tacit knowledge, geographic proximity can still be important for tacit knowledge-related business activities and jobs.

2.3.4 Communication and Knowledge Transfer

The speed of transferring codified and tacit knowledge – within a firm, between firms, and between a firm and customers – bifurcates. Before the new ICT, transferring either kind of knowledge took some time. With ICT, codified knowledge can travel virtually instantly. According to Stiglitz (1985), [tacit] knowledge transfer costs are non-negligible, especially in high-tech industries.[33] Although the use of the new ICT

[32] For example, we cannot put into words everything you need to know to be able to ride a bicycle the first time without falling.

[33] Stiglitz did not explicitly use the term "tacit" knowledge in the paper. But, I infer from his explanation in the text that he used the word knowledge to mean tacit knowledge.

decreases the amount of time for transferring codified knowledge, the amount of time for transferring tacit knowledge has not changed as much. For example, the best way to convey tacit knowledge is "learning by doing." Learners learn through demonstration and practice, such as in the classic master-apprentice relationship in which observation, imitation, correction, and repetition are used in the learning process. (Marshall, 1920; Polanyi, 1966; Arrow, 1962; Lundvall, 1994).

If the relative importance of tacit-knowledge increases, spatial proximity remains important, because tacit knowledge is less transferable. Combined with the importance of speed and the difficulty of tacit- knowledge transfer, communicating tacit knowledge may become an important location concern, at least for knowledge-related business activities. The concentration-dispersion impact remains to be examined empirically.

2.3.5 Place as a Job Holder

Many small to midsize start-ups in the Boston metropolitan area are headed by people who were previously at a senior level at pioneering computer companies such as Wang Laboratories, Digital Equipment Corporation (DEC), or another of the region's established companies that went out of business (*Boston Globe*. April 6, 2003). Although 40 to 50 percent of establishments in Silicon Valley closed during the same period (Zhang, 2003), the number of computer-related jobs in Silicon Valley continued to grow during the 1990s.[34] I maintain that the boundaries of individual firms become fuzzy. A region's industry system seems to play a role in creating and sustaining jobs beyond individual firm's success and fail.

[34] Source: U.S. Bureaus of Labor Statistics. Author's calculation.

Furthermore, Florida (2002) argued that workers, at least the "creative class," have more location leadership and tend to go to "creative" places. Then, he argued, firms follow the "creative class." Consequently, firms are enticed to locate in "creative places" where the "creative class" resides. Markusen, 1994, among others, presumes that the firm itself is the primary job holder; yet, there is a growing evidence that place, rather than firms, may play the role of job holder. The relative mobility of (skilled) workers and jobs remains to be examined.

In summary, knowledge-related business activities include creating knowledge, sharing knowledge, identifying clients' demands, communicating with existing and potential customers, and so forth. Tacit knowledge becomes the key element of the high-tech business success. I hypothesize that proximity is still, or even more, important for those jobs in the high knowledge-generating business activities and the degree of geographic concentration of the high knowledge-generating jobs may not decreases because (1) tacit knowledge is much less transitory than codified knowledge and (2) the high knowledge-generating jobs deal with tacit knowledge and implicit learning, which is not easily transferable over distance and can hardly be replaced by machines in the foreseeable future. In other words, the job concentration level may remain high or sometimes gets higher.

Chapter 3

Geographic Concentration of U.S. High Knowledge-Generating Jobs

Economic geographers rediscovered job-location issues as a new "frontier." (Krugman, 1991) However, Head, Ries, and Swenson (1994) said that most evidence on the causes and magnitude of current industry location has been based on stories, rather than statistics; thus, a quantitative analysis on the effect of geographic concentration-dispersion patterns remains to be conducted.

Moreover, no one has conducted systematic longitudinal analysis on the geographic concentration of jobs at the metropolitan area level by the 4-digit NAICS industry. For a longitudinal empirical exploration on the geographic concentration of jobs at the metropolitan area level and at the detailed industry level, data availability is critical. Longitudinal studies to examine these questions are rare, partly because of the lack of consistent and coherent datasets and partly because of the highly complicated data processing involved.

As I discussed in Chapter 2, "death of distance" is true at an individual firm level. However, I hypothesize that "death of distance" at an individual firm level, which is driven by new ICT, paradoxically, enables spatial aggregation of knowledge-related business activities. In other words, concentration of knowledge-related business activities at a spatially aggregated regional level may increase. For example, the semiconductor production units of the largest semiconductor manufacturing companies, such as

Solectronics, Freescale, and Samsung, are found in Texas metro areas.[35] Texas metro areas seem to keep attracting semiconductor production activities. Specifically, I empirically explore the concentration-dispersion pattern of the high knowledge-generating business activities.

3.1 Data and Measurement

For a longitudinal empirical exploration at the metropolitan area level and at the detailed industry level, data availability is critical. Virtually no analysts have done longitudinal studies to examine the geographic concentration pattern change over time, partly because of the lack of consistent and coherent datasets and partly because of the highly complicated data processing involved even when data are available. Fortunately, the Bureau of Labor Statistics (BLS) released a consistent and comparable 1990-2000 dataset at the metropolitan area level by four-digit NAICS.[36] I use this dataset to conduct a coherent longitudinal analysis of concentration and dispersion of jobs.

This dataset cleared two major obstacles for a longitudinal analysis – geographic definition generalization and industry classification generalization. The definition of metropolitan areas has changed from 1990-2000. For example, San Jose Metropolitan Statistical Areas (MSA) includes San Benito county and Santa Clara county in 2000, but San Jose MSA counted only Santa Clara county in 1990. The industrial classification system also changed from the Standard Industrial Classification (SIC) to the North

[35] The Solectronics' headquarter is located in Silicon Valley and the Samsung's headquarter is located in Seoul, Korea. Both firms' units in Texas are the semiconductor manufacturing units.
[36] As of spring 2005, BLS has released the data through 2003. With the identical formula, Gini coefficients of every industry suddenly plummet in 2001, then they up-surge the next year, and then plummet again in 2003. These annual ups and downs are as big as the decadal changes. I conclude the 2001, 2002, and 2003 data are not reliable. I omitted those years in this study.

American Industry Classification System (NAICS) in 1997. For example, Computer Systems Design and Related Services (NAICS 5415) is a new industry classification, and I can find no comparable industry classification in the SIC. Mainly due to the geographic and industry definition changes during the 1990s, a valid longitudinal study was virtually impossible until the BLS released the recent dataset.

3.1.1 Business Activities and Industry Data

Business activities are the main foci of my empirical analysis, and I use the number-of-jobs data at the four-digit NAICS level by BLS. The Economic Census division of the Census Bureau assigns one NAICS classification to each establishment.

For example, IBM has multiple establishments in the United States, with seven branches in Massachusetts, according to ReferenceUSA (2005). Some of these branches are classified in manufacturing and others are classified in retail or service, based upon their major activities (Table 3-1).[37]

Although IBM is known as a computer company, some branches are classified as, for example, retail or professional service. When BLS aggregates the job numbers to a metropolitan area, IBM's jobs in the retail branch, for example, are added to the retail industry, instead of the computer industry. The BLS' job numbers, therefore, can be interpreted as the number of jobs by business activity.

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[37] The classification by Census at each individual establishment level is not available due to privacy protection. ReferenceUSA is a private business-data firm that compiles the firm information, such as NAICS and number of jobs, based upon its own survey and publicly available data. Because the NAICS classification in ReferenceUSA is each establishment's self-assignment, the ReferenceUSA classification may vary from the Census' classification. I note that regardless of self-assignment, not every IBM branch claims computer manufacturing.

Table 3-1. IBM Branches in Massachusetts with NAICS

City	NAICS*	Number of Employees
Marlborough	3341	Unknown
Newburyport	4431 (5416)**	5-9
Waltham	4431 (5416)**	500-999
Wellesley	4431	5-9
Westborough	5112 (4431/5415/5416)**	250-499
Westborough	4431	1-4
Auburn	4431	1-4

* NAICS 3341: Manufacturing / Computer and Peripheral Equipment Manufacturing
NAICS 4431: Retail / Electronics and Appliance Stores
NAICS 5112: Information / Software Publishers
NAICS 5415: Professional, Scientific, and Technical Services / Computer Systems Design and Related Services
NAICS 5416: Professional, Scientific, and Technical Services / Management, Scientific, and Technical Consulting Services
** ( ) shows secondary activities.
*** Source: ReferenceUSA (2005)

3.1.2 High Knowledge-Generating Industries

Paytas and Berglund (2004) defined the high knowledge-generating industries as those that exceed the U.S. average for both research and development expenditures per employee ($11,297) and the proportion of full-time-equivalent R&D scientists and engineers in the industry workforce (5.9%).

The following six production industries and three service industries at the four-digit NAICS level meet these two criteria:

1. Basic chemical manufacturing (NAICS 3251);
2. Computer and peripheral equipment (NAICS 3341);
3. Communications equipment manufacturing (NAICS 3342);
4. Semiconductor and electronic component manufacturing (NAICS 3344);
5. Electronic instrument manufacturing (NAICS 3345);
6. Software publishers (NAICS 5112);
7. Architectural and engineering services (NAICS 5413);
8. Computer systems design and related services (NAICS 5415); and

9. Scientific research and development services (NAICS 5417).[38]

These industries are also the most intensive users of new information and communication technology such as the Internet, Intranet, EDI, and E-commerce.[39]

3.1.3 Measurement

I use Gini coefficients to measure the level of geographic concentration of jobs by business activities.[40] The Gini coefficient was originally developed to measure income inequality, and it works best when the units of analysis can be assumed to be equal. In measuring geographic concentration using the Gini coefficient, an analyst must deal with three issues: One is the different size of geographic units; the second is the aggregation level of industry, for example 3-digit or 4-digit industry level; and the third is the rank of geographic areas.

Various studies have adopted slightly different versions of the Gini coefficient. For example, Krugman (1991) used a rather straightforward Gini coefficient at the State level and at the 3-digit SIC industry aggregation. Audretsch and Feldman (1996) adopted a weighted Gini coefficient. Taking this further, Ellison and Glaeser (1997) empirically calculated the sensitivity of the Gini coefficient for various geographic units and by various industry aggregation levels. Specifically, they calculated the geographic concentration by County, State, and Region and by 2-digit and 4-digit industry

[38] There are 330 four-digit NAICS industries.
[39] Source: Annual Survey of Manufactures – Computer Network Use Supplement 1999. No ICT usage statistics are available for the service industries.
[40] To encompass the entire range of U.S. jobs, I treated the rest of employment in non-MSA areas as "the other" area.

classification. Their calculations reveal that the Gini coefficient is sensitive to aggregation levels.

To study the location pattern by detailed business activity, I assume that the metropolitan area is the most appropriate geographic unit of analysis. The state is too big to be regarded as individual economic entities. Likewise, the county has little to do with an economic activity. For example, the Boston metro area has five counties, although all of the counties work together on many issues as one economic unit. For the purposes of categorizing industry agglomeration, I decided that the 4-digit NAICS is a sufficiently detailed aggregation level for this study. Table 3-2 shows an example of the 4-digit NAICS industries within the 4-digit NAICS classification number 334.

Table 3-2. 3-digit and 4-digit NAICS

NAICS	Title
334	Computer and electronic product manufacturing
3341	Computer and peripheral equipment mfg.
3342	Communications equipment manufacturing
3343	Audio and video equipment manufacturing
3344	Semiconductor and electronic component mfg.
3345	Electronic instrument manufacturing
3346	Magnetic media manufacturing and reproducing

Source: U.S. Census

Finally, I use the Location Quotient (LQ) as a rank order. A share-based rank tends to underestimate smaller metropolitan areas and a weighted-Gini coefficient tends to overestimate smaller metropolitan areas. By ranking metropolitan areas by their LQ, I obtain a relatively un-biased Gini coefficient.

3.2 Change of Concentration Level of High Knowledge-Generating Industries during the 1990s

From both my interviews and my empirical analysis, I find that jobs in the high knowledge-generating *production* industries became further concentrated during the 1990s. During the same time period, jobs in the high knowledge-generating *service* industries dispersed. In the former industries, producers are the major knowledge generators, while in the latter industries, tacit knowledge is derived mostly from the interaction between firms and customers. Correspondingly, the jobs in the former industries agglomerate with each other, but the jobs in the latter industries locate near to their customers. (Figure 3-1)

Place <Figure 3-1> here.

In the high knowledge-generating production industries, for example, my interviews indicate that when a firm, anywhere in the world in theory, needs semiconductor manufacturing, the use of the new ICT enables the firm to leverage the Austin and Dallas, TX area – which is highly specialized and advanced in semiconductor manufacturing – by sending its sub units to the Austin and Dallas area and/or utilizing partnerships with existing firms in Silicon Valley.[41]

In the high knowledge-generating customer-oriented industries, a similar agglomeration can occur, but for different reasons and in a different way. For example,

[41] The new ICT increases the possibility of remote collaboration. The actual remote collaboration outcome is, however, also subject to other factors, such as cost and intellectual property. The new ICT is only a necessary condition, but not a sufficient condition for remote collaboration to occur.

approximately 52 percent of the nation's total procurement in homeland security products and services in 2004 was done in the Washington, D.C. metropolitan area (Mayer, 2005). The firms and branches located in the DC area are typically involved from the beginning to the end of a federal government project. (Markusen, Hall, Campbell, and Deitrick, 1991) An interviewee said that "if you want to work with the Federal government, at least your branch should be there [Washington, DC] in order to understand what they really want and who has authority for a contract. It is an on-going relationship. It works like a club." (personal interview, Open GIS Consortium, December 8, 2006) In the case of Parsons Brinkerhoff, the major clients were in the New York City area; hence, the development team wants to be close to the location of clients for better mutual understanding. In sum, firms can be close to both suppliers and customers due to the use of the new ICT. In consequence, paradoxically, high knowledge-generating production business activities agglomerate near each other; whereas high knowledge-generating service business activities tend to disperse in order to be closer to customers.

Currently available BLS statistics, however, may underestimate the degree of dispersion of the high knowledge-generating service industries.[42] An interviewee of mine told me that his marketing director spent two-thirds of his work hours in Europe in order to meet European customers last year. Likewise, many professional workers make business trips to meet customers for design, consulting, conferencing, and so forth. These business road warriors are, however, generally counted only at their primary working location. As a result, the actual degree of job dispersion in the high knowledge-generating service industries may be greater than the statistics reveal.

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[42] The underestimation issue is raised by Professor Frank Levy.

3.3 Spatial Monopoly: "Winner-takes-all"

Five out of the six high knowledge-generating production industries show a "winner-takes-all" kind of spatial monopolization of jobs.[43] I calculated a dominance ratio to measure the significance of the top share holder relative to the second highest share holder. The dominance ratio remains high or increases for the five industries. For example, San Jose-Sunnyvale-Santa Clara, CA MSA (a.k.a. Silicon Valley) maintained over 16 percent of the jobs in the Computer and Peripheral Equipment Manufacturing industry (NAICS 3341) in the United States. Yet, all four secondary places – including Boston-Cambridge-Quincy, MA-NH MSA, Los Angeles-Long Beach-Santa Ana, CA MSA, Minneapolis-St. Paul-Bloomington, MN-WI MSA, and New York-Northern New Jersey-Long Island, NY-NJ-PA MSA – lost job share during the 1990s. The ratio of the job share of Silicon Valley, the top share holder, and the job share of the Boston metro area, the second highest job share holder, increased from 1.6 in 1990 to 2.9 in 2000. (Figure 3-2) This increasing dominance of the top share holder is the case in the following five of the six high knowledge-generating production industries: Basic chemical manufacturing (NAICS 3251); Computer and peripheral equipment (NAICS 3341); Semiconductor Manufacturing (NAICS 3344); Electronic instrument manufacturing (NAICS 3345); and Software publishers (NAICS 5112).

Place <Figure 3-2> here.

[43] I combined two adjacent metropolitan areas in Texas – Dallas and Austin – for the semiconductor job-share calculation.

3.3.1 Increasing Returns vs. Agglomeration Economies

To account for the possible effect of individual firm's scale economies, or the effects of the size of individual establishments, regarding job concentration, I investigated the employment size per establishment. The high knowledge-generating industries' average individual establishment size decreased during the 1990s, although their geographic concentration increased.

As seen in Figures 3-3 and 3-4, the average employment size per establishment has declined from 1990 to 2000. In Silicon Valley, this dropped by approximately 27 percent from 262 in 1990 to 190 in 2000. The nationwide average employment size per establishment of the computer industry has dropped by 13 percent from 144 in 1990 to 125 in 2000.[44]

Both the decreasing number of establishments with more than 500 employees and decreasing average number of employees per establishment strongly suggest that there is no significant impact of individual firm's economies of scale on the geographic job concentration. In other words, the data show that there are not even a handful of dominant establishments. Rather, the job dominance of Silicon Valley as a region in the computer and peripheral equipment industry was caused by the agglomeration of many small establishments.

Place <Figure 3-3> and <Figure 3-4) here.

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[44] Arising from this decrease in average number of employees, I note an issue that should be examined, but no datasets are readily available. Although the average employment size has decreased, an establishment may produce more if it adopts more automated productive technologies that require fewer employees.

3.4 Qualitative Evidence: Interviews

Here, I illustrate some examples, from my interviews, of tacit knowledge – product development knowledge and market-need knowledge – and how hard it can be to transfer this knowledge between co-workers and between a firm and customers in the high knowledge-intensive industries. Interviews also reveal that decision making is a complicated process, instead of conspicuous and objective outcome.

3.4.1 Knowledge Permeation with Customers and Colleagues

One of my interviewees, Jim, who works in the Millennial Net – which produces wireless sensor network devices – said, "I got the truly key idea [for the product] from a potential customer during my early marketing tour." [45] His original target customers were manufacturing assembly lines, which can use the sensor devices for production automation. However, the customer who gave him the key idea for business success was the manager at a window company, which he had never imagined before. The warranty on the company's window lasts seven years. In case of a water leakage within the warranty period, the company usually ends up paying the full price of the house due to the high repair cost. The window company consequently wants an tiny and long-lasting electronic device to detect a window-related water leakage, which can be embedded under the window and will last more than seven years. Therefore, Jim focused on small size and long battery life, so that the device can last more than ten years. He said, "My product became a great hit."

[45] Interview on May 31, 2005 with Millennial Net, Inc. Name is a pseudonym.

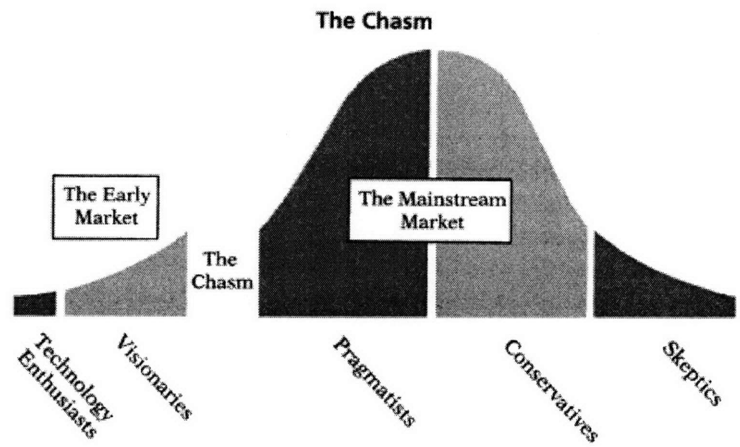
He recalled that success is very important. This success story, according to him, increased his company's visibility and led Millennial Net to different industries as customers, including manufacturing assembly lines.

Jim emphasized the importance of customers for his products. He introduced me to the notion of the "chasm." Moore (1991) used the term "chasm" and argued that there is a significant chasm for high-tech businesses to overcome between the few early-adopting visionary consumers and the majority of more pragmatic consumers. To cross the chasm, the seller must understand the user's needs.

According to Moore (1991), technology enthusiasts and visionaries brave trials and tribulations. They are not too bothered by the fact that the product does not work. They are willing to make it work. In contrast, pragmatists want a complete product, a 100% solution to their problem including customer-support services, such as training, technology, policies and procedures, customer support, etc. The majority of the market consists of pragmatists, and as a result, they are the key to business success. Moore said pragmatists do not accept references concerning new products from visionaries but only from one another. Conservatives get involved only when they have to, and want a completely hassle-free product. Skeptics will not adopt the new products, and often try to influence others to stay away. (Figure 3-5)

> The point of greatest peril in the development of a high-tech market lies in making the transition from an *early market* dominated by a few *visionary* customers to a *mainstream market* dominated by a large block of customers who are predominantly *pragmatists* in orientation. The gap between these two markets, heretofore ignored, is in fact so significant as to warrant being called a *chasm*, and crossing this chasm must be the primary focus of any long-term high-tech marketing plan. (Moore, 2002, p. 5, italics are in the original quote.)

Figure 3-5 The *Revised* Technology-Adoption Life Cycle



Source: Moore, 2002, p.17 (Italics is in the original diagram.)

Besides understanding the market demands, Jim notes that realizing the idea within his company is another very hard and long process. High-tech product concepts can make various promising products, but there is no one-size-fits-all solution. To make one product, a company has to deal with trades-offs between various product capabilities. In Jim's case, his science and engineering colleagues see much potential for their technology. For example, given the current available technology, he can develop his two-way mesh wireless network device working toward either low-energy consumption with limited technical capability or short battery life with maximum technical capability.

Actually, he listed the following six key objectives involved in a trade-off; (1) power supply (e.g., battery vs. AC) and consumption, (2) scalability (e.g., few communication specifications vs. a full range of communication specifications), (3) data rate (e.g., few frequencies vs. many frequencies), (4) range (e.g., 20-feet vs. 300-feet range), (5) mobility (e.g., fixed vs. mobile), and (6) level of integration (e.g., compatible with existing products vs. new standard). Because the combination of these six trades-offs at various degrees yields too many possible permutations to test, he had to prioritize a set of characteristics for the most saleable product and give up some other characteristics. To make one product, he had to stick to his decision. Otherwise, he said, "my firm would stray and might have failed to cross the chasm." (personal Interview, 2005. Millennial Net, Inc)

His decision created critics and disagreement within his firm. This was partly because there was no market information available for the conceptual product. His colleague scientists and engineers also do not want to compromise some features regarded as having technical superiority, such as full compatibility. As a result, internal negotiations were required. "So, I had to spend much of my time to communicate my *philosophy* to my colleagues."

From this experience, he began to appreciate the importance of interactions with his customers and workers. Consequently, his marketing director spent two-thirds of his time in Europe last year, which is his new market frontier.

3.4.2 Bounded Rationality

Before concluding this section, I note that the location choice for a firm is also limited by personal knowledge. In 2004, Jim had to make a big location decision. His then space in Cambridge, MA, was too small to add additional workers, and he had to move. He seriously considered the West Coast for his new location. However, he could not create a full benefit-cost matrix of all locations for now and into the future. Such a matrix is inherently impossible to build (correctly), partly because this high-tech product is unprecedented. No market information is available. Even if Jim had assumed that he might be able to gather the necessary information, gathering information would be costly.

Jim approached the problem from another perspective. He could persuade himself that he could find the necessary skilled workers, high-tech suppliers, and financial support in the Boston metropolitan area where he had lived for a long time since coming to MIT in 1995. He could not find a compelling reason for relocation to a new place, such as Silicon Valley. Therefore, he decided to remain in the Boston metropolitan area, because he was satisfied with Boston. Interestingly, he referred to his locational reasoning process as a "best rational decision."

In summary, my empirical findings suggest that geographic proximity is still important for the high knowledge-generating industries. Yet, the aggregated location pattern does diverge according to the type of business activities. The high knowledge-generating production industries show more concentration, whereas the high knowledge-generating service industries show more dispersion. On the one hand, in the high knowledge-generating production industries, production activities and the interaction between their close collaborating producers are the key generators of the tacit knowledge. On the other hand, in the high knowledge-generating customer-oriented industries, the firm-client interactions are the key generators of the tacit knowledge. In these customer-oriented industries, both firms and clients go through an on-going mutual-learning process, which cannot be easily codified, or once it is codified, that knowledge tends to be out-dated. These differing knowledge needs are the primary driver behind location decisions in these two different types of industries, and explain the geographic location patterns that result.

Chapter 4

Multinational R&D Units in Foreign Countries: Outsourcing or Customer Outreach? The Case of Korea

In terms of location of multinational R&D units in foreign countries, analysts are asking: are these units a result of outsourcing or of an attempt to do customer outreach? Corporate R&D is a typical high knowledge-generating business activity. Most analysts presume that R&D's are the same regardless of location. If this is the case, the presence of multinational R&D units in foreign countries can be a counter example of the findings of the previous chapter.

In the previous chapter, my empirical results suggest that jobs in the knowledge-creative production activities tend to agglomerate geographically. However, this fails to explain the phenomenon of corporate R&D units of advanced multinational firms within this sector that are located in remote developing and middle-income countries. Why do advanced multinational firms set up R&D units in distant places? What do the multinational R&D units in remote places actually do? Is this outsourcing?

Outsourcing has become commonplace in the new economy. Outsourcing, in general, means substitution of high-cost workers with low-cost workers, allowing multi-national firms to cut costs by locating an establishment in a low-wage developing or middle-income country. The use of the new ICT substantially accelerated the outsourcing of manufacturing and back-office activities during the last decade. Even government agencies have joined this outsourcing trend recently. For example, New York City is now processing its parking-tickets in Ghana (New York Times, July 22, 2002).

This kind of functional separation is not an entirely new business practice. "Back-office" appeared as a buzz word on Wall Street two decades ago. (BusinessWeek, November 2, 1985) Firms' goals to maximize their profits and minimize their costs have not changed. What has changed is the availability of the new ICT, which enables firms to (1) send their separable sub-units to the most desirable location globally regardless of distance and (2) easily collaborate with other business entities regardless of distance. As scattered business operations become profitable, firms increasingly adopt this model.

However, according to Piore (2004), R&D outsourcing is intrinsically different from manufacturing or back-office outsourcing. R&D is known to require advanced technology and accumulated knowledge and experience, seemingly making it a likely candidate for geographic clustering around centers of tacit knowledge. He indicated that locating R&D in remote places leads to problems of integration and coordination with other divisions of business and appears to be less than economically optimal.

Piore's Mexico study reveals that multinational R&D in Mexico was a result of an organic development process. That means, the R&D personnel in the multinational R&D in Mexico are more likely to be educated and trained in the United States and have some experience with the U.S. mother company. Continuous mutual learning between the U.S. R&D and Mexico R&D was necessary. In other words, Mexico's R&D stems from the U.S. trained workers who are in the same language community, instead of indigenously and independently developed.

However, as I discuss in detail later, multinational companies' R&D units are established recently in Korea although Korea had few human interactions with U.S. firms whereas the Mexico R&D units did. Although multinational R&D units in Korea are known as an effort of outsourcing, Korea is not a good breeding ground for cultivating new knowledge because of the lack of close interaction. Therefore, the following questions arise: What makes multinational firms establish R&D units in Korea? What do they do?

To answer these multinational R&D outsourcing questions, I interviewed four multinational R&D units, including IBM, Texas Instrument, Motorola, and Nokia which is located in the Seoul metropolitan area. I sought to identify the actual activities of these multinational firms' R&D. For reference, I compare these multinational R&D activities with local firms' R&D activities, including Samsung, LG, Hynix, and Cellient.

4.1 R&D Research Framework

Conventionally, all firms conducting R&D in an industry are assumed to conduct similar tasks, such as pursuing new ideas, and produce a similar kind of outcomes, such as patents and prototypes among firms. However, researchers have found important differences, with the various types of R&D even within a single industry varying from basic research, which is generally long-term, to applied development, which is generally short term. (Amsden, 2002) Even though a variety of research and other literature has been published about R&D, and the importance of R&D in creating and sustaining economic growth, researchers have yet to establish a system for classifying different types of R&D activity. Amsden and Chiang (2003) argued that the incumbent measurement is so comprehensive that it is more of an R&D project evaluation tool as opposed to a framework through which analysts can understand and identity R&D activities.

The Organization for Economic Cooperation and Development's (OECD) Frascati Manual is one of the most popular tools to sort R&D types. The Frascati manual classifies research into three distinct types: basic, applied, and experimental development. Nevertheless, it does not characterize different types of R&D beyond a very limited number of selected characteristics, such as the classification of R&D personnel (scientist versus technician, for example). It does not differentiate between types of R&D by time frame (short-term R&D versus long-term R&D, for example), although more theoretical approaches tend to be focused on long-term R&D. Furthermore, types of R&D and variations in selected characteristics are not systematically connected with one another, and the same disconnectedness tends to characterize country-specific codes of research occupations. (Amsden and Tschiang, 2003)

Amsden and Tschang (2003) advanced the R&D taxonomy by suggesting an objective measurable framework through which analysts can assess various R&D activities. They first distinguish measurable indicators in R&D activities and then characterize R&D types using those indicators. As summarized in Figure 4-1, the objective indicators are: (1) search purpose, (2) research object, (3) output type, (4) measure of performance, (5) time horizon, (6) techniques used for the activities, (7) available human resources and their qualifications, and (8) size of effort. In addition, I suggest R&D facilities and tools as the ninth indicator because today's high-tech R&D

requires substantial investment in advanced capital equipment and infrastructure to conduct R&D activities.

Amsden and Tschang then articulate five distinctive R&D types: (1) pure science; (2) basic research; (3) applied research; (4) exploratory development; and (5) advanced development. They define pure science as research activity mostly pursuing experimental or theoretical work to acquire new knowledge without any particular application. Although basic research appears very similar to pure science, it uses applications and searches for "marketable" products. Applied research is defined as original investigation but with a specific practical aim. Explanatory development is defined as systematic work drawing on existing knowledge directed towards producing new products or services. The goal of advanced development is generally to produce a manufacturable prototype. I summarize a simplified taxonomy of R&D using this approach in Table 4-1.

Table 4-1. A Simplified Taxonomy of R&D

R&D Type / Measures	pure science	basic research	applied research	exploratory development	advanced development
search purpose	Intrinsic knowledge		↔	Manufacturability	
research object	Uncovering new scientific principles		↔	Differentiating products	
output type	Intellectual properties (IP), research papers		↔	Manufacturable products	
measure of performance	IP, patents, papers		↔	Sale, revenue	
time horizon	Long-tem		↔	Short-term	
techniques used for the activities	Scientific		↔	Engineering	
human resources and their qualifications	Ph.D in broad fields		↔	Bachelor or Master in few specific fields	
Facilities and tools	Experimental		↔	Product evaluation	

Source: Amsden and Tschang (2003). Modified by Author.

4.1.1 Interviews

Two of us conducted interviews to identify the R&D activities of domestic and multinational firms operating in Korea.[46] We selected ten comparable firms, with four being Multinational Companies (MNC) and six Korean national firms in the high knowledge-generating industries located in the Seoul metropolitan area We interviewed the following multinational firms: (1) Korea IBM, a US-based multinational firm offering both IT services and IT manufacturing; (2) Motorola Korea, a US-based multinational telecommunication equipment manufacturer; (3) Texas Instruments (TI), a US-based semiconductor company; and (4) Nokia TMC, a Finland-based telecommunication-equipment company.

Nokia TMC was an interesting unique case. Nokia TMC closed its Korean R&D a couple of months before we conducted our interview. The workers in the Nokia TMC then decided to take over the Nokia TMC R&D and transform it into Cellient, a local R&D company. Although most of the workers stayed, as I discuss later, their activities changed substantially. Cellient exemplifies the difference between the type of R&D work conducted by a multinational and the type of R&D conducted by a local firm.

The sample of local firms consists of: (1) Samsung Electronics, a world-class telecommunications, semiconductor, display, and computer manufacturer; (2) Samsung SDI, a world-class display company; (3) LG Electronics, an electronics and

[46] I conducted the interviews with Jooyoung Kwak, with funding by the Science and Technology Policy Institute (STEPI) of Korea.

telecommunication equipment company; (4) LG-Philips LCD,[47] a display company; (5) Hynix, a semiconductor manufacturing company; and (6) Cellient, a telecommunications equipment startup. All the firms differ in employment size, annual revenues, number of affiliates, industry of origin and corporate governance features.

Table 4-2. Interview sample of firms conducting R&D in Korea

Product	Multinational	Local
Electronics	Korea IBM (USA)	Samsung Electronics*, Samsung SDI, LG Electronics, LG-Philips LCD
Telecommunications	Motorola Korea (USA) Nokia TMC (Finland)	Samsung Electronics* Cellient
Semiconductor	Texas Instrument (USA)	Hynix Samsung Electronics*

* Samsung Electronics produces all three products.

In addition to conducting the interviews, I collected quantitative data on the firms. In the following sections, I aggregate the findings into two groups – multinational and local R&D – to protect identities as per the firms' request. A description of Thin Film Transistor Liquid Crystal Display (TFT-LCD) technology is provided to help the reader envision the R&D process. TFT-LCD makes a good exemplary high-tech product because the technology is relatively simple to understand conceptually and the story of its advancement brings into focus issues that typically surface during the development of a high-tech product.

[47] LG-Philips LCD, a joint venture, is here classified as a domestic firm not only because LG holds more than half of the stock, but also because LG controls both the R&D and manufacturing.

4.2 Comparison between Local and Multinational R&D Units in Korea

I compared local and multinational R&D units in Korea from the following perspectives; (1) search and objectives; (2) output, performance measure, and time horizon; (3) R&D workforce; and (4) R&D facilities.

4.2.1 Search and Objectives

In Korea, R&D conducted by domestic firms is starkly different from research carried out by multinational firms. All of the domestic firms in the sample do some degree of basic and applied research, whereas no multinational firm located in Korea undertakes pure science or research. Domestic firms generally conduct R&D to uncover new scientific principles. The local firms believe this basic research is vital if they are to remain competitive. In order to introduce new products, whether radical or incremental, the domestic firms need to understand the underlying principles of a given field. In other words, they cannot compete in the market without conceiving and developing new products in their R&D units.

In contrast, multinational firms with Korean-based R&D divisions do only basic research locally. They are usually one part of a global network of multinational firms in which the multinational corporation (MNC) conducts pure or basic research in advanced countries. Without exception, of those MNCs we interviewed, their purpose in being in Korea is to customize products and services and support sales and services in the Korean market.

TFT-LCD Example

TFT-LCD is a sandwich-like structure with liquid crystal filled between two polarized glass plates. (Figure 4-1) TFT Glass has as many TFTs as the number of pixels displayed. A color filter generates color. Liquid crystals transform according to the difference in voltage between the color filter glass and the TFT glass. The amount of light supplied by back light is determined by the amount of transformation of the liquid crystals.

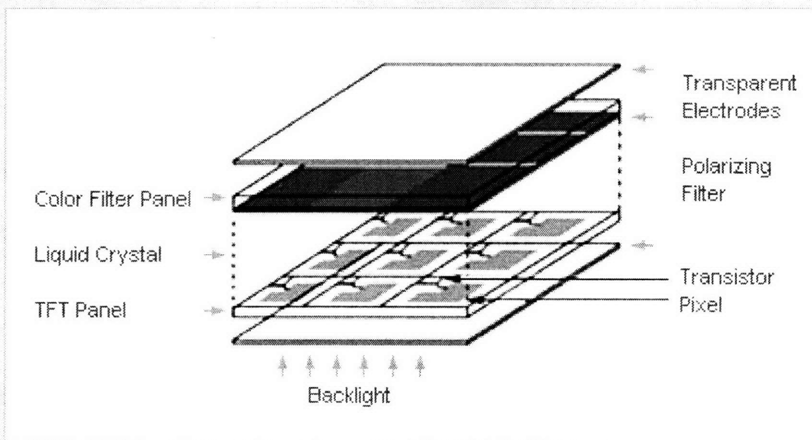
Liquid crystals are neither entirely solid nor liquid. Solid molecules always maintain their orientation and stay in the same position with respect to one another. Molecules in liquids are just the opposite; they can change their orientation and move anywhere within the liquid. One feature of liquid crystals is that they are affected by electric current. A particular sort of nematic[48] liquid crystal, called twisted nematics (TN), is naturally twisted. Applying an electric current to these liquid crystals will untwist them to varying degrees, depending on the voltage applied. LCD's use these liquid crystals because they react predictably to electric current in such a way as to allow control the passage of light.

As light strikes the first glass filter, it is polarized. The liquid crystal layer guides the light to the second polarized filter. If the light is

[48] Liquid crystals are either isotropic or nematic. The key difference is that the molecules in isotropic liquid crystal substances are random in their arrangement, while nematics have a definite order or pattern.

aligned with the polarized glass filter, it will pass through. As a varying electric charge is applied to the liquid crystals, they twist or untwist. Consequently, light can (or cannot) pass through a certain area of the LCD, which makes that area brighter (or darker) than the surrounding areas.

Figure 4-1. A prototype of TFT-LCD



Current R&D-related issues: Today's consumers demand thinner and larger displays, quicker response times for better viewing of quick moving images, and low energy consumption. Firms are eagerly searching for ways to fulfill these needs in order to increase their competitiveness in the market. Therefore, R&D topics include the search for new liquid crystal substances, new back light sources, new circuit designs, and process innovations for production yield increases.

The degree of R&D conducted by local firms on the issues described in the TFT-LCD example, ranges from basic research to advanced development. For example, a local company successfully and dramatically shrank the thickness required for a TFT-LCD by developing an innovative side power supply system for the transistors. Power supply to transistors was traditionally delivered from the back. With this old method, the thickness of the TFT-LCD cannot be reduced below a certain point.

Supplying power from the side, as illustrated in Figure 4-1, is not an easy task. It requires a deep understanding of electro-magnetism and basic research. It also requires partial three-dimensional circuitry on what is essentially a two-dimensional plane. Consequently, the company acquired a patent for this innovation, which is now licensed widely throughout the world.

Another issue is heat. As the size of a display gets bigger, the heat emitted by the TFT-LCD increases dramatically and becomes a major challenge to solve. As a result, local firms began hiring chemical/physical thermodynamic scientists who had never previously been in the R&D work force in this industry in Korea, whereas multinational counterparts did not. (I discuss work-force-related issues in more detail later.)

Furthermore, local firms are also researching alternative materials, such as Organic Light-Emitting Diodes (OLED). The response time of OLED is 1,000 times quicker than TFT-LCD. Quick response is essential for fast-moving motion pictures, such as car races or science-fiction movies. OLED technology also does not need back lighting, because it emits light by itself. Therefore, an OLED display has the potential to be thinner and far more energy efficient than TFT-LCD.[49]

[49] According to Samsung Electronics, OLED is now used for the display of some motion picture-ready cell phones.

However, multinational firms in Korea do not conduct this type of R&D. Instead, they are more interested in modifications[50] of circuit design in order to squeeze circuit boards into a good-looking sheath. Their R&D target is primarily product customization for local customers.

4.2.2. Output, Performance Measure, and Time Horizon

The final outputs in R&D departments of domestic firms include both (1) concept-based intellectual property and (2) short-term market share and profit gains. All domestic sample firms are involved in generating concept-based intellectual property. They require R&D personnel to produce intellectual property in the form of patents or papers. According to the interviewees, this intellectual property is the most important performance measure for R&D personnel working at domestic firms. A local firms' management board is interested in both short-run profits and long-run sustainable profit-generating sources. As managers, they try to balance these needs accordingly. This means they are often willing to undertake long-term R&D projects even when they generate no short-term profit.

In contrast, the R&D personnel in the multinational firms are normally evaluated based upon the manufacturability and/or marketability of a specific R&D project outcome.[51] All interviewees of multinational R&D units in Korea count short-term profit as the single most important criterion for evaluating R&D outcomes. Therefore, they do not conduct long-term R&D, because it rarely generates a sufficient short-term gain.

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[50] Modification might also be very complicated work. But, in terms of the broad R&D spectrum, it is usually for one product for a short-term purpose.

[51] One multinational firm told us that it values intellectual property and research papers of its R&D personnel. Yet, they are optional.

Furthermore, if they fail to show the profitability of their R&D unit within a short period of time, generally less than a year, headquarters are more likely to ask the R&D units in Korea to quit the R&D project.

Neither multinational nor local firms seem explicitly to conduct pure scientific research within their Korean R&D units. However, local firms' long-term R&D projects naturally require some degree of pure scientific research as part pf their mid- and long-term R&D projects.

As mentioned earlier, local and multinational firms show a clearly distinguishable difference in the time horizon of their R&D. On the one hand, all of the local firms sampled conduct R&D projects, such as searching for new substance for better display or biometric-based security system development, that take five years or longer as well as shorter projects, such as minimizing the length of antenna of cell phones. A longer R&D time horizon is closely related to the fact that domestic firms pursue basic and applied research. On the other hand, multinational R&D units generally conduct one-year R&D projects, such as changing the shapes of cell phones.[52] One multinational company reported a three-year R&D project, but its continuation from one year to the next was contingent upon the success of the previous year's R&D product profitability. Multinational firms clearly intend to focus on the later stages of R&D; exploratory development or advanced development.

4.2.3 R&D Workforce

[52] According to Motorola's R&D director, changing the outer shell of a cell phone is not simply a changing a case. He mentioned, as cell phones get smaller, all the inside parts are entangled with outer shells. Therefore, redesigning a outer shell requires redesigning inside parts including the printed circuit board, location of antenna, and so forth.

Another stark discrepancy can be found between local and multinational R&D workforces. The number of R&D-designated personnel of local firms ranges from 500 to over 1,000.[53] Local R&D units have a higher percentage of staff with post-graduate degrees than their multinational counterparts. For the local firms, a minimum of 70 percent of R&D staff have advanced degrees, whereas the multinational firms have no more than 30 percent. In contrast to the MNCs, local firms hire researchers from a wider set of fields that includes physics and chemistry in addition to the industry's traditional disciplines, electrical engineering, and computer science.

Multinational R&D firms are typically much smaller than the local firms, with no more than 50 R&D personnel. In general, their interests only extend to graduates with degrees in electrical engineering and computer science. Moreover, their workforces are made up mostly of bachelor's degree holders plus a small number of managers with master's degrees. They said that undergraduate degree holders are enough for product localization or incremental product improvement. Furthermore, they tend to recruit only experienced workers from local firms.

In addition, the R&D activities of local firms are not constrained to R&D designated personnel working at R&D specific facilities. The R&D workforce and their activities extend to every place within a firm. Local firms even place R&D personnel on the manufacturing shop floor. Managers stressed the importance of on-site R&D for building competitiveness both in product and process development. None of the multinational firms had broad R&D efforts in Korea.

[53] I did not add the number of researchers doing R&D on the production line. Korean firms value the R&D "on the shop floor," and there are many R&D personnel on the production line. If I were to include the gross number of researchers, domestic firms would show much larger R&D labor forces than their multinational counterparts.

The different pattern of education level and distribution for the employees reflects the different type and purpose of R&D conducted by domestic and multinational firms in Korea.

4.2.4 R&D facilities

Local firms have a prototype production capability within their R&D's facilities in order to facilitate the knowledge flow between R&D and production as well as to shorten the development process. Most of the prototypes of local R&D units are manufactured at in-house facilities. Therefore, the knowledge flows back and forth between research and development continuously, which helps to expedite the process of getting the R&D to the market. On the one hand, local R&D units had also made substantial investments in equipment to test the validity of new technologies. On the other hand, multinational R&D units in Korea do not have these capabilities.

4.3 Multinational R&D Units in Korea: IBM, Motorola, and Texas Instruments

History of multinational R&D units development in Korea also help us to understand the characteristics of them. I illustrate three cases: IBM, Motorola, and Texas Instruments.[54]

International Business Machines, Co. (IBM): It established a Korean branch in 1967 as they were installing a government computer system. Now, IBM has many big customers in Korea including Korean government organizations, many banks, and major

[54] Sources are my interviews, their Websites, and publicly available publication such as newspapers and news.

companies, such as Samsung and LG. IBM used to have a technical support team with about six staff. They said that there many people demanding a combined service of business innovation strategy and information technology, especially since the Korean financial crisis in 1997. IBM gradually expanded their proactive customer-support team and finally launched an independent IBM Korea Technology Laboratory (IBM-KTL) in 2003. IBM-KTL is the R&D organization in Korea of IBM, employing more than 100 full-time staff.

The response to the Korean financial crisis required Korean major banks to upgrade computer systems and conform to international financial practices and code systems. Furthermore, several major banks underwent mergers or expanded through acquisitions. Upgrading and consolidating of the existing financial system, especially across different firms, was a great challenge. In providing these products and services, IBM, and its competitors, must understand the existing systems and business practices. The government agencies and banks also need to understand the new system to a certain degree. Understanding local customers' needs and customizing high-tech products to meet the local needs are a mutual learning process.

This mutual learning brings up the issues of complexity and speed. The interviewees indicated that not all in-house system customization and business practices are properly documented. Furthermore, bankers often times do what they need to do, but they are not necessarily conscious of what they are doing. Because all those practices need to be codified in the system to a certain degree, bankers and IBM have to spell out what they are not conscious of through an intensive mutual-learning process. This process requires close and intensive interactions between the firm and its customers.

Most parts of this process *can* technically be done without geographical proximity per se, due to the use of new ICT. However, according to the interviewees, if they do this remotely, the speed of this process would drop dramatically. In the fiercely competitive global market, IBM cannot afford a slow process. Otherwise, other competitors, who are willing to come in and work faster, may take over its customers. The fiercely competitive and fast-paced market environment contributes to the increasing importance of proximity to customers.

Texas Instruments (TI): It established a Korean branch in 1977 when they began Original Equipment Manufacturing (OEM) with a Korean firm. TI's R&D organization is the TI Digital Signal Processing Solution Center. Digital Signal Processing (DSP) Integrated Circuits (IC) is a major product line of TI in Korea and TI is the major supplier of DSP-IC in Korea. DSP-IC is a key component used to convert analog-to-digital or digital-to-analog signals. Today, virtually all digital devices such as cell phones or digital audio devices have at least one DSP-IC.

TI's key customers include Samsung Electronics, Samsung SDI, LG, LG-Philips and Hynix. DSP-IC is a standardized product to a certain degree, but most of the market for DSP-IC is in customized products. Similar to the IBM case, TI works closely with, for example, Samsung Electronics. There is a continuous mutual feedback interaction between TI and its customers. For example, Samsung Electronics often times asks for a customized DSP-IC for its latest cell phones or TVs.

TI's R&D unit staff also spend much of their time educating local customers and college students about TI's DSP-IC. TI said that this is an important marketing strategy for developing potential local customers, and persuading them to adopt TI's DSP-IC.

They offer support to local customers willing to adopt TI products, including Micro-control Units (MCU) for home electronics, LCD Driver IC for laptops, Custom IC (CIC), and so forth.

Motorola: It began its OEM semiconductor business in Korea in 1967. They launched an independent R&D unit in 2000, called the Motorola Korea Technology Center. This R&D center came to Korea after the world-first commercialization of the Code Division Multiple Access (CDMA) cellular phone in Korea in 1996.[55] The infrastructure of the Korean cell-phone network was based upon CDMA. Because CDMA was an unprecedented and unique technology, Motorola had to modify its cell phones to work in the Korean cell phone environment. Similar to the IBM and TI cases, Motorola's focus is mainly on customization and marketing directed towards local consumers.

Furthermore, Motorola was interested in the advanced applications in the information and communication technology in Korea. For example, banking by cell phones has become common place. When I visited Korea in 2003, a friend of mine took me out to a dinner. When he paid the bill by credit card, in a couple of seconds, his cell phone rang. The text message on the cell phone showed how much was charged on his credit card by the transaction. Today, Koreans can view TV shows on their cell phones, too.

As Motorola's R&D director said, "Motorola needs to tap into this state-of-the-art cell-phone use in real life. The future that we imagine is already here in Korea." He also appreciated Korea's ubiquitous high-speed wired and wireless internet infrastructure, beyond any individual firm's capacity, which enables the technology to work. Motorola

[55] CDMA was commercialized in Korea in 1996, and was the first country in the world to do so.

adopts new technology and customizes their phones to meet the local environment and to respond to their local customers' taste in areas such as equipment color and shape.

In summary, the interviews reveal that the multinational-owned R&D units are closer to being customer-relations- and customization-intensive-units than pure research units, although the R&D units of the multinational firms in Korea are labeled "R&D." The multinational R&D units focus on specific product development targeting local customers, instead of rather more fundamental scientific research. They are conduits of outreach to local customers, which conduct (1) the flexible customization of their products to meet local customers' demands and (2) customer management and marketing in the highly competitive global market. The fiercely competitive and fast-paced market environment contributes to the increasing importance of close customer management. Therefore, based upon the actual activities taking place, the presence of multinational R&D units in Korea does comply with my finding that service-oriented high-knowledge-generating jobs tend to disperse geographically for proximity to customers.

Chapter 5

Conclusion

5.1 Summary

More high-tech firms are conducting their business over long distances today than a couple of decades ago because of the use of new information and communication technology (ICT). Consequently, Cairncross, (1997, 2001), among others, asserts that, on the one hand, there is an emerging "death of distance" in businesses and jobs. On the other hand, however, some regional scientists find high geographic concentration of high-tech industry and jobs (Audretsch and Feldman, 1996, among others). Regional scientists articulate that geographic proximity is still important, at least, to the high-tech industry and other knowledge-related business activities. My research offers a ground work for understanding the paradox – more dispersed high-tech business practices and higher geographic concentration of high-tech jobs in the new economy.

The purpose of this research is three-fold. First, I conduct a longitudinal empirical analysis on the geographic-concentration pattern of knowledge-related business activities. Conventional cross-sectional comparisons between different industries are not sufficient to verify the high concentration of knowledge-related jobs. There has been a lack of systematic longitudinal empirical analyses of the job-concentration pattern, mainly due to data unavailability and noncompatibility over time. In this research, I fill the gap in the existing literature. Second, I bridge economics and regional science theories in order to understand the job-location pattern in the new economy. Although both strands of thought are concerned with the jobs, industries, and location patterns, the bridging of the two different perspectives – firm-oriented perspective and region-oriented perspective – is necessary in order to understand the paradox of more location freedom and higher concentration of business activities in knowledge-intensive industries.

First, I focus on high knowledge-generating industries in this research. I hypothesize that proximity still plays an important role in business location of high knowledge-generating business activities due to less transferable tacit knowledge and implicit communication, so that there is, at least, no drastic geographic dispersion of jobs in those business activities. Even in cases where codified knowledge is almost omnipresent because of the new information and communication technologies, it becomes valuable only if it is complemented with tacit knowledge, which is less transferable than codified (Leamer and Storper, 2001). Furthermore, in the high knowledge-generating *production* business activities, it is the production venues and networks where proximity matters most in creating and distributing tacit knowledge; in the high knowledge-generating *service* business activities, most tacit-knowledge creation and transactions occur at the firm-customer relationship venues.

I empirically investigate high knowledge-generating industries that exceed the U.S. average for both research and development (R&D) expenditures per employee ($11,297) and the proportion of full-time-equivalent R&D scientists and engineers in the industry workforce (5.9%) (Paytas and Berglund, 2004). Using these 'high knowledge-generation' criteria, Paytas and Berglund (2004) identified ten high knowledge-generating industries at the four-digit NAICS level – six production industries and three service industries. These industries are also the most intensive users of the new ICT, such as Internet, Intranet, EDI, and E-commerce. To calculate Gini Coefficients, job shares, and Location Quotients (LQ), I mainly rely on the U.S. normalized annual employment data by Metropolitan Statistical Area and by four-digit NAICS from 1990 to 2000 by the Bureau of Labor Statistics (BLS).

Both my interviews and my empirical analysis suggest that the jobs in the high knowledge-generating *production* industries became further concentrated during the 1990s. During the same period, the jobs in the high knowledge-generating *service* industries dispersed. In the former industries, producers are the major knowledge generators, while in the latter industries, tacit knowledge is derived mostly from the interaction between firms and customers. In consequence, the jobs in the former industries tend to agglomerate, but the jobs in the latter industries tend to disperse in order to be close to customers. The increasing location freedom decreases the concentration level of customer-intensive activities, unless the customers themselves are concentrated as in the case of the Federal government.

In the high knowledge-generating production industries, the interviewees indicate that when a firm needs to manufacture computers or peripheral equipment, the use of the new ICT enables the firm to leverage, for example, Silicon Valley. This region is highly specialized and advanced in computer and peripheral-equipment manufacturing, and those firms send their subunits to Silicon Valley or utilize partnerships with existing firms in Silicon Valley.

Interestingly, five out of the six high-knowledge generating production industries show a 'winner-takes-all' kind of spatial monopolization of jobs. For example, San Jose-Sunnyvale-Santa Clara, CA MSA (a.k.a. Silicon Valley) maintained over 16 percent of jobs of the Computer and Peripheral Equipment Manufacturing industry (NAICS 3341) in the United States. Yet, all four secondary places – including Boston-Cambridge-Quincy, MA-NH MSA, Los Angeles-Long Beach-Santa Ana, CA MSA, Minneapolis-St. Paul-Bloomington, MN-WI MSA, and New York-Northern New Jersey-Long Island, NY-NJ-PA MSA – lost job share during the 1990s. The ratio of the job share of Silicon Valley, the top share holder, and the job share of the Boston metro area, the second highest job share holder, increased from 1.6 in 1990 to 2.9 in 2000.

A second set of questions arises from an apparent anomaly to the findings of my first set of questions around job concentration or dispersion. The above hypothesis and research findings suggest that those jobs in the knowledge-creative production industry tend to agglomerate geographically. However, this fails to explain the phenomenon of R&D units of advanced multinational high-tech production firms locating in remote developing and middle-income countries. Why do those firms set up R&D units in other countries rather than in their home countries? What do the multinational R&D units in foreign countries actually do?

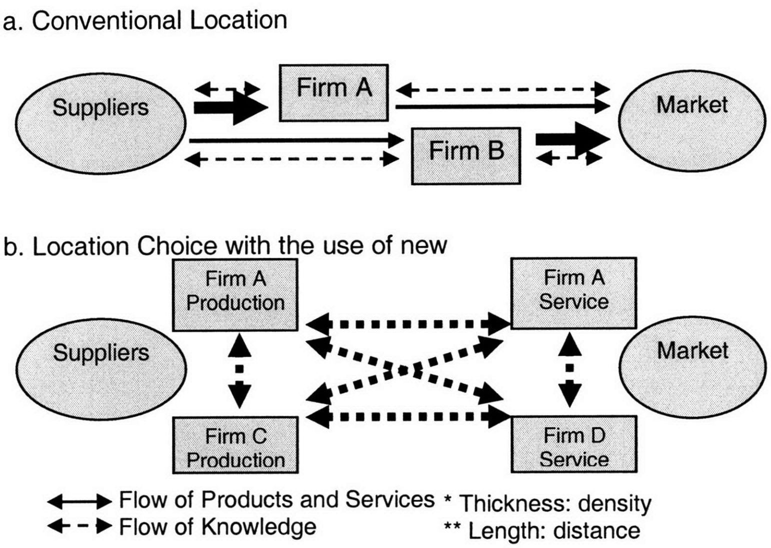
To answer these questions, I identify their actual activities and compare multinational and local R&D operations in Korea. Interviewees reveal that they are closer to being customer-intensive units, although the R&D units of the multinational firms in Korea are labeled "R&D." The multinational R&D units focus on specific product development targeting local customers, instead of more general scientific research. They are conduits of outreach to local customers, which conduct (1) the flexible customization of their products to meet local customers' demands and (2) customer management and marketing in the highly competitive global market.

For example, IBM has big customers in Korea including Korean government organizations and many major banks. I find that understanding local customers' needs and customizing high-tech products to meet local needs are an intensive mutual-learning process that requires close interactions between the firm and its customers. The fiercely competitive and fast-paced market environment contributes to the increasing importance of close customer contact, too. Therefore, based upon the actual activities taking place, the presence of the multinational R&D units in Korea complies with the general findings of my investigation of the first locational question on job concentration.

In my study, I have found that the use of new ICT heightens the degree of the spatial division of labor and generates the paradox of individual firm's location freedom and spatial concentration of jobs. For example, when a firm needs to manufacture computers or peripheral equipment, the use of the new ICT enables the firm to leverage Silicon Valley, which is highly specialized and advanced in computer and peripheral equipment manufacturing, by sending its subunits to Silicon Valley or utilizing existing firms in Silicon Valley. In addition, this heightened spatial division of labor due to the use of the new ICT leads to the spatial monopolization of jobs.

Figure 5-1 is a conceptual diagram of new framework to conduct location pattern research. In the conventional location theories, a firm is the unit of location choice although a firm consists of various sub units, such as R&D, production, marketing, and so forth. As the division of labor over space becomes easier than before due to the new ICT, firms can break its sub units and send them to another part of world to maximize the utility of location for each sub unit. Often times, firms focus on their strength and rely on other firms regardless of distance. Paradoxically, this industry organization change tends to increase the geographic concentration of the jobs in the high knowledge generating industries.

Figure 5-1. Conceptual Diagram: Location Freedom and Concentration of Business Activities with the new ICT



Source: Author

5.2 Policy Implications

Job location is one of the primary concerns of scholars and practitioners in the economic development field. (Bartik, 1991) Nevertheless, the labor demand side of job location in the new economy remains to a great extent an issue within the theory and practice of regional economic development. (Alonso, 1990; Barnes 2004)

In this study, I help to answer a series of policy questions that have been central issues of planners and policy makers. How can we secure jobs for citizens? How can we get a region's workers ready for the new job market? How can we advance a disadvantaged region's economy in the new economy? How can we build and sustain a region's competitiveness?

For economic development policy, I found that local governments need to pay attention to the specific business activities, instead of attempting to recruit a whole firm, as the degree of spatial division of labor increases. I also show evidence of the importance of local knowledge capability and local assets for local economic prosperity. If a place can build on less mobile and highly valuable local assets, ranging from natural resources to local high-tech knowledge to cultural milieu, it tends to have a stronger pull on relevant business activities.

For technology-based capacity building in underdeveloped areas, Kim's (1997) three-stage model – acquisition, assimilation, and improvement – probably still holds. During the early stage of their industrialization, underdeveloped areas acquire mature technologies. Although production at this stage may be merely an assembly of fairly standard, undifferentiated goods, it helps local business personnel and technicians acquire important experience in production technology and project execution knowledge through learning by doing. The relatively successful assimilation of general production technology and the increased capability of local scientific and engineering personnel lead to the gradual improvement of product lines through local efforts in research, development, and engineering. In proceeding along this trajectory of acquisition, assimilation, and improvement, the region can build its own local knowledge assets.[56]

[56] These activities tend to overlap and occur concurrently in practice, instead of in sequence. (Lee and Lim, 2001)

5.2 Future Research

In terms of theory development, I have the following recommendations for future research. First, analysts need to pay close attention to the nature of business activities – what activities are actually conducted within business units – beyond name, industry or occupation. For example, Sony's R&D unit in Brussels "was highly limited to local adaptation of the product, only for translation of brochure and labels." (Motoyama, 2005, p. 6) In this case, what this unit actually does – brochure translation – is significantly different from what the broad name "R&D" implies.

Second, analysts need to conduct further research on the relationship between place and job concentration. For example, while Silicon Valley maintained over 16 percent of U.S. computer and peripheral equipment manufacturing jobs during the 1990s, 40 to 50 percent of establishments in Silicon Valley died during the same period. (Zhang, 2003) Firm entities came and went, but the number of jobs in the region continued to grow. This fact suggests that regions can be viewed as a job holder.

Third, a conventional linear-model specification has limitations in explaining the non-linear bifurcating pattern of spatial monopoly. Linear models assume that a place's job share would grow "proportionately" to its characteristics. However, my empirical analysis suggests that only the top place prospers and the secondary places have withered as new ICT technologies have been applied, even if the secondary places also had a significant mass of employment at the beginning of the 1990s.

5.3 Research Limitations

U.S. Labor Market vs. Global Labor Market: During the 1990s there was an accelerated process of internationalization of production, distribution, and management of goods and services (Castells, 2000). There was growth in the number of international production networks and international shifts of employment from the United States to other parts of the world. That means that increasingly the U.S. labor market is not isolated from the world labor market. For example, Hicken (1998) found that the U.S. share of world employment in the computer hard disk drive (HDD) industry decreased from 11 percent in 1995 to 7 percent in 1997. The U.S. share in assembly employment decreased disproportionately from 7 percent in 1995 to 2 percent in 1997. The U.S. computer industry experienced a significant drop in assembly employment.

This kind of global division of labor suggests that there might be a potential shift in the quality and quantity of jobs in the U.S. computer industry. The characteristics of the U.S. computer industry, as a whole, might have shifted towards more knowledge-oriented activities with increasing off-shoring of manufacturing during the 1990s. In this study, I do not separate or discuss the potential effects of these changes due to the lack of data availability. Nevertheless, this effect may not affect my main argument. McKendrick (1998) found a "dispersed concentration" pattern of the Hard Disk Drive (HDD) industry on the global scale.[57] His finding of a global geographic pattern is rather similar to my U.S. only geographic pattern.

The 1990s vs. Longer-term wave: As seen in Figure 3-1, there were fluctuations of concentration levels during the 1990s. The trends tended to be a little stronger in the second half of the decade when the economy was recovering. In order to make valid

[57] McKendrick (1998) used the number of firms, instead of the employment numbers.

generalizations about trends in these industries, we would benefit from a longer period of analysis.

In summary, this study confirms that the concentration level of knowledge-intensive jobs is still high and increased from 1990 to 2000. This concentration increase is mainly led by the dominant job holding region, such as Silicon Valley for computer industry and Austin-Dallas, TX for Semiconductor Manufacturing industry. The interviews affirm that tacit knowledge plays a important role in this increasing concentration pattern. Besides, business reorganization such as modularization and functional separation helps this paradox of increasing location freedom and increasing concentration of business activities.

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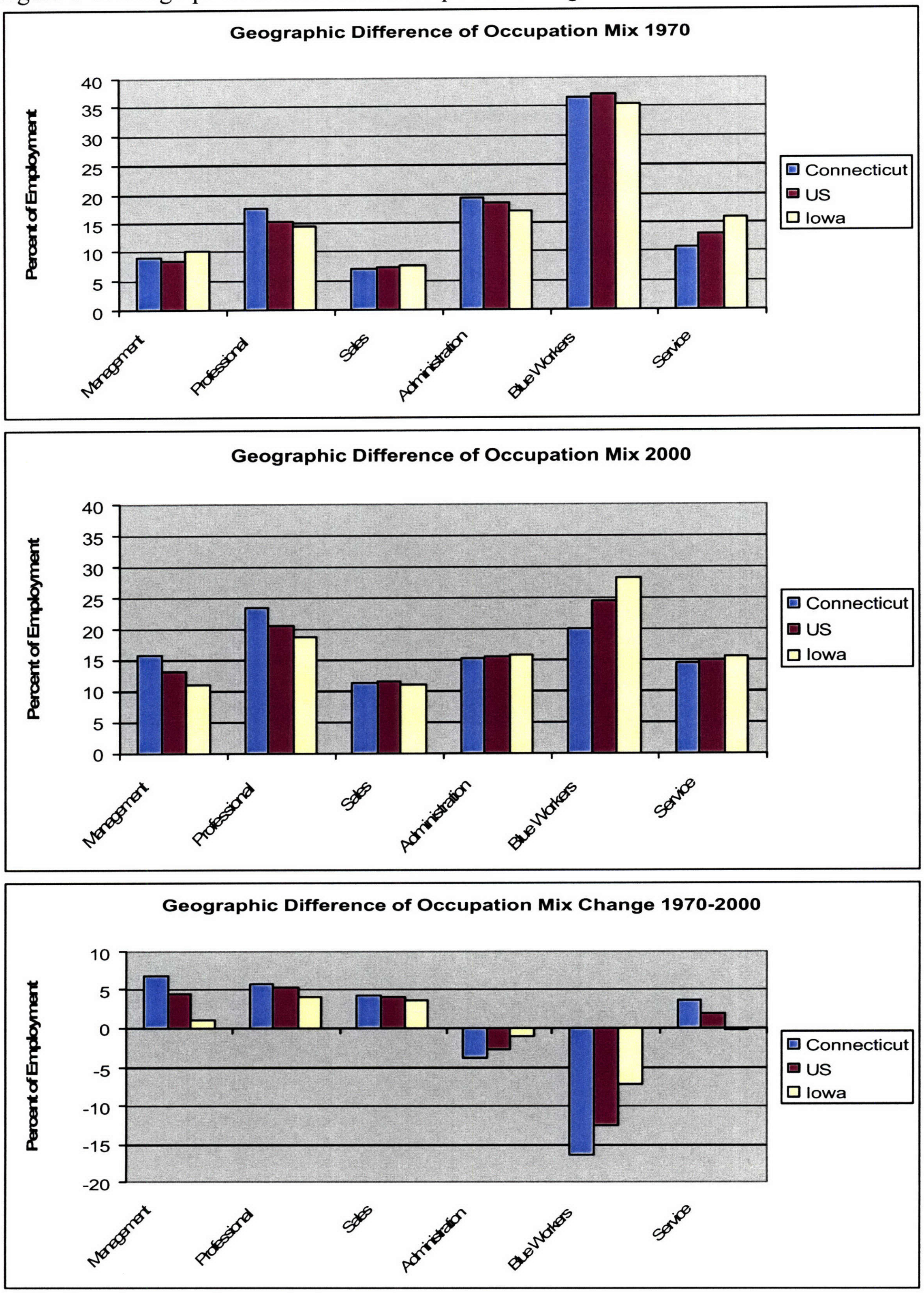
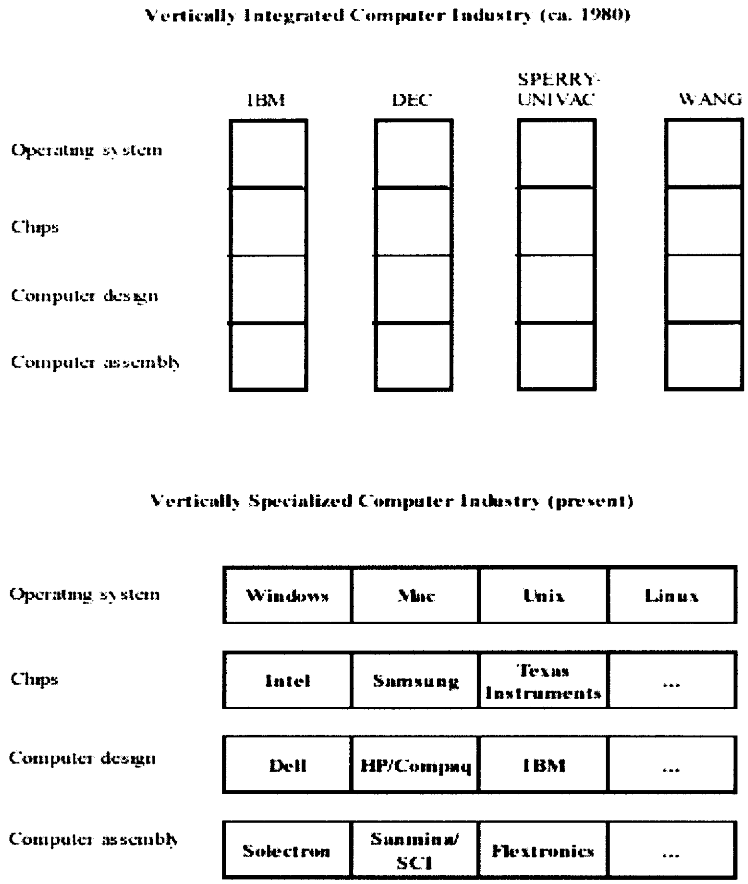
Appendix A. Figures

Figure 1-1. Geographic Difference of Occupation Change 1970-2000



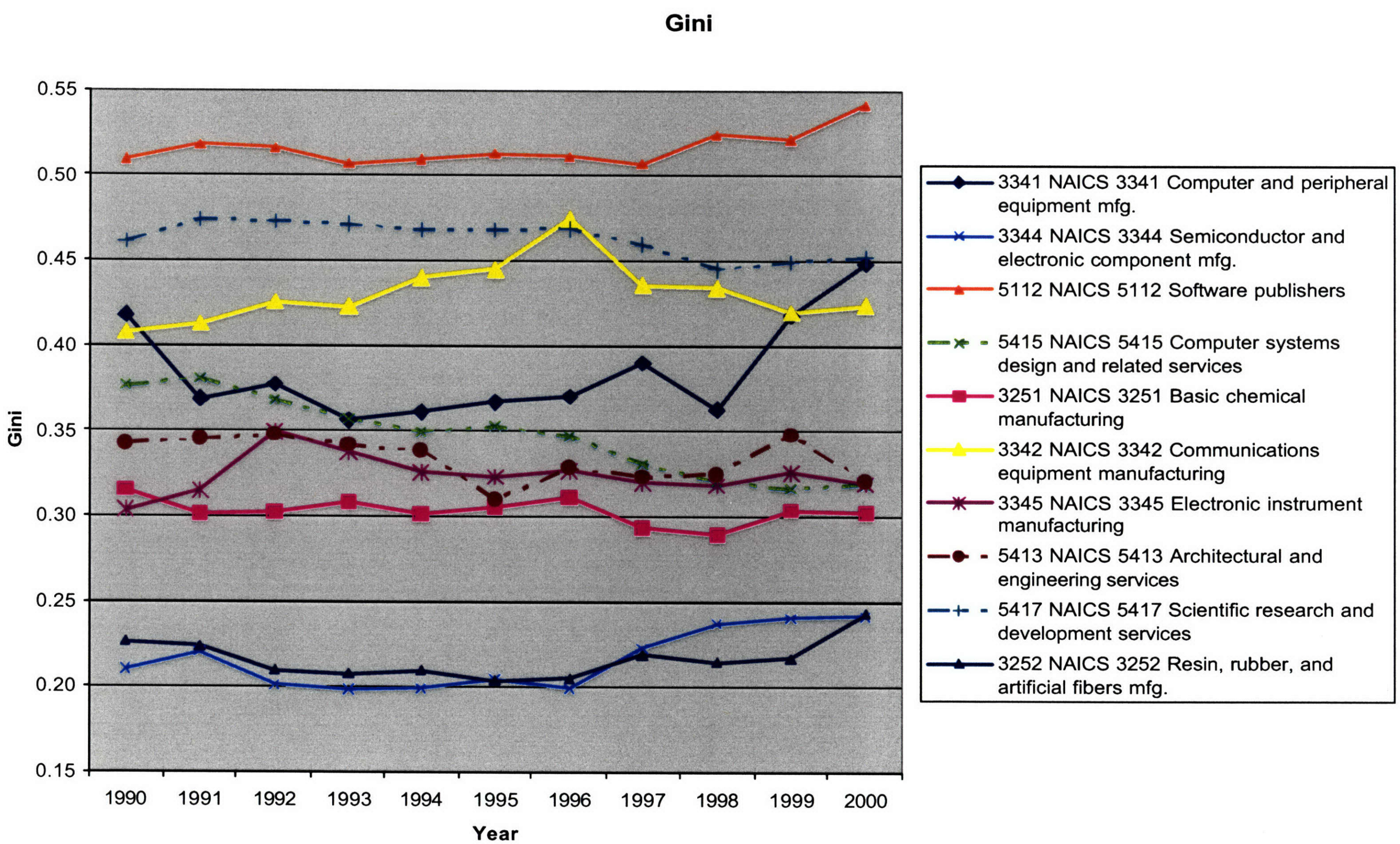
Source: Census 1970 and 2000.
Note: 16-year and older employed workers in 1969 and 1999 respectively.
* Author produces these figures based upon Levy and Murnane's (2004) figures.

Figure 2-5. Transformation of the Organization of Electronics Production



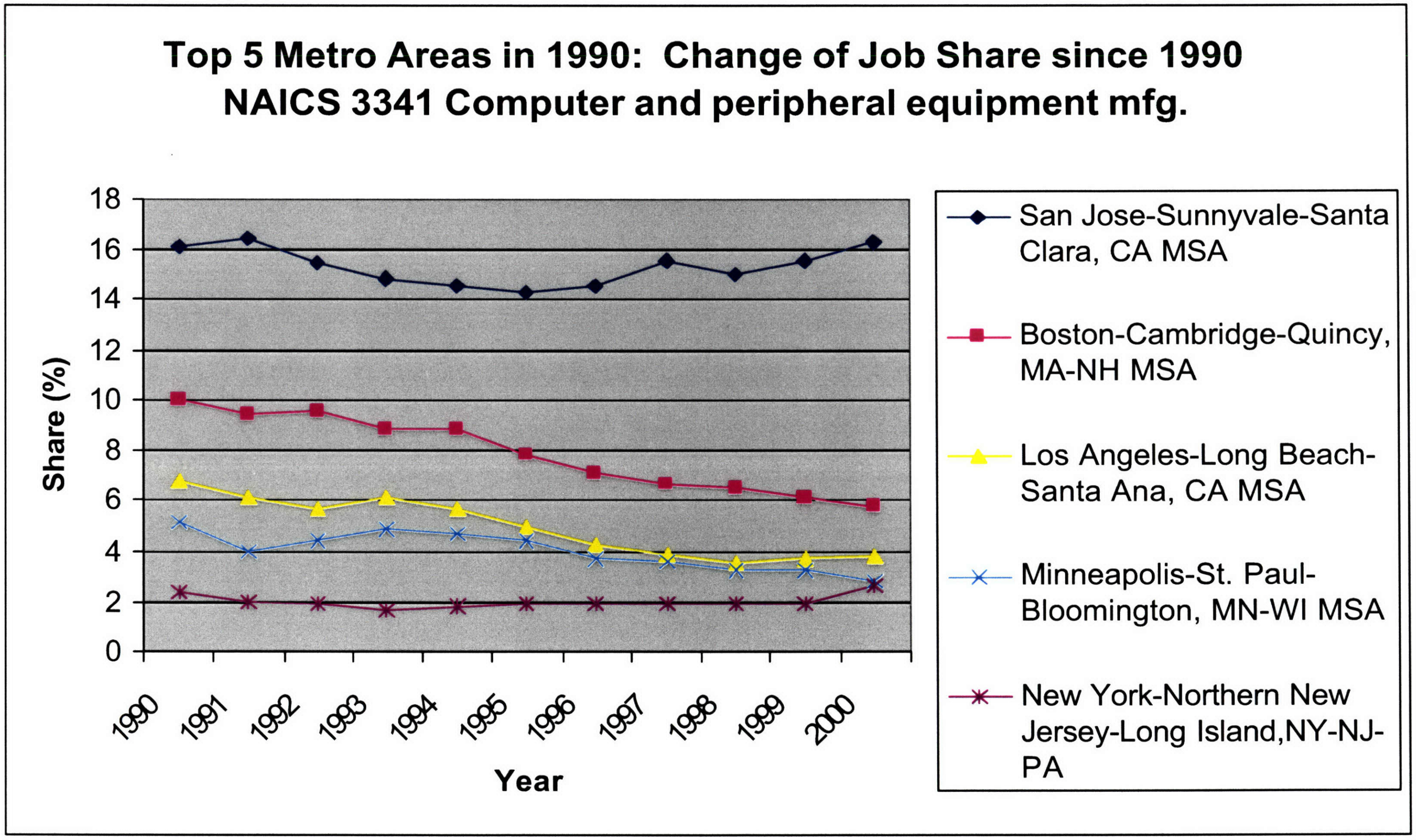
Source: Gangnes and Assche (2004)

Figure 3-1. Concentration Change by Industry during the 1990s (Gini)



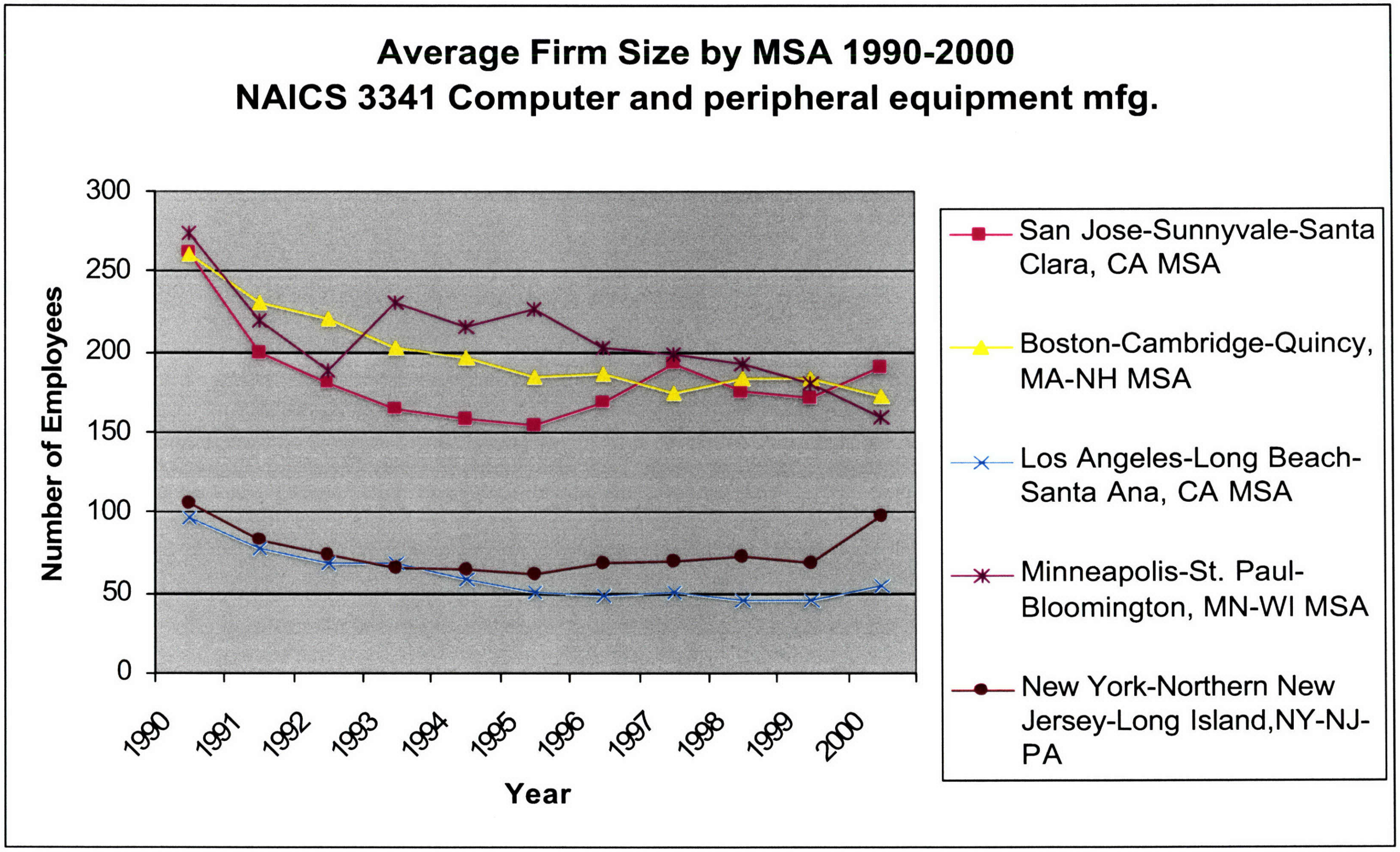
Source: Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW). Author's calculation

Figure 3-2. Change of Job Share during the 1990s: Computer Industry (NAICS 3341)



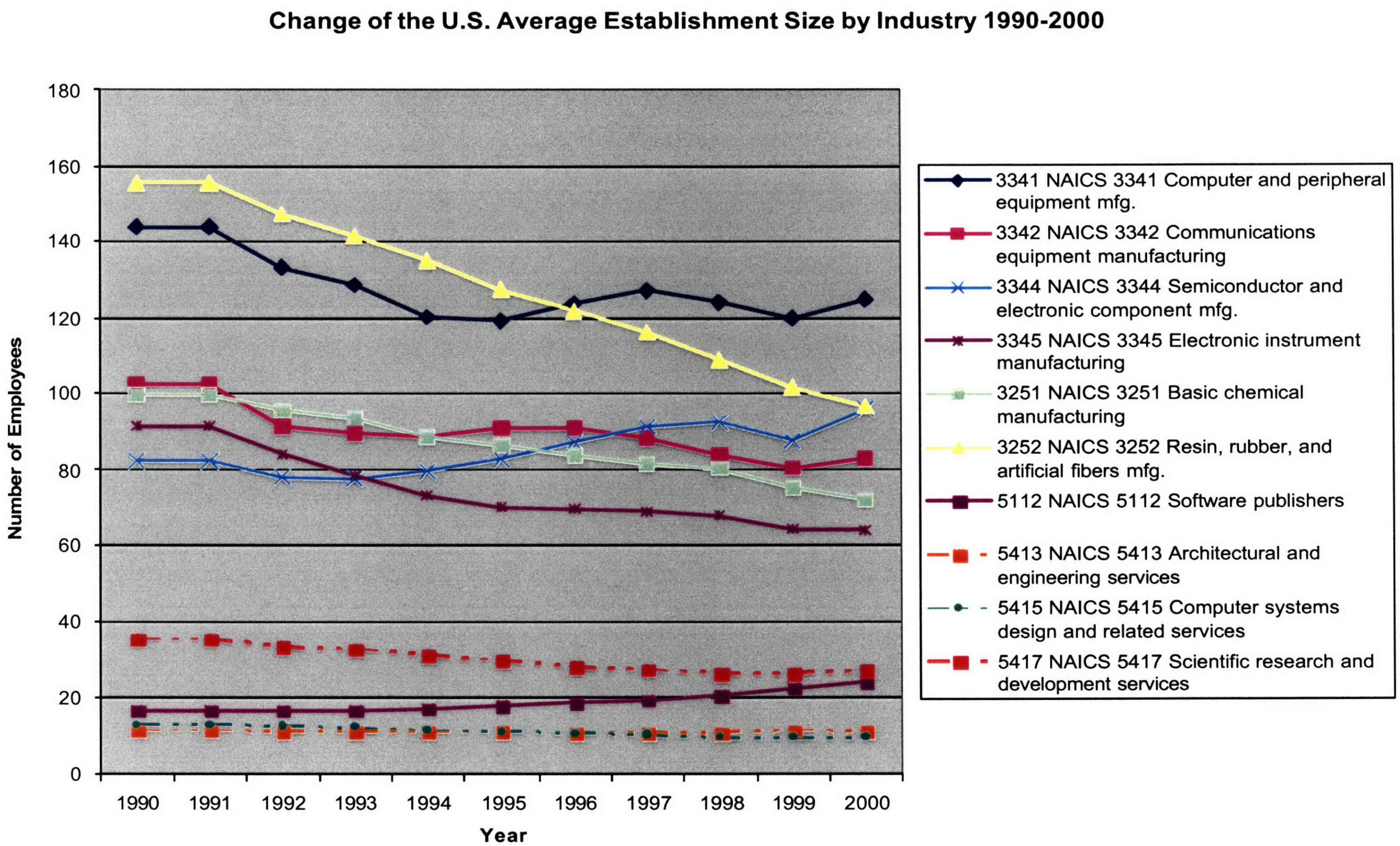
Source: Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW). Author's calculation

Figure 3-3. Average Establishment Size of Computer Industry. Metropolitan areas with highest job share, 1990-2000.



Source: Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW). Author's calculation

Figure 3-4. National Average Establishment Size Change 1990-2000.



Source: Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW). Author's calculation