"The spatial-temporal cluster development in the healthcare service industry – an integrated GIS approach"

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The spatial-temporal cluster development in the healthcare service industry – an integrated GIS approach

Abstract

This paper examines the clustering patterns and changes in the service industries and healthcare industry in particular in the United States at county scale for the past three decades (1969 to 2000). This study integrates Geographic Information System (GIS) and various spatial-temporal analytical tools to conduct empirical regional economic analysis. The method is built upon a loose-coupling of the GIS module using ArcGIS, and various statistical and temporal analytical modules using Excel, Visual Basic, SPSS, and SAS. This method allows both spatial and temporal analysis of industry clusters and regional economic development. Analytical tools such as the location quotient (LQ) technique and Moran's I statistics are employed. The paper applies this method to trace and analyze both spatial and temporal clustering patterns in the service industries as a whole and healthcare industry in particular across the sixty-two counties in the New York State over the past three decades.

Key words: healthcare services, Geographic Information System (GIS), regional economic development, industry cluster analysis, and spatial-temporal regional economic analysis.
JEL Classification: I10, O16, O21, O44, Q56, R12.

Introduction

Developing practical GIS applications for business and economic analyses and planning has been a hot topic both for academic researchers and GIS industry practitioners. Rogerson and Fotheringham (1994), and Boasson (2002) outline the benefits of integrating spatial analysis and GIS. They argued that from a GIS perspective, there is an increasing demand for GIS systems that "do something" other than display and organize data, whereas from the spatial analytical perspective, there are advantages to linking statistical methods and econometric modeling to various databases and display capabilities of a GIS. Thus, they argue that GIS can facilitate a spatial analysis and may even provide insights that would otherwise be missed. Moreover, GIS could possibly lead to an improved understanding both of the attributes being examined and of the procedures used to examine them.

As for the integration between GIS and spatial analysis, Openshaw (1991), Anselin and Getis (1991), Wise and Haining (1991), Goodchild et al. (1992), Rogerson and Fotheringham (1994) and Boasson (2002) have suggested various possibilities. Openshaw (1994), for instance, suggested two exploratory space-time-attribute pattern analyzers relevant to GIS. Getis (1994) illustrated the spatial dependence and heterogeneity and proximal databases and outlined a procedure for enhancing the capability for GIS to display and aid in the evaluation of spatial dependence and heterogeneity. Hornsby and Egenhofer (2000) developed a theoretical model based on the explicit description of change with respect to states of existence and non-existence for identifiable objects. They argued that the basis for tracing these changes is the concept of object identity.

However, there are various implementation problems when it comes to integrating GIS and spatial statistical analyses even in the latest versions of GIS software such as ArcGIS 9. In his review of statistical spatial analysis in geographic information systems, Bailey (1994) pointed out that despite widespread recognition that the analysis of patterns and relationships in geographical data should be a central function of GIS, the sophistication of certain areas of analytical functionality in many existing GIS continues to leave much to be desired. Openshaw (1994) stressed the need for space-time attribute pattern analysis relevant to GIS. More specifically, he pointed out that there was an obvious need to be able to analyze the emerging heap of geodatabases created by GIS. It is widely recognized that GIS development, in terms of spatial and temporal analysis capabilities, has not been able to handle the analysis of the range and abundance of geographic data (Openshaw, 1991, 1992). O'Kelly (1994) suggested that geographers have been slow to integrate both temporal and spatial dimensions into GIS. There are formidable technical obstacles, but even at the fundamental research level, analysts have been unable to operationalize the role of space and time in simple models.

Despite the debates about the importance and potential benefits of integrating GIS with spatial and temporal analysis, and despite the recognized theoretical benefits of using GIS in regional economic studies, few geographers and regional economic planners manage to operationalize the concept of integrating GIS with business and economic analyses to capture both the temporal and spatial aspects of regional economic development. Moreover, few of

the existing GIS programs reviewed to date have covered all the functions that enable the researcher to undertake all his or her planning studies. Some programs allow a high degree of cartographic accuracy in the final presentation, while other programs offer simple methods to add data to a map. But many of these programs do not directly allow a display of progress or development on screen nor do they allow complicated spatial statistical studies.

In summary, from the review of prior studies in applying GIS to regional economic analysis, it is clear that the issue of integrating GIS with regional economic planning and analysis has largely remained at the stage of discussions despite the promise of commercial GIS such as ArcGIS to add some improvements that allow for better import of spreadsheet data as well as improved spatial statistics routines. There seems to be a paucity of operational frameworks that can incorporate the advantages of GIS and the existing tools of regional economic analysis.

In this study, in order to bridge this gap, we develop and operationalize a loose-coupling of ArcGIS as the GIS module, and Excel, Visual Basic, SPSS, and SAS as the spatial-temporal regional economic analysis modules so as to integrate GIS with various spatial econometric analytical techniques such as the location quotient (LQ) technique and Moran's I statistics. This method allows both spatial and temporal dimensions of the analyses of the economic development. Using GIS in combination of Excel and statistical packages, Pick et al. (1988) developed a cluster analysis approach to marketing research in the border lands region of Mexico.

Our study applies the integration GIS framework to the study of the industry clusters in the service sector and the healthcare industry in particular. It traces both spatial and temporal clustering patterns of changes and development in the healthcare service industry and the service sector as a whole across the 62 counties in New York State over a period of three decades from 1969 through to 2000. The empirical findings show that the application of this integrated framework to regional economic analysis might facilitate both the statistical and visual exploration of the spatial autocorrelation of a region's industrial concentration, changing industrial structure, and economic development across space and over time. We input spatial and time-series econometric and statistical results into GIS mapping system. In this way, we are able to visualize the evolution of spatial clustering in healthcare service industry across space and time. Our results show that this integrated GIS framework can assist planners and decision-makers in studying the trends and patterns for regional economic development.

For regional economic development, our study sample is the healthcare service industry in New York State. What motivates us for using the healthcare service industry at a state level for implementing our integrated GIS model is that the federal and state governments and municipalities tend to believe that the service sector and the healthcare services in particularmust beevenly distributed across space. However, Boasson (2002) examines the spatial autocorrelation of major industries in all the counties in the United States and finds that at the national level, service industries exhibit a pattern of statistically significant spatial autocorrelation. This finding has prompted us to conduct a close-up look at the spatial distribution of the healthcare services at a county and state level because it is important for the government to make sure that each local community has equal access to healthcare services. The implications of our findings at this level would allow county and state governments to improve healthcare services and make long-term decisions on regional economic development.

The remainder of this paper is organized as follows. Section 1 introduces an integrated approach that allows a dynamic and interactive integration of geographical information systems, business and economic analysis, spatial statistical analysis, and time-series analysis. Section 2 applies this approach to the analysis of the service industry clusters and the healthcare industry cluster. Section 3 presents empirical results. The final Section concludes the study.

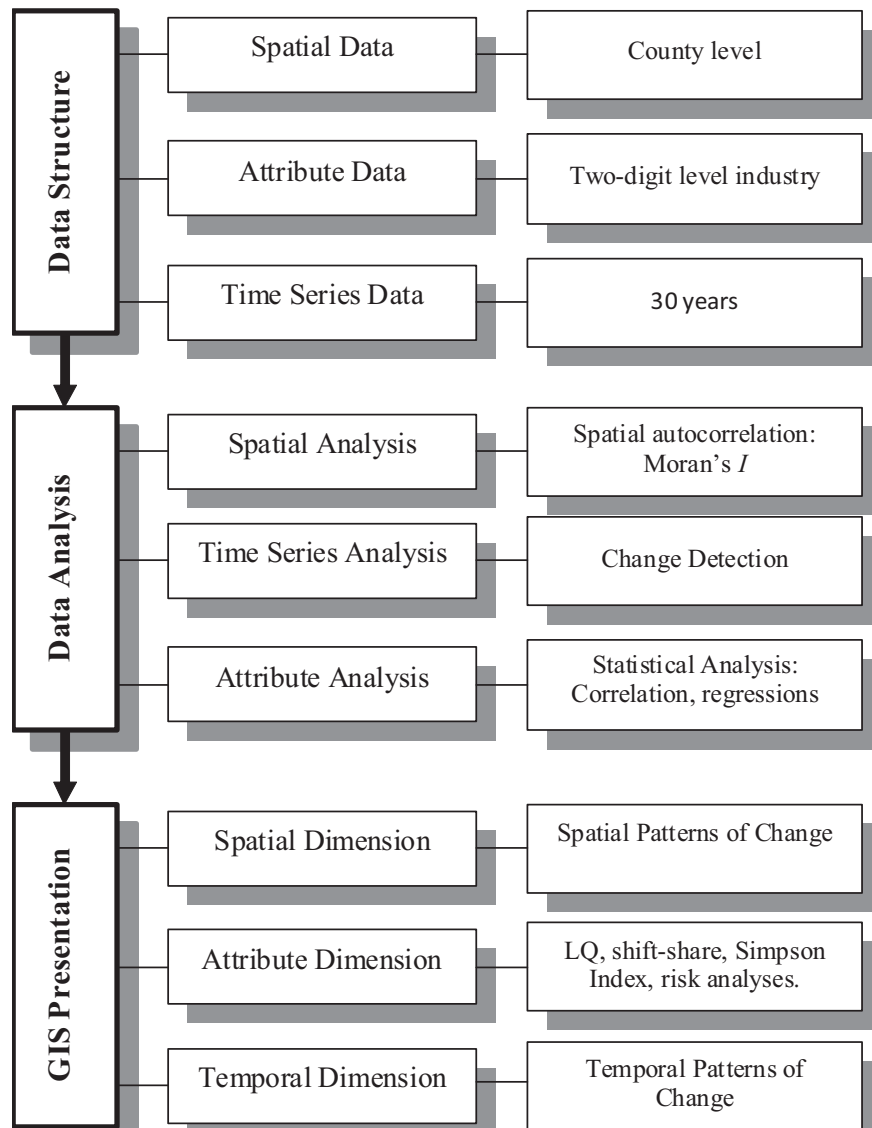## 1. A framework for integrating GIS and economic and business analysis

GIS is viewed as involving the interactions among four basic functions. The first function is the characterization of reality by a set of data and measures (an input function). For instance, data on the location of different industries would be an input, as would the set of measures constituting location quotients, regional competitive share components, and so on. The second function of a GIS would be the storage of the resulting location quotients, regional competitive share components, regional portfolio returns and variances, and other values – storage by the location, spatial arrangement (topology) or in terms of other characteristics. This function is of obvious value for an analyst or policy-maker requiring data at any given point of time. A third function is analysis – a function that breaks into four parts. The first is selection or sampling of observational units from the database, together with the choice of the proper scale of measurement. The three other parts of the function are manipulation, exploration and confirmation (validation).

In our first function, the *data input function* involves entering the information or values of industrial employment, payrolls, and incomes incurred in the healthcare service industry of all 62 counties in New York State over the period of 1969 through to 2000. In the second function, i.e., *the GIS storage function*, the incomes and employments of each industry for each county (location) and for each year are stored into the model. In the third function, i.e., *the analysis function*, *the selection* involves selecting the period of analysis, scales of mapping and measurements, and the space of analysis. In *the GIS manipulation phase*, location quotients are computed for each industry, for each county and for each year. Then, these computed location quotients are stored using a geographic information system such as ArcGIS, MapInfo or other similar programs, for each region and for each time period. Then, the change of location quotients and the rate of this change over time are computed. In *the GIS exploratory phase*, spatial and temporal patterns and relationships are examined. Research questions are then posted.

These speculative inquiries and insights lead to the *GIS confirmation and validation phase*. In this phase, hypotheses are tested and spatial and statistical analyses are conducted. Global Moran's *I*, and local Moron's *I*s statistical procedures are employed to test the presence or absence of spatial autocorrelation and the presence or absence of regional clusters.

Empirically, ArcGIS, statistical software packages, spreadsheets, macros, and a series of model-based computations are employed to develop this framework for a dynamic integration of geographic information science (GIS) and regional economic analysis (see Figure 1).

Source: Boasson (2002).

Fig. 1. Framework of integrating GIS and regional economic analysis

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2. The data and measurements of variables

The spatial database used in this research contains information on the employment and income or payrolls for major industries for the all the 62 counties in New York State. The data are extracted from the Regional Economic Information System 1969-2000 (Bureau of Economic Analysis, 1998, 2003) from the U.S. Department of Commerce, Economics and Statistics Administration Bureau of Economic Analysis. The unit of observation is at the level of counties and companies in the healthcare service industry in New York State. The time period covers 32 years from 1969 through 2000.

The variables for each of the 32 years of personal income by the healthcare service industry are created. The earnings and employment are place-of-work measures. The values of these variables are edited and analyzed in a spread sheet program. Edit step includes cleaning up data, attaching county names through look up tables to FIPS codes as used by the ArcGIS program, and searching for missing data. The analysis includes calculating the location quotient (LQ) for each county for each of the 32 years, finding the change in LQ from year to year, and the change in LQ from the first to the last year of the time series, and the change in LQ for each of the average of five years period.

The location quotient (LQ) is defined as a measure of the relative spatial concentration based upon either employment or income in a given industry in one area (the "subject economy") compared with another area (the "benchmark economy"). Alternatively, a LQ evaluates the degree that a region specializes in a certain industry by comparing the ratio of employment within the industry in a region, to national employment within the industry. This ratio is compared to the ratio of total regional employment to total national employment. Formally, the location quotient is the numerical equivalent of a fraction whose numerator is employment in a given industry in the subject economy relative to a total employment in the subject economy, and whose denominator is employment in the given industry in the benchmark economy. Mathematically LQ is defined as:

$$LQ_i = \frac{e_{ij}/e_{tj}}{e_{iN}/e_{tN}},$$

where e_{ij} – payrolls or employment of ith industry in the jth county; e_{tj} – payrolls or employment of total industries in the jth county; e_{iN} – payrolls or employment of ith industry in the nation; e_{tN} – payrolls or employment of total industries in the nation.

The average annual rate of growth is that rate of growth which, if applied as a discrete compound rate of growth to the initial value (X_m) for n time periods, will result in the second value (X_{m+n}). Mathematically, annual average rate of change (AARC) is measured by:

$$r = \sqrt[n]{\frac{X_{m+n}}{X_m}} - 1 \ ,$$

where r is the average annual rate of change (AARC); X_m is the value of the time series X at time m; X_{m+n} is the value of the time series X at time $m + n$.

To measure the presence or absence of spatial auto-correlation or spatial dependence, we employ Moran's I statistics as suggested by Rogerson (2001), and Drennan and Saltzman (1998). Moran's I is computed as follows:

$$I = \frac{n \sum_{i}^{n} \sum_{j}^{n} w_{ij} (y_i - \bar{y})(y_j - \bar{y})}{\left(\sum_{i}^{n} \sum_{j}^{n} w_{ij} \right) \sum_{i}^{n} (y_i - \bar{y})^2} \ ,$$

where n – number of regions; w_{ij} – a measure of the spatial proximity between region i and j.

Alternatively, if the variable of interest is first transformed into a z-score, then a much simpler expression for Moran's I results:

$$I = \frac{n \sum_{i} \sum_{j} w_{ij} z_i z_j}{(n-1) \sum_{i} \sum_{j} w_{ij}} \ .$$

The calculation of these statistics is conducted in the Excel Spreadsheet utilizing Rookcase that is an Excel Visual Basic (VB) Add-in for exploring Global and Local Statistical Autocorrelation (Sawada, 1999).

3. Empirical results

As a first step, we examine the changes in spatial distribution and the temporal trend of all service industries at the national level as shown in Figure 2.
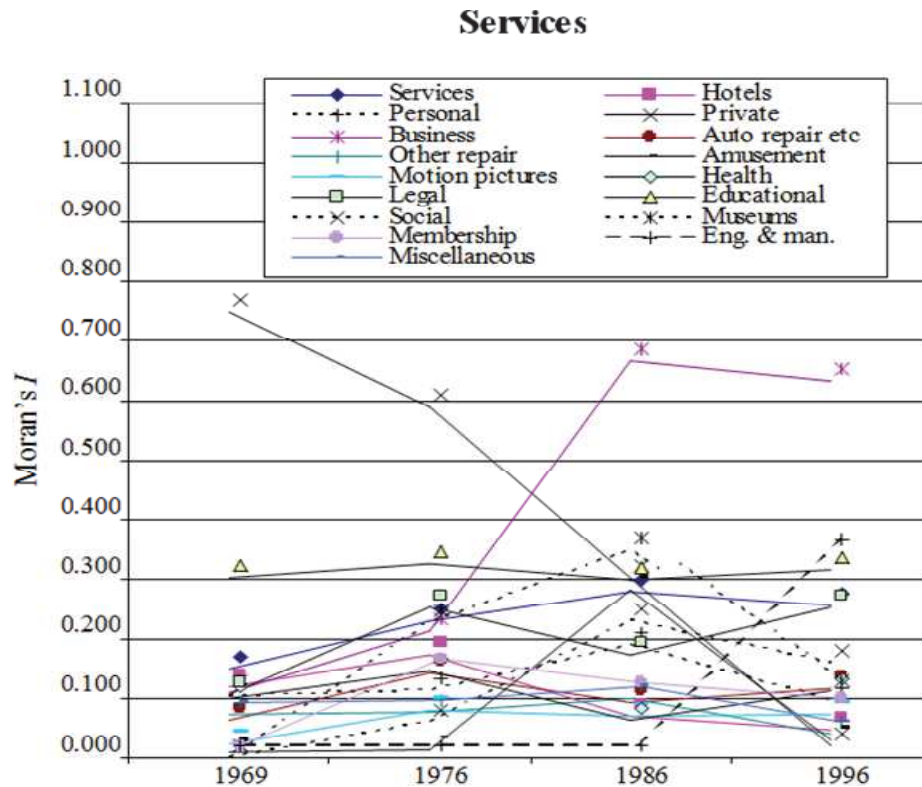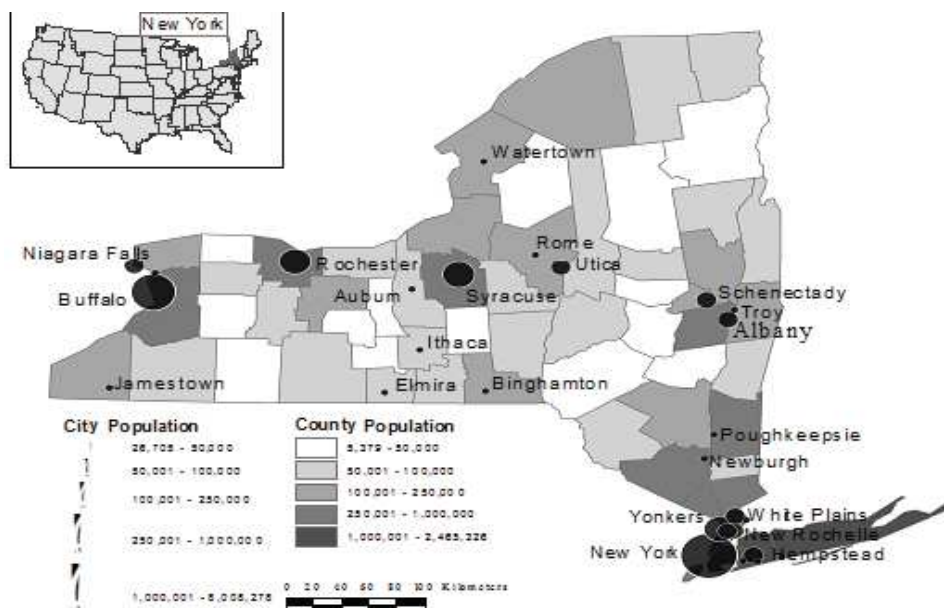
Services

Source: Boasson (2002).

Fig. 2. Services at the national level: change in Moran's *I*, selected years 1969-1996

The service sector exhibits a pattern of spatial auto-correlation and has a significant Moran's *I* of 0.149 and 0.258 in 1969 and 1996, respectively. The service sector as a whole has a substantial increase of about 73% in spatial clustering, the biggest increase of all industry sectors in spatial dependence over the three decades under the study. The breakdown of the service sector shows that the biggest increase in spatial dependence in this sector is the activity for business services, which has an increase of 470% from 1969 to 1996. The activity for motion pictures and the activity for amusement and recreation services though relatively low in spatial clustering have positive changes in spatial dependence of 214% and 200% respectively. Legal services have an increase of 136% in spatial clustering.

This result has prompted us to focus our analysis on the healthcare service industry at a local level. Our goal is to find out whether the spatial and temporal patterns are the same at the state and county levels as we found at the national level. The main rationale for selecting New York State is that New York is a large state both in terms of area and population. Figure 3 shows the distribution of New York State's population by county and cities with a population above 20,000 in the year 2000. The population is unevenly distributed around the state with approximately half of the state's population concentrated in the vicinity of New York City. The map also shows the location and size of cities with population over 25,000 at the same time. The general distribution is similar for the entire study period. In particular the concentration of the population in 14 counties around and including New York City has increased. According to the US Census the population in the 14 counties was 12.9 million or 68.2% of the state's population in the year 2000. In the year 1970 the population in the same 14 counties was 12.3 million or 67.3%.

Source: U.S. Bureau of the Census

Fig. 3. New York State: major cities, their population, and county population in 2000

Since healthcare services are personal services and both federal and local governments want to make sure that each region should have equal access to healthcare services, we would expect that the location quotient for healthcare services should be close to one. To verify our hypothesis, we carry out an in-depth analysis of the temporal trend and spatial patterns of the health-care service industry in comparison with the service sector as a whole. Although there is an overall increase in spatial autocorrelation of the service industry as a whole, the concentration of the healthcare services seem to show a different picture.

Measured by location quotients, we analyze the temporal development and trend of healthcare service industry in comparison of the service sector as a whole in New York State from 1969 to 2000. Figure 4 shows a general decline in the spatial clustering of the various services and of the healthcare services in particular, indicating a more evenly distributed pattern of the healthcare services over the years.
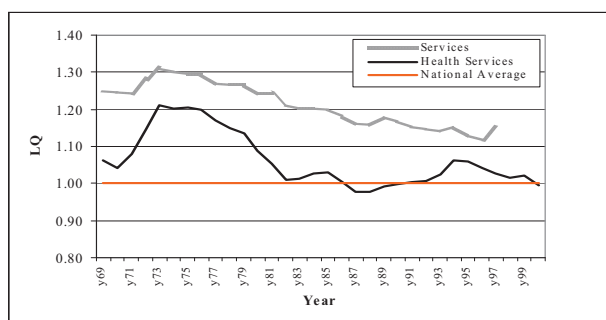

Source: Bureau of Economic Analysis (2003).

Fig. 4. LQ for the service sector and health services in New York 1969-2000

In order to analyze both the spatial and temporal trends in the healthcare service industry in New

York State, we input the results of the location quotients for each county and each year into ArcGIS and measure the spatial autocorrelation by computing the Moran's I. Using a loose-coupling of ArcGIS, Excel look-ups, Visual Basic, SPSS, SAS, and PowerPoint animation, we have created a series of maps that can be shown in a dynamic and interactive manner via PowerPoint animations. In this way, we are able to visualize a dynamic trend in the healthcare service industry across space and time. Examples of these maps are shown as follows.
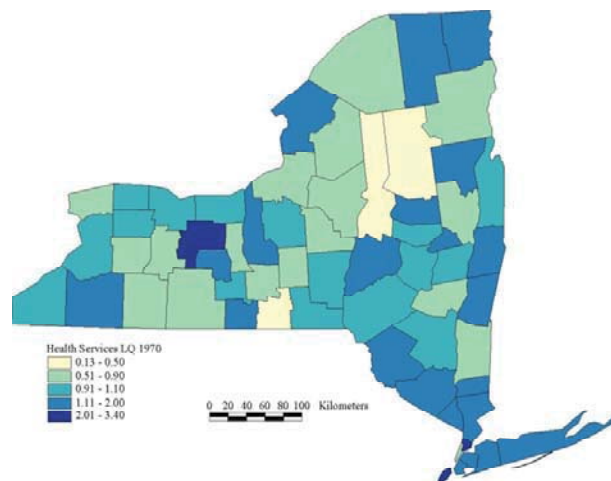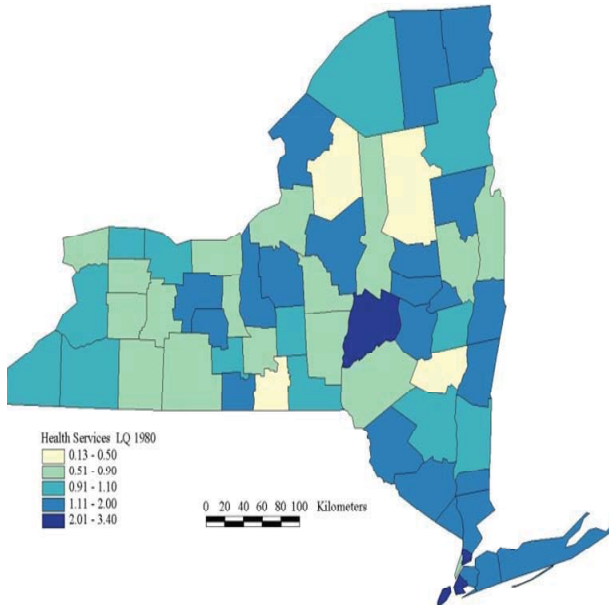

Notes: Moran's I = 0.377, z-Normal I = 2.460, d = 36 km.

Fig. 5. Health services: LQ in 1970

Figure 5 shows the results of the spatial development of the industry concentration of the healthcare service industry in New York in 1970. The results show that the concentration of the healthcare service industry measured by LQ is not evenly distributed across the 62 counties of New York State. Moran's I statistics which measures spatial autocorrelation or

spillover effects show that there is a positive spatial-autocorrelation in the healthcare service industry in the 70's with a Moran's *I* of 0.377 and the test statistics are significant with a z-Normal *I* of 2.46.
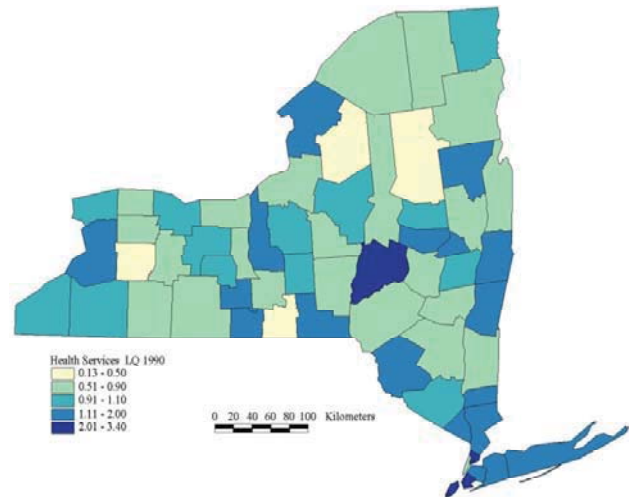

Source: Moran's *I* = 0.459, z-Normal *I* = 2.969, *d* = 36 km

Fig. 6. Health services: LQ in 1980

Figure 6 shows the results of the spatial development of the industry concentration of the healthcare service industry in New York in 1980. The results show that the spatial concentration of the healthcare service industry measured by LQ has been increasing in year 1980 with a Moran's *I* statistics of 0.46, indicating an increasing positive spatial-autocorrelation in the healthcare service industry in the 80's versus that in the 70's and the test statistics are significant with a z-Normal *I* of 2.97.
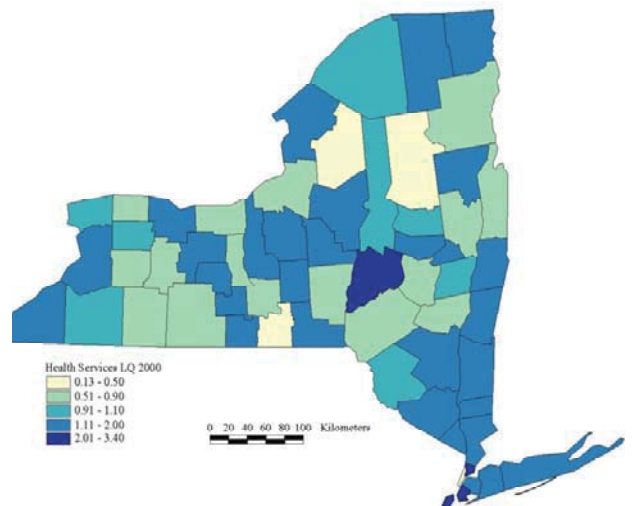
Figure 7 shows the results of the spatial development of the industry concentration of the healthcare service industry in New York in 1990. The results show that even after a decade since 1980, the pattern of spatial concentration of the healthcare service industry measured by LQ has been stable in the year 1990 with a Moran's *I* statistics of 0.46, indicating a positive spatial-autocorrelation in the healthcare service industry in the 90's similar to that in the 80's and the test statistics are significant with a z-Normal *I* of 2.99.

Source: Moran's *I* = 0.462, z-Normal *I* = 2.985, *d* = 36 km

Fig. 7. Services: LQ in 1990

Source: Moran's *I* = 0.298, z-Normal *I* = 1.967, *d* = 36 km

Fig. 8. Health services: LQ in 2000

Figure 8 shows the results of the spatial development of the industry concentration of the healthcare service industry in New York in 2000. The results show that since 1990, the spatial autocorrelation of the healthcare service industry clusters has been declining with a Moran's *I* statistics of 0.298, a decrease of about 35% in year 2000. Despite of this decline, the spatial autocorrelation in the healthcare industry clusters remains positive and the test statistics are significant with a z-Normal *I* of 1.97.
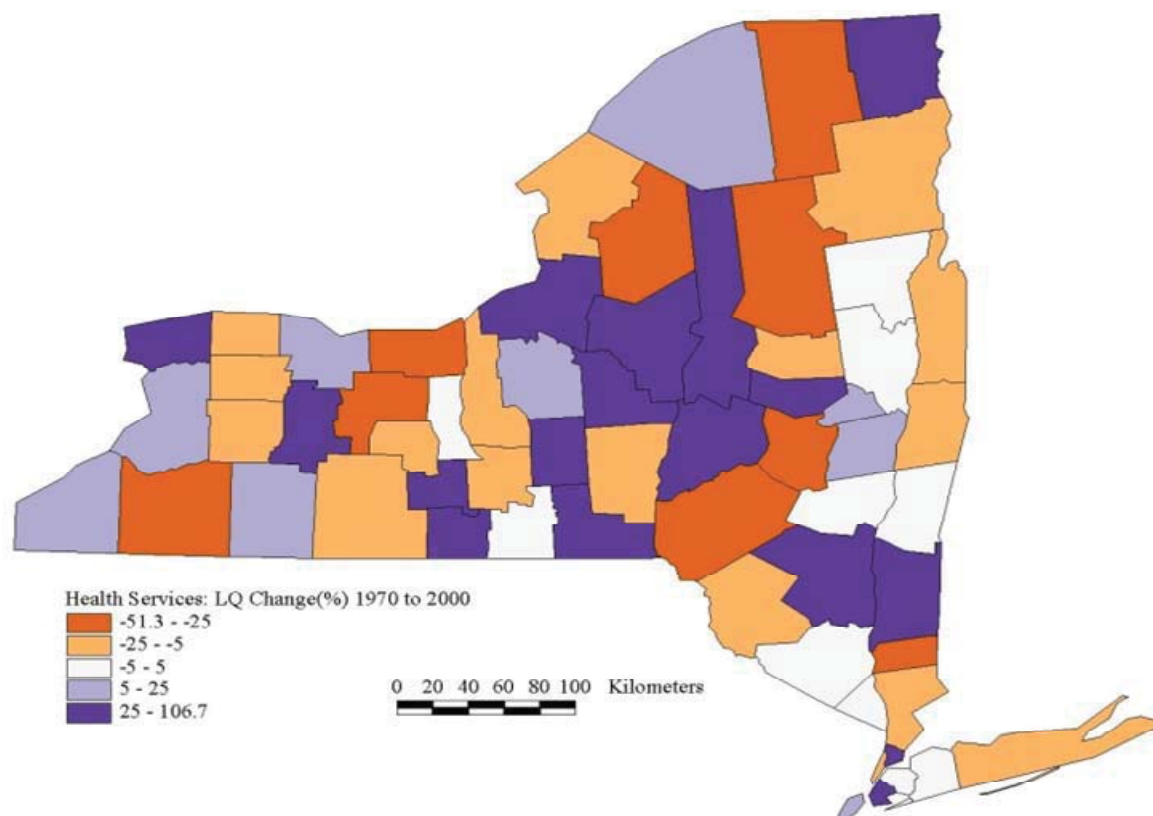
Fig. 9. Health services: change in LQ from 1970 to 2000

Figure 9 shows graphically the relative change in the concentration of the healthcare services in New York State from 1970 to 2000 by county measured by the Location Quotient. The higher level of the clustering of the healthcare services seems to be increasing from the year 1970 to the year 2000.

Table 1 shows numerically changes in the concentration of the healthcare services over the period from 1970 to 2000. For the higher level of industry concentration, there were 36 counties in year 2000 versus 28 counties in 1970 that have a LQ value of more than 1.1, an increase of 31%, indicating that healthcare services have become a net export industry in these 34 counties by the year 2000. However, for the lower levels of industry concentration, there is a general trend for a moderate decline in the concentration of the healthcare services. For instance, in 1970 there were 21 counties with a LQ value of less than 0.9 while in the year 2000, there were 20 counties, a decrease of about 5%. In addition, the number of counties that have a LQ value of 0.9 to 1.1 is only 8 in the year 2000 versus 15 in 1970, a decrease of 47%. This pattern formed in the healthcare services may probably correspond with the population change in New York State over this period as a few counties in Upstate New York have witnessed a big decline in population while healthcare services in these counties have been maintained. This trend will result in an increasing value of LQ for certain counties while a decreasing value of LQ for other counties.

Table 1. Comparison of LQ by counties and percentage of the total population of New York State 1970 to 2000

LQ	1970		1980		1990		2000	
	Counties	Pop. %	Counties	Pop. %	Counties	Pop. %	Counties	Pop. %
< 0.9	17	14.2	21	16.3	24	17.1	21	14.8
0.9 - 1.1	17	20.6	11	15.7	15	17.4	5	3.4
> 1.1	28	65.1	30	68.0	23	65.5	36	81.8
Total	62	100	62	100	62	100	62	100

Conclusion

In this study of the healthcare industry clustering, we implemented the Boasson's (2002) model for integrating GIS, spatial statistical analysis, and business and economic analyses. Based on a loose-coupling of ArcView as the GIS module and Excel, Visual Basic, SPSS, and SAS as the spatial-temporal regional economic analysis modules, the implementation of this model has enabled us to examine both the spatial and temporal autocorrelations and industry clustering in the service industry as a whole and in the healthcare industry in particular.

Overall, our results indicate that there is a general tendency for all service industries to form geographically concentrated clusters and there is a positive and increasing spatial autocorrelation across all service industry clusters. The service

sector as a whole has a substantial increase of about 73% in spatial clustering, the biggest increase of all industry sectors in spatial dependence over the past 28 years. The biggest increase in spatial dependence is the activity for business services, followed by the activity for motion pictures and the activity for amusement and recreation services and by legal services.

Although there is an overall increase in spatial autocorrelation of the service industry clusters as a whole, there is a general decline in the concentration of various services and of the healthcare services in particular, indicating a more even distribution of the healthcare services over the years. The trend for the healthcare service industry shows that there is a positive spatial autocorrelation measured by Moran's *I* statistics in the 70's followed by an increase of spatial dependence in the 80's, a stable period in the 90's and a decline by 35% in spatial autocorrelation of the healthcare industry concentration by the year 2000. Despite the fact that there is a decline in the positive spatial dependence in the healthcare industry clusters, the higher level of the clustering of the healthcare

services seems to be increasing from 1970 to the year 2000. For the higher level of industry concentration, there is an increase of 31% in the number of the counties that have a LQ value of more than 1.1 from 1970 to 2000. However, for the lower levels of industry concentration, there is a general trend for a moderate decline in the concentration of the healthcare services.

This clustering pattern formed in the healthcare services may probably correspond to the population change in New York State over this period as a few counties in Upstate New York have witnessed a big decline in population while healthcare services in these counties have been maintained. This trend will result in an increasing value of LQ for certain counties while a decreasing value of LQ for other counties. Thus, we come to the conjecture that there is a negative or an inverse relationship between the change in population and the change in healthcare service industry concentration. Our research in the near future will focus on the investigation of our conjecture for the healthcare service industry.

References

1. Anselin, L. & Getis, A. (1991). *Spatial statistical analysis and Geographical Information Systems.* Paper presented at the 31st European Congress of the Regional Science Association, Lisbon, Portugal.
2. Bailey, T.C. (1994). A review of statistical spatial analysis in geographical information systems. In A.S. Fotheringham & P.A. Rogerson (Eds.), *Spatial Analysis and GIS* (pp. 13-44). London and Bristol PA USA: Taylor & Francis.
3. Bureau of Economic Analysis (1998). REIS Regional Economic Information System 1969-1996.
4. Bureau of Economic Analysis (2003). Regional Economic Information System 1969-2001 (REIS). Retrieved October 20, 2003, from http://www.bea.doc.gov/bea/regional/reis/.
5. Boasson, E. (2002). *The development and dispersion of industries at the county scale in the United States 1969-1996: an integration of Geographic Information Systems (GIS), location quotient, and spatial statistic.* Unpublished Ph.D., University at Buffalo, Buffalo, NY.
6. Drennan, M.P. & Saltzman, S. (1998). Regional and spatial econometric analysis. In W. Isard (Ed.), *Methods of Interregional Analysis and Regional Analysis*, Aldershot; Brookfield, Vt: Ashgate Publishing, pp. 135-210.
7. Getis, A. (1994). Spatial dependence and heterogeneity and proximal databases. In A. S. Fotheringham & P. A. Rogerson (Eds.), *Spatial Analysis and GIS*, London and Bristol PA USA: Taylor & Francis, pp. 105-120.
8. Goodchild, M. F., Haining, R. P., Wise, S. M., & others. (1992). Integrating GIS and Spatial Data Analysis: problems and possibilities,. *International Journal Geographical Information Systems*, 6 (5), pp. 407-423.
9. Hornsby, K. & Egenhofer, M.J. (2000). Identity-based change: a foundation for spatio-temporal knowledge representation. *Int. K. Geographical Information Science*, 14 (3), pp. 207-224.
10. O'Kelly, M.E. (1994). Spatial analysis and GIS. In A.S. Fotheringham & P.A. Rogerson (Eds.), *Spatial Analysis and GIS* (pp. 65-79). London and Bristol PA USA: Taylor & Francis.
11. Openshaw, S. (1991a). Developing appropriate spatial analysis methods for GIS. In D. J. Maguire, M.F. Goodchild & D.W. Rhind (Eds.), *Geographical Information Systems Principles and Applications*, Vol. 1, pp. 389-402, London: Longmans.
12. Openshaw, S. (1991b). A spatial analysis research agenda. In I. Masser & M. Blakemore (Eds.), *Handling Geographical Information*, London: Longman.
13. Openshaw, S. (1992). Some suggestions concerning the development of artificial intelligence tools for spatial modelling and analysis in GIS, *Annals of Regional Science*, 26, pp. 35-51.
14. Openshaw, S. (1994). Two exploratory space-time-attribute pattern analyser relevant to GIS. In A.S. Fotheringham & P. A. Rogerson (Eds.), *Spatial Analysis and GIS*, London and Bristol PA USA: Taylor & Francis, pp. 83-104.
15. Pick, J., Nag, S. & Butler, E.W. (1988). *A cluster analysis approach to marketing research in the Borderlands Region of Mexico*, Paper presented at the 1988 BALSA Proceedings.
16. Rogerson, P.A. (2001). *Statistical Methods for Geography*. London, Thousand Oaks, California: Sage Publications.
17. Rogerson, P.A., & Fotheringham, A.S. (1994). GIS and spatial analysis: introduction and overview. In A.S. Fotheringham & P.A. Rogerson (Eds.), *Spatial Analysis and GIS*, London and Bristol PA USA: Taylor & Francis, pp. 1-10.

18. Sawada, M. (1999). ROOKCASE: an Excel 97/2000 visual basic (VB) add-in for exploring global and local spatial autocorrelation. *Bulletin of the Ecological Society of America*, 80 (4), pp. 231-234.

19. U.S. Bureau of the Census Census (2000). *Population, Housing Units, Area, and Density: 2000 New York by County*. GCT-PH1. Washington, DC: Bureau of the Census (http://factfinder.census.gov/servlet/GCTTable?_bm= y&-geo_id=04000US36&-_box_head_nbr=GCT-PH1&-ds_name=DEC_2000_SF1_U&-redoLog=false&-mt_name= DEC_2000_SF1_U_GCTPH1_ST2&-format=ST-2 (accessed 7 June, 2011).

20. Wise, S. & Haining, R. (1991). *The role of spatial analysis in Geographical Information Systems*, Paper presented at the Annual Conference of The Association of Geographic Information, Birmingham.