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Information Technology Impacts on Urban Spatial Structure in the Chicago Region

This paper examines the impact of information technology on urban spatial structure in the Chicago region. Urban scientists are challenged to understand in what ways information technology has influenced the distribution of urban economic activities: concentration or dispersion. Using data collected in the Chicago region, orientation of establishments toward the center is tested to separate the impact of locational features of centers from the impact of information technology. The result reveals that information technology has attraction as well as spillover effect on urban spatial structure and thus concentration rather than dispersion is dominant at a local scale in the Chicago region. It was found, however, that center-orientedness varies depending on the sector.

Urban spatial structure can be viewed as the spatial distribution pattern of various urban activities. The spatial distribution of these activities often results from various economic location decisions of individuals or a group of establishments. If the scale of interest moves to a more aggregate level, those issues return to the distribution patterns of economic activities. In other words, location and distribution are just two sides of the same coin.

Many possible factors can affect the decision-making process of those agents in an urban area. Traditionally, the most popular explanatory variable for urban economic activities is the economic imperative. Since most private firms consider increasing profit, if not always profit maximization, in every decision-making process, it is not so unusual to consider this as a primary moderating factor. Several concepts are related to this criterion: agglomeration economies, external economies, and/or urban economies. In similar fashion to individual concerns about the relation of residence related to workplace, firms are also concerned about their location in relation to their potential/substantial labor force.

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In recent decades, one of the major breakthrough achievements in the world is the development of information technology (IT). IT can be defined in various ways. While local area networks (LAN) represent one type of recent technology, telephone and fax provide examples of earlier IT innovations. IT now encompasses server equipment, fiber-optic lines, high-speed access to the Internet and a whole range of associated software, including e-mail. In relation to an examination of the relationship between IT and the distribution pattern of activities in an urban area, two aspects need to be considered in refining the concept of information technology. First, IT should always represent a bundle of up-to-date technologies. For example, while telephone and fax could be a part of IT in a broader sense, since they are ubiquitous, it would be difficult to demonstrate any significant impact on the spatial distribution of activities in an urban area. The second aspect to be considered is the physical nature of the technology; the influence of IT will be manifest through the distribution and access to physical components rather than just software and applications. It would be hard to find a spatial implication of the latter since they are not bound to a specific location. In addition, they are secondary in that they can be useful only when a platform for the software and applications (that is, built-in physical infrastructure such as hardware and equipment) is provided. As a consequence, IT in this analysis is defined as the combination of telecommunication and computer technology. Telecommunication technology is about the speed of data transmission; integrated services digital network (ISDN) and asymmetric digital subscriber line (ADSL) are two examples of the technology. Computer technology is related to digitization (or "digitalization") of data and information; computers as well as other peripheral equipment are in this category.[1]

Along with the rapid development of computer technology, IT has had great influence on society in general as well as on the personal lifestyles of individuals. Without doubt, there seems to be a certain relationship between IT and changing urban spatial structure in that geography is the spatial projection of the society. There has been a significant volume of research on this topic, especially since the late 1980s. One of the more contentious issues is whether IT has had an influence on the contemporary urban spatial structure and, if so, whether it has led to the concentration or dispersion of urban activities. Most of the research has been conducted using qualitative and descriptive methods, while there are relatively few studies that adopted quantitative models. Reasons for this trend are the lack of adequate data to measure or depict the level of IT influence and the lack of adequate methodology to measure the spatial impact of IT on distribution patterns. In addition, if such data are needed at a more disaggregated geographic scale, then the difficulty increases. For example, it is not easy to measure how many people have access to a computer in their residences and how frequently they use the Internet and e-mail in a certain geographic zone. Likewise, it is difficult to collect data on the level of usage of IT by establishments in a certain geographic zone. For this reason, some of the empirically driven analysis related to this topic has rather focused on a larger geographic scale of research area, such as the intermetropolitan context. Some examples include telecommunication and the transition of regional urban hierarchy (Wheeler and Mitchelson 1989; Alles, Esparza and Lucas 1994) or global urban hierarchy and urban systems (Warf 1989), and the internet network and the accessibilities of cities in the national urban systems (Wheeler and O'Kelly 1999).

The purpose of this paper is to measure the potential influence of IT on the urban spatial structure in an intrametropolitan context and to compare the significance of

1. For more information on the technical aspect of IT, refer to Atkinson (1998). He classified three functions of IT in his paper: transmission, conversion of information into digital form, and distribution and routing.

IT-related and non-IT-related variables. The next section discusses previous literatures focusing on IT and its impact on urban spatial structure. Section 2 introduces the models that will be used and section 3 presents the empirical results and interpretations of the models for Chicago. Finally, section 4 concludes the paper.

INFORMATION TECHNOLOGY AND URBAN SPATIAL STRUCTURE

Evidence from the recent research on urban distribution patterns reveals that IT is currently considered a growing factor in explaining urban spatial structure in that information and communication technology is seen as a way to overcome the costs of spatial separation. To some extent, the question of whether IT has been important in explaining the shape of urban forms has been narrowed down to the question of whether IT has an influence on the dispersed distribution pattern of urban activities.

Gordon and Richardson (1997, p. 95) support the dispersion hypothesis. They conjectured that such technology leads to a dispersion of urban activities, possibly up to the stage where "geography is irrelevant." They noted that a more compact or concentrated distribution pattern has been dominant when transport or communication costs were high but the costs are likely to continue to fall in the future. A similar theme was tackled by Drucker who concluded that "office work, rather than office workers, will do the traveling (Drucker 1989, p. 38)." But the critical issue here is whether transportation and communication are complementary or competitive: Are they complementary, so that increasing adaptation of communication technology induces higher transportation demands? Or are they competitive enough, so that communication technology is able to replace most of transportation demands? If the former is the case, geography still might matter even with the advent of the new communication technology.

Some authors stay in the middle of the spectrum in the dispute. While they agree with the potential impact of IT on dispersion, they also believe that IT might work for concentration at the same time, either explicitly or implicitly. Yen and Mahmassani (1997), among many others, have noted that the development of telecommunications technologies may affect land use patterns and play a role in the growth of economic activities and the spatial distribution of industry. Specifically, these authors suggested two aspects of office-location decisions by organizations in assessing the impact of the new technology. Those are (1) the need for certain organizations to locate where they can access telecommunications networks and (2) increased opportunity for the organization to locate its offices in areas where infrastructure costs are generally less than traditional office locations such as downtown areas. Essentially, these two conditions imply another type of concentration eventually. It will be definitely a dispersion if activities move away from the central business district (CBD) to outer areas. However, firms will have to be concentrated in limited areas equipped with IT infrastructure insofar as the network does not provide equal access everywhere. In this sense, the expected distribution pattern may be called "dispersed concentration."

While limited accessibility to the information network (especially high-speed access) may be one factor in favor of a concentrated pattern, complementarities between telecommunication and transportation or face-to-face contacts are another relevant factor. Gaspar and Glaeser (1998) tried to uncover the relationship between IT and face-to-face interactions and/or cities that facilitate those interactions. In the empirical analysis using telephone call data, the authors concluded those two are complements rather than substitutes. As a result, the centralizing forces in cities did not seem to vanish. Instead of establishing a single framework to prove the relationship, they listed several different results from the regression analyses in different specifications. However, as the authors noted several times, it is very hard to separate the exclusive effect of IT in their regression models.

Some authors find the issue of limited value and that there is no clear evidence as to whether IT has an influence on concentration and/or dispersion. Arguing against the optimistic view of technology, Salomon (1996) mentioned that there have been overly great expectations of the information age, that is, that telecommunications can eliminate the effects of distance and as a result can have profound effects on the spatial organization of society. He also identified four assumptions underlying the proposition that cities will disperse due to improved IT: (1) substitutive relationship between transportation and telecommunications, (2) substitution of information for material goods, (3) ubiquity of telecommunications, and (4) the recognition that the dispersal has been constrained by congestion and travel costs. Even though he claimed that a complete change of urban form could not be expected in the information age, he agreed there are some changes that may result from these technological changes. One example of telecommunications' dispersal effect is the emergence of back-office activities located remotely from the core organization (Richardson and Gillespie 1996; Salomon 1996). Further, there exists a gap, according to Capello (1994), between the introduction of new IT and changes in the spatial pattern of firms. This is ascribed to an overestimation of the technological potential and to optimistic and superficial analysis of the relationship between the new technology and spatial restructuring. She also noted that in the long run, those technologies lead to new production strategies, such as the "just-in-time" system that will require a physical proximity (either in the interurban or the intraurban context) between firms and eventual spatial clustering of economic activities. But as Fujita and Hamaguchi (2001) noted, firms (in the research, specifically users of intermediate goods) can be more dispersed with better-developed transportation/communication infrastructure as in the examples of many developed countries.

Research has been devoted to elaborating the "concentration-dispersion" debate at a more detailed level and exploring the subsequent urban spatial structure generated by IT. In a conceptual discussion of this relationship, Peitchinis (1992) explored the effect of a more broadly defined computer technology (rather than information technology) on the location pattern of economic activities in industrial organization. Some of the features to be expected in the future, based on his findings, are (1) a global dispersion of production processes, (2) a spatial concentration of management, and (3) an increasing dispersion of human participation in the work processes. In a paper exploring the IT impact on cities, Moss (1998) argued that both concentration (centralization) and dispersion (decentralization) are possible in the future. Regardless of the resultant distribution pattern, however, the author suggested that telecommunication has a positive impact on local economic development. Atkinson (1998) provided a more systematic review of the relevant literature. He classified and reviewed five topics related to the impact and provided a comprehensive projection of the urban and economic future in favor of the dispersion impact of the technology, especially IT's role in overcoming distance/locational constraints. Some of the early attempts to establish a theoretical model to explain the IT impact are found in the work of Kutay (1986a, b, 1988). While the two earlier papers focused on models of office location and the impact of IT, a more generalized approach (a model of the urban systems) was featured in the third paper. The findings suggested that the new technology would lead to an increased level of economic disadvantage in the center and, as a result, decentralization of activities. Some recent research has attempted to combine theoretical frameworks with empirical evidence. Shen (1999, 2000a), for example, devised an adjusted accessibility measure to incorporate location, transportation, and telecommunication for employment opportunities (Shen 1999) as well as other types of opportunities (Shen 2000a). The result showed that geographic location becomes less and less important whereas transportation and, in recent years, telecommunication factors have been more significant.

On a more conceptual level, the geography and/or distribution of economic activities can be redefined on the basis of information flows. Echeverri-Carroll (1996) noted that the effect of geographical relationships between organizations cannot be conceptualized without understanding intraorganizational and interorganizational computer networks that bind particular locations together. And even though spatial decentralization continues to be relevant, the process is characterized by much higher functional integration using the information network (Echeverri-Carroll 1996). It is implied that network connectivity can be a more important factor in deciding geographical relationships (that is, concentrated or dispersed) than physical distance especially in the information age. It is obvious that the scope of geography here embraces not only territorial but virtual concepts. But Echeverri-Carroll does not agree that such technology leads to the demise of the concept of "distance." Echeverri-Carroll concluded that since "these technologies also impose higher investments on interfirm linkages and more stringent restrictions on labor's skills and flexibility, both . . . restrain the location of industry in space" (1996, p. 148).

While a larger portion of the relevant research has focused on location decisions of business units considering the IT impact, a relatively smaller number of studies have attempted to link the impact of the new technology with residential location decisions and the consequent commuting pattern of households. Residential distribution may be less sensitive to IT than is the distribution of economic activities either because only a small portion of people (that is, telecommuters) are influenced by IT or because the IT infrastructure may not be among the most important decision-making criteria for residential location. As a result, it is hard to find an obvious trend for this pattern. Yen and Mahmassani (1997) concluded that insufficient evidence is available to confirm the impact of telecommuting on household residential location notwithstanding the expectation that increased mobility due to telecommunication technology makes it possible for households to move farther away from the urban core. It is not, however, completely unexpected considering that urban residential location is not based on economic criteria alone and, rather, access to urban amenities may keep people in cities. Mokhtarian (1998) focused more on the spatial residential pattern related to commuting; she noted that the effect of the new technology is not to reduce travel but to increase the flexibility of travel and as a result, total travel may be higher and/or shifted to the off-peak periods. The ability to commute less often due to telecommuting often leads to relocation of the residence farther away from work, sometimes enough for the total commuting vehicle miles traveled (VMT) on a smaller number of commuting days to exceed the previous levels (Mokhtarian 1998). At a systemwide level, this trend may result in a decentralizing effect on urban form [for a more detailed discussion on the theoretical model of residential relocation due to telecommuting, refer to Lund and Mokhtarian (1994) or Stough and Paelinck (1996)]. Mokhtarian (1998) also suggested that this is not the case as far as part-time, short-term telecommuting is involved for, in such cases, decentralization may result from other reasons. Rather than the flexibility of commuting, Shen (2000b) focused on the residential location flexibility. From the analytical perspective, he concluded that a polarization of residential location flexibility emerged, providing increasing flexibility for people equipped with information and communication technology but not for others. He also noted that an ignorance of the travel generation effect of telecommunication may overestimate the flexibility.

One of the major objectives of this research is to provide empirical evidence to the debate on the IT impact on urban spatial structure. Two relevant research questions identified and tested in the later sections are (1) whether IT is influential in shaping urban spatial structure and, (2) if it is, whether it works as a centrifugal or a centripetal force.

MODEL DERIVATION

Among many economic sectors that affect the shaping of spatial structure, manufacturing, retail, and service sectors have been chosen to be examined in this paper for the analysis of urban spatial structure of economic activities. In Figure 1, the urban spatial structure is defined as the spatial structure or distribution of economic activities. The number of establishments[2] in each sectoral category in 1995 in Chicago is used to construct a set of dependent variables described below. Urban activity is examined separately in the three economic sectors as well as the total. Different sectors are expected to show different patterns and explanations.

There are two types of dependent variables considered in the analysis. The first one is the activity level measured simply by the number of economic activities (establishments).[3] By examining these variables, the analysis is able to determine whether the IT-related variables or others are significant in explaining higher or lower levels of such activities. In this context, it is more related to an “attraction” effect.

The second is the distribution pattern around a certain zone of interest. This is measured by a local indicator of spatial association (LISA). Anselin (1995a, p. 94, 1995b, p. 42) defined LISA as any statistic that satisfies the following two conditions:

- The LISA for each observation provides an indication of the extent of significant spatial clustering of similar values around that observation, and
- the sum of LISAs for all observations is proportional to a global indicator of spatial association.

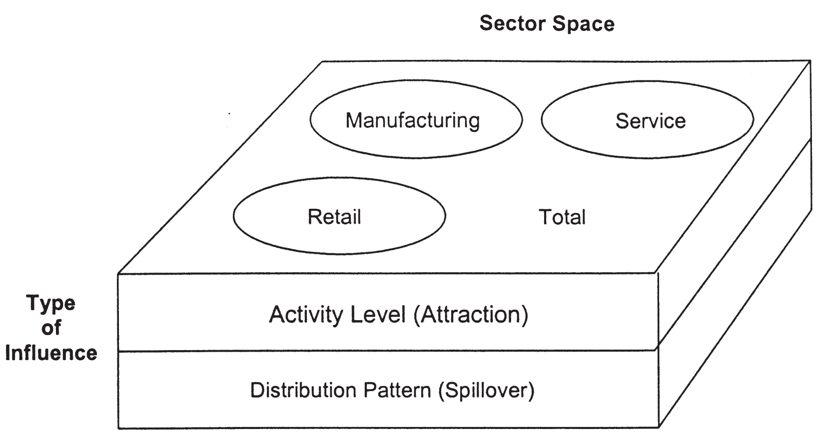

FIG. 1. Classification of Dependent Variables

2. 1995 ZIP code business pattern provides the number of establishments in each ZIP code zone by each sector. From the census definition, an establishment is a single physical location at which business is conducted or services or industrial operations are performed. It is not necessarily identical with a company or enterprise, which may consist of one or more establishments. When two or more activities are carried on at a single location under a single ownership, all activities generally are grouped together as a single establishment. The entire establishment is classified on the basis of its major activity and all data are included in that classification

3. Since the regression analysis is run based on the ZIP code zone data and the size of the ZIP code zones is not identical, the number of establishments in each zone is not independent of areal size variation. To remove this problem, an adjusted value (similar to density) is calculated by dividing the number of establishments in a zone by the corresponding areal size.

One of the frequently used LISAs is the local Moran that is defined as

$$I_i = \left(z_i \,/ \sum_i z_i^2\right) \sum_j w_{ij} z_j \qquad (1)$$

where z_i = observation in i in the form of deviation from the mean, and w_{ij} = spatial weight matrix.

The interpretation of this indicator value is conceptually the same as Moran's I.[4] For example, higher values reflect positive spatial autocorrelation, or the concentration of similar values of observation. Lower values reflect negative spatial autocorrelation, or dispersion or repulsion of similar values of observation over the space. To calculate I_i, the first dependent variable (the adjusted number of establishments in zone i) is indicated as z_i and the inversed squared distance weight matrix as w_{ij}.[5] By investigating these variables, the analysis is able to reveal whether the IT-related variables and others are significant in explaining the spatial distribution pattern of urban activities in terms of tendencies for concentration or dispersal. In this sense, it can be considered a "spillover" effect. Combining these two dependent variables enables the analysis to provide a comprehensive picture of urban activity patterns and the impact of information technology on them. In sum, there are eight dependent variables[6] to be explained and as a result eight regression models are built with a series of independent variables for Chicago.

The sets of independent variables are grouped in Table 1. The first group is the IT-related variables. While a direct measure of IT and/or usage level of those technologies are the most desirable data for this category, as noted earlier, it is very difficult, if not impossible, to obtain such information in a practical sense. Since there are few available data sources on the level of this function by disaggregate zones within an urban area, alternative indices will be derived to represent the level of IT intensity. Those are (1) the number of information-intensive establishments, (2) the number of usual telecommuters, and (3) the number of potential telecommuters.

TABLE 1
Classification of Independent Variables

Group	Variable	Description
IT	**ITFIRM**	Number of establishments in information-intensive sector in 1995
	UTEL	Estimated number of usual telecommuters in 1990
	PTEL	Potential number of telecommuters in 1990
Center Orientedness	**CBD**	Distance from the CBD
	JHR	Job-housing ratio: # of employees (1992) / # of employed residents (1990)
People	**POP**	Total population in 1990
	POPM	Manufacturing-employed residents in 1990
	POPR	Retail-employed residents in 1990
	POPS	Service-employed residents in 1990

4. In fact, those two are related in that Moran's I is the average of all values of local Moran.

5. Since the contiguity weight matrix just considers the influence of adjacent neighbors, it may not work appropriately when dealing with a set of smaller areal units in an urban area in which spillovers may extend beyond contiguous zones. As a result, a distance weight matrix is used instead.

6. Those are four activity levels (total, manufacturing, retail, and service) and four distribution patterns (total, manufacturing, retail, and service).

The first one is related to the level of information infrastructure that seems to be more closely linked to firm activities rather than individuals. Sinden (1995) used SIC 7902 (telecommunications) in the research to examine British economic restructuring process in the telecommunication services. More often than not, secondary data do not allow this level of detailed information to be adapted, especially when the research is conducted at a more disaggregate geographical level. As a result, several authors have tried to use surrogates. Moulaert and Djellal (1995) used NAE 7703 (information technology and organization consulting sector) and 7704 (computer services) as alternatives in research in France. Another study by Tofflemire (1992) focused on SIC 6000 (F.I.R.E.), 73 (business services), 81 (legal services), and 87 (engineering, accounting, and management services) in the United States. Both studies are common in that they considered the level of producer services in a region as reflective of the level of IT. ITFIRM in the present analysis is composed of those establishments in SIC 73, 81, and 87.

The "usual" telecommuters (UTEL in this analysis) are defined as those respondents that answered "worked at home" to the census question asking workers by what mode they usually traveled to work, excluding self-employed workers and workers in particular occupations (Handy and Moktarian 1996, p. 168).[7] While usual telecommuters are substantial participants in telecommuting, the number of potential telecommuters (PTEL) has to be estimated indirectly. Adopting Nilles' proposition (1988) that 50 percent of workers are "information workers" and 80 percent of them are potential telecommuters, Handy and Moktarian (1996) defined "potential" telecommuters as those with certain occupations classified as telecommuting-conducive: executive, administrative, managerial; professional specialty; technicians and related; sales; and administrative support. Those two telecommuter variables[8] are included in the model to measure the significance in explaining the urban spatial structure. They are used as a proxy for the level of IT infrastructure of a certain zone. In other words, a zone with a higher proportion of those information-related workers may have higher levels of network infrastructure than others.

The second group of variables in Table 1 is advanced to examine the impact of centrality on the level of activity and distribution patterns. CBD is the Euclidean distance between the centroids of the CBD and each zone.[9] It is clear that the CBD focuses on the influence of the urban center. JHR (job-housing ratio) is obtained by calculating the ratio between the number of employees (who work there) and the number of employed residents (who live there) in a zone. The 1992 Economic Census was used to gather the information on employment by place of work and the 1990 Population Census was the source for the number of employed residents at the ZIP code area level. Usually, a center is characterized as having a higher number of economic activities and a relatively lower rate of residents. Considering higher affordability of economic activities for urban rent than residential activities, it is not unusual to expect that relatively more economic activities can be seen than residential activities. As a result, a higher rate of JHR is expected to represent stronger centrality trends. It is used for measuring the influence of subcenters as well as the CBD.

The third group of variables in Table 1 includes population and employed residents (counted based on where they live). Population is used as a general measure for the

7. They include private household workers, protective services, farming, forestry and fishing, precision production, craft and repair, operators, assemblers, inspectors, transportation and material moving and handlers, helpers, laborers. At a more disaggregate areal level in the analysis, this number is estimated using the relative employment share of such occupations in corresponding areas.

8. For a more comprehensive discussion on the estimation of the usual and the potential telecommuters, refer to Handy and Moktarian (1996).

9. The centroids of each zone are obtained in the form of *(longitude, latitude)* and as a result, the distance between them is measured in degrees.

product market (demand) while employed residents in an individual sector is used as a measure for the labor market (supply).[10] All these four variables are used only in the equations for corresponding economic activities.

There are four possible outcomes for the relationship between IT variables and two dependent variables: activity level (attraction) and distribution pattern (spillover). Table 2 summarizes those outcomes. By applying this framework in the interpretation, the analysis is able to determine whether the controversial propositions and hypotheses about IT impact are valid or not: whether the IT factor is critical in location and/or distribution of economic activities and whether it leads to concentration/dispersion of activities or not.

There are also four ways to interpret the outcome of the center-orientation related-variables, especially in this case, the sign of the coefficients. Table 3 shows the conceptual classification of the impact of center orientation.

The positive sign for the CBD would imply that economic activities are more intense as we go farther from the CBD and a negative value would indicate the opposite. In the case of positivity, we cannot expect the traditional monocentric shape of the city. On the other hand, a positive JHR reflects the higher level of economic activities that can be seen in more generally defined city centers (city center or subcenters). Each listing in the box is the anticipated dominant type(s) of centers within a city for each of the economic sectors with corresponding signs.

To remove the influence resulting from different areal size, some variables that contain raw numbers (that is, number of establishments, residents, employment, etc.) are divided by the area to be transformed into standardized numbers—similar to the density measure. But when it is necessary to compare actual numbers of employment and residents as in obtaining job-housing ratio, they are used without transformation. In addition, some other variables such as ratio and distance are not transformed since

TABLE 2
Possible Outcomes of the Model for IT Impact

		Distribution pattern (spillover)	
		↑↑	↑↓
Activity level (attraction)	↑ ↑	Higher activity level with concentrated pattern	Higher activity level with dispersed pattern
	↑ ↓	Lower activity level with concentrated pattern	Lower activity level with dispersed pattern

NOTE: ↑ increase in IT variables (independent). ↑↓ increase or decrease in corresponding dependent variables.

TABLE 3
Interpretation of the Coefficients of Center Orientedness Related Variables

		JHR	
		+	−
CBD	+	Subcenter (multicentricity)	Noncenter (even distribution)
	−	CBD and/or Subcenter (multicentricity)	CBD and/or Noncenter (monocentricity)

10. That means, only relevant sectoral variable is used in each equation. For example, the equation for manufacturing only includes POPM as a measure of labor market.

they do not depend on the areal size. It is also noted that all the variables except LISA take the form of *(I+W)_Variable*, where *I* is the identity matrix and *W* is the spatial weight matrix. As Anselin and Bera (1998) noted, when data are based on administratively determined units, there is no reason to believe economic behavior conforms to these units. As a result, it is appropriate to incorporate adjacent economic values into a value of interest weighted by distance. The spatial weight matrix used in the analysis is the squared inverse distance matrix. While the contiguity matrix would have been simpler to handle, it only considers the values of the adjacent neighboring ZIP code zones in the model. The influence of attraction and spillover of economic activities, however, may reach further than one ZIP code zone, especially in an urban area where each ZIP code area is smaller. By combining the spatial weight matrix, the model is able to consider not only the level of an economic activity (that is, number of establishments) in a certain zone, but also the level of the economic activity around the zone. Mathematically, it calculates a spatially weighted average level of economic activities around the zone of interest. It is noted, however, that LISA is in itself combining such information and does not take the same form as others in the model.

ANALYSIS RESULTS: IT, CENTER ORIENTEDNESS, AND URBAN ACTIVITIES IN CHICAGO

The empirical analysis considers 306 zip code zones in the Chicago CMSA. Information technology needs to be considered as a crucial explanatory factor for the Chicago economy in two aspects. First, the Chicago economy has recently been in transition from the traditional manufacturing-dominated industrial structure to a more service-driven economy. More advanced and sophisticated service activities as well as the specific manufacturing activities connected to such services usually make a higher demand on information technology. Recently identified economic trends in Chicago, such as the hollowing-out process, provide other forces to attract the new technology. As Hewings et al. (1998) noted, the intrametropolitan dependence in Chicago has been replaced in the last two decades by the dependence on sources of supply and demand outside the region. The increased distance of industrial backward and forward linkages between firms is facilitated in large part by advanced transportation systems (lowering the cost of interaction) and information technology (providing rapid and reliable contacts with more distant suppliers and markets). Relevant variables are derived from the 1990 U.S. Population Census, the 1992 U.S. Economic Census and the 1995 ZIP Code Business Pattern. As mentioned before, all the variables related to raw numbers (for example, number of establishments, people, etc.) are standardized by their areal size in order to reduce the areal size effect.

Table 4 provides the estimation results on total employment in Chicago. As for the equation of activity level (attraction effect), ITFIRM showed significant positive relation with the dependent among IT-related variables. It suggests that more establishments will be attracted to an area if it is recognized as the area with a higher level of IT infrastructure. It is plausible that an individual establishment might want to locate or relocate in such areas with higher accessibility to the information network. Two other IT-related variables in the analysis, UTEL and PTEL, showed conflicting signs with each other. But the magnitude of the coefficients of UTEL and PTEL was much smaller than that of ITFIRM and as a result it might not be considered as critical relative to ITFIRM in the model. It is also thought that those two IT variables (UTEL and PTEL) are related to the level of IT infrastructure especially for personal or residential access to the information network rather than to the level of IT infrastructure for an establishment's access. Two variables to measure center orientedness revealed a strong tendency for establishments to locate in the central areas. A negative coefficient for the CBD means a lower level of economic activities at a farther distance from the CBD, while positive coefficient of JHR implies higher levels of economic

TABLE 4
Estimation Results on Total Employment in Chicago

	Activity level	Distribution pattern
Constant	1.8608	−0.2367
	(0.002)**	(0.000)**
ITFIRM	1.3195	0.0457
	(0.000)**	(0.000)**
UTEL	−0.1387	0.0053
	(0.000)**	(0.000)**
PTEL	0.0229	−0.0011
	(0.000)**	(0.000)**
CBD	−2.2581	0.1927
	(0.005)**	(0.000)**
JHR	14.7738	0.7682
	(0.022) *	(0.010)**
POP	0.0042	0.0000
	(0.000)**	(0.653)
Adj-R^2	0.9896	0.9834

NOTES: * significant at 95 percent; ** significant at 99 percent.

activities at both the city center and subcenters. Overall, economic activities prefer to locate either in the CBD or subcenters of the city in terms of the intrametropolitan location decision. It is also noted that POP as the source of labor force and market was significant but with a smaller coefficient.

For the distribution pattern (spillover effect), ITFIRM revealed a positive sign that was significant even if the magnitude is small. Again, the positive sign here means a more concentrated pattern of those economic activities around the zone of interest.[11] A higher level of IT-related infrastructure is seen to lead to a more concentrated distribution of economic activities rather than working as a facilitator to a more dispersed pattern, at least in terms of the intrametropolitan distribution. As is the same in the previous case, UTEL and PTEL have conflicting signs but the magnitude of the coefficients are relatively small. The positive coefficient for the CBD suggested that higher concentration patterns are expected as we go farther from the CBD, while the positive coefficient of JHR showed that a more concentrated distribution pattern is expected around the centers of a city. Combining these two results implies that more concentrated patterns are prevailing especially around subcenters of a city. Population was not very important in explaining the distribution pattern.

The IT factor is seen to stimulate a more intense economic activity and a relatively concentrated distribution pattern over space. Notwithstanding the suggestions of dispersion influences due to the IT factors, limited availability and accessibility of those high technology establishments in limited space seems to have led to such concentration tendencies. Center orientedness variables revealed higher activity levels in urban centers and more concentrated distribution patterns around subcenters. In that the CBD is not considered the only center of the city and concentration is also obvious around subcenters, it is more or less classified as polycentricity and in a more specific term, "dispersed concentration."

11. Strictly speaking, the precise interpretation should be that a positive sign means a more spatially concentrated pattern of similar levels of zonal economic activities (either more economically active zones near economically active or less active zones near inactive). However, the positivity for the ITFIRM here can be interpreted as a spatial concentration of economically active zones since it is found that ITFIRM also draws a higher level of economic activities in the previous (activity level) regression. In other words, ITFIRM works to attract establishments to the surrounding areas as well as to the zone where the activity is located.

Table 5 provides the estimated results for the manufacturing equations. A similar pattern can be seen for the IT-related variables in the equation of activity level as in the equation for all establishments above. As a result, a similar interpretation can be applied to this: a higher number of manufacturing establishments in areas with better IT infrastructure. Center orientedness variables also show similar patterns. More manufacturing establishments prefer to stay near the CBD or city subcenters with lesser significance. Establishments in this sector are attracted by the labor force but with lesser influence on the location decision compared to other variables.

The equation of distribution type also revealed similar results for manufacturing. With smaller magnitudes for the coefficients of UTEL and PTEL and with conflicting signs, ITFIRM led to a more concentrated distribution pattern of manufacturing activities. Center orientedness variables were not significant in the model, so that the distribution pattern is not greatly influenced by those factors. In other words, the distribution pattern near the centers may not be so different from the one far from them. While location in a center yields certain advantages to manufacturing establishments (from the result for activity level), it does not have enough spillover effect on surrounding areas to drive a concentrated distribution pattern. The distribution pattern is also dependent on the labor force but with smaller coefficients, suggesting a greater concentration pattern near larger labor force pools.

Overall, the IT variable works as an attraction factor, so that it leads to an increase in the activity level of manufacturing in a zone as well as demonstrating a spillover effect over the surrounding areas. Center orientedness can be summarized again as "dispersed concentration." While it works as an attraction for further manufacturing for a certain zone, it does not have much of a spillover effect over the surrounding space. Just like the IT variable, POPM has both effects (attraction and spillover) in both equations.

The estimation results for the retail sector are summarized in Table 6. In similar fashion to the previous two estimates, ITFIRM was positively significant and the influence from two others was relatively small. Center orientedness variables showed a little different pattern from others. The CBD was not significant in the model, reflecting that retail activities are independently distributed along with the distance from the CBD. The negative coefficient of JHR implied that more retail activities can be seen outside of centers. One plausible explanation is that, by nature, the retail sec-

TABLE 5
Estimation Results on Manufacturing Sector in Chicago

	Activity level	Distribution pattern
Constant	0.3288 (0.000)*	−0.1930 (0.011) *
ITFIRM	0.0300 (0.000)*	0.0423 (0.000)**
UTEL	0.0050 (0.084)	0.0085 (0.002)**
PTEL	−0.0021 (0.000)**	−0.0024 (0.000)**
CBD	−0.4011 (0.000)**	0.0601 (0.538)
JHR	1.3565 (0.125)	1.0147 (0.212)
POPM	0.0143 (0.000)**	0.0055 (0.000)**
Adj-R^2	0.8321	0.8857

NOTES: * significant at 95 percent; ** significant at 99 percent.

TABLE 6
Estimation Results on Retail Sector in Chicago

	Activity level	Distribution pattern
Constant	0.5214 (0.004)**	−0.3812 (0.000)**
ITFIRM	0.1710 (0.000)**	0.0460 (0.000)**
UTEL	−0.0016 (0.811)	0.0138 (0.000)**
PTEL	0.0093 (0.000)**	−0.0008 (0.015) *
CBD	−0.3642 (0.127)	0.3839 (0.000)**
JHR	−5.8158 (0.004)**	−0.8851 (0.014) *
POPR	0.0077 (0.289)	0.0010 (0.465)
Adj-R^2	0.9491	0.9782

NOTES: * significant at 95 percent; ** significant at 99 percent.

tor has a tendency to be closer to their customers rather than to employment centers. The labor force factor was not significant in this model.

In terms of the distribution pattern, the same pattern can be seen for the IT related factors: more concentration with a higher IT level. The positive coefficient for the CBD and the negative coefficient for JHR implied that a pattern of more concentration can be seen outside of the CBD and subcenters. Again, labor force consideration was not so important in the model.

In sum, IT variables showed attraction and spillover effects in and around the area as in other sectors. Center orientedness revealed that it also has both an attraction and spillover effect but this time outside of the city centers. It is thought that the sector seeks market-oriented locations closer to residential population, while city centers have relatively less residential population compared to employees.

Finally, the estimation results for the service sector are summarized in Table 7. As before, ITFIRM showed positive significance while the other two IT-related variables demonstrated a smaller contribution in the model. Center orientedness variables were not significant in this sector; diverse combinations of service activities may blur the trends in this case. For example, some higher-order services such as business or producer services may want to locate in central places rather than outside while, for example, personal services may prefer more market-oriented locations like retail sectors. Even if there is little significance, the negative coefficient of CBD and positive coefficient of JHR still implied a mild center orientation of service activities. Closeness to its labor force was significant in this sector.

The equation for the distribution pattern also revealed that ITFIRM was significant in explaining the concentrated distribution pattern as in other sectors. The negative coefficient for the CBD implied a more concentrated pattern around the CBD. The insignificance of the coefficient of JHR suggested that there is no obvious distribution pattern outside of the CBD regardless of whether it is near subcenters or not. Even if it is not significant, the positive coefficient for JHR implied a mild tendency of concentration around the subcenters. The labor force factor was not significant in explaining the distribution pattern.

As before, IT factors have attraction as well as spillover effects on the location/distribution of service sectors. The sector has a mild center orientedness but not as strong as other sectors in the economy, possibly due to the complexity of service ac-

TABLE 7
Estimation Results on Service Sector in Chicago

	Activity level	Distribution pattern
Constant	0.1970	−0.2430
	(0.459)	(0.000)**
ITFIRM	0.6929	0.0441
	(0.000)**	(0.000)**
UTEL	−0.0724	0.0064
	(0.000)**	(0.000)**
PTEL	−0.0037	−0.0008
	(0.536)	(0.313)
CBD	−0.3237	−0.0008
	(0.363)	(0.000)**
JHR	3.9470	0.6343
	(0.215)	(0.116)
POPS	0.0308	−0.0009
	(0.002)**	(0.449)
Adj-R^2	0.9906	0.9703

NOTES: * significant at 95 percent; ** significant at 99 percent.

tivities and their diverse implications on location in space. The labor force factor has an attraction effect but no spillover influences.

In terms of the attraction effect of IT, the service sector was more sensitive than other sectors and the manufacturing was least sensitive. Service establishments were considered to take more advantage of higher levels of IT infrastructure than other sectors. A large amount of interaction within and between establishments can be observed in the service sector and, in that sense, area equipped with high tech would be good places for them to locate. In contrast to services, manufacturing is more related to handling tangibles, for example, transporting, processing, and shipping products, with relatively fewer opportunities for using IT technology than the service sector that is more related to intangibles. However, the spillover effect around the area was almost the same as that observed for other sectors. All of them showed a strong spillover effect for the IT measure.

When considering center orientedness, retail pushed itself to a farther area from the centers. But central places were attractive ones for manufacturing and service establishments. Especially related to the sensitivity of the coefficient, manufacturing was more sensitive to distance decay than service while service had a higher sensitivity for city centers in general. In terms of spillover effects, there was no significance sign in manufacturing, a significant concentration pattern outside of city centers in retail, and finally, a more concentrated pattern around the CBD for services. Variables for the markets for products and service and labor force showed varying results for different sectors.

CONCLUSION

This paper attempted to explore the impact of information technology and the center orientedness tendency of activities on the distribution pattern of urban economic activities in the Chicago CMSA. For this purpose, a series of regression models was built for the three economic sectors of manufacturing, retail, and service. Two aspects of the impact were examined: an attraction effect on a certain zone (level of activity) and a spillover effect on surrounding areas (distribution type). The results can be summarized as follows.

First, the impact of information technology on the distribution pattern of urban economic activities was very influential on the agglomeration processes of establishments in individual sectors in Chicago. It worked in a positive direction for both of the aspects of the influence: attraction and spillover. Despite the centrifugal drives of information technology on urban distribution, limited availability and accessibility of a well-equipped information network in certain areas seemed to restrict the favorable location of establishments and as a result a more concentrated distribution pattern was observed. It seemed that even if the IT may work as a centrifugal force in the future when the technology is more evenly distributed over space, it is working as a centripetal force, at least for now, when the distribution of the technology is still uneven.[12] Table 8 shows that all the sectors in the analysis are classified as of the type in the upper left box of Table 2.

Secondly, center orientedness appears in a different way in different sectors in Chicago. Both the center and subcenters of the city were attractive locations for manufacturing establishments. However, spillover from the centers can be seen only around suburban centers. The fact that a larger area is needed for this type of activity seems to restrict the expansion of establishment activities around the CBD where land values and rent are very high. The retail sector was more or less footloose in terms of location. While the CBD was an attractive location for those establishments,[13] noncentral areas were also attractive ones. It is thought that the former relates more to serving employees near their workplaces while the latter is more related to serving population near their residences. In terms of spillover, it was seen only in noncentral regions. Service sectors showed more center orientedness than any other sectors. Both attraction and spillover effects were strong in and around the center and subcenters of the CBD. Figure 2 depicts the map of individual sectors in the two-dimensional space of attraction and spillover effect.

A more precise analysis awaits more detailed data especially related to the level of the information infrastructure measured in a more direct way. In addition, the amount of information flow between zones, if there is any proxy to represent it, will give another horizon to apply to the spatial weight matrix. Also, more detailed sectoral classifications will provide a more specific relationship between individual sectors and the influence of information technology. For example, it may be an interesting work to categorize different industries along with the strength of their relationships with IT and forecast the future location/distribution pattern under different policy measures related to IT infrastructure.

TABLE 8
Sectoral Classification for IT Impact

		Distribution pattern (spillover)	
		↑↑	↑↓
Activity level (attraction)	↑ ↑	Manufacturing Retail Service	
	↑ ↓		

NOTE: ↑ increase in IT variables (independent). ↑↓ increase or decrease in corresponding dependent variables.

12. This tendency is also found in the interurban context. Fujita and Hamaguchi (2001) noted that the customers of intermediate goods are more dispersed with the well-developed transportation/communication infrastructure (in most developed countries) than with limited infrastructure (in many developing countries).

13. It should be reminded, however, that the significance of this coefficient was very low.

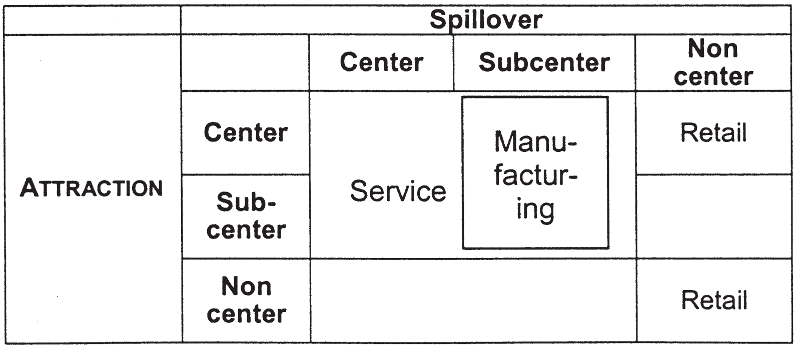

FIG. 2. Sectoral Map of Attraction and Spillover in Chicago

One of the important factors not explicitly considered in this analysis is knowledge spillover. A relatively strong concentration of economic activities in spite of a more developed IT may be ascribed to the need for an interaction of knowledge (rather than information) that can be easily transferred through face-to-face contact. As Glaeser (1994) confirmed, knowledge exchange as a way of intellectual spillover requires geographic proximity. Such closeness, however, sometimes does not have to mean a geographic one. Using a more sophisticated framework, Echeverri-Carroll and Brennan (1994) showed that the innovations in firms located in lower-ranked cities depend on their (network) accessibility (rather than geographic proximity) to some top-ranked cities while the innovations in firms located in the higher-ranked cities are influenced by geographic proximity. Future studies will be enriched if they are able to combine this type of the knowledge spillover effect as an explanatory variable in the location decision model of firms. Furthermore, if the framework of the model is able to separate the effect of knowledge interaction from the information exchange, locational factors can be analyzed at a more sophisticated level and as a result, the dominant forces of urban economic distribution pattern can be identified with greater precision.

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