



Economic Clustering and Urban Form: The Case of Hamilton, Ontario

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Abstract

A body of literature has emerged over the past three decades to quantify the sprouting form of our contemporary cities. This paper adds to this literature by investigating the urban form of the City of Hamilton in Ontario, Canada. The novelty of this research is the use of firm micro data for the examination of the types of economic clustering and their influence on urban form. Furthermore, we devise a statistical approach for the identification of agglomeration economies and for the examination of the evolution of urban form. Our findings suggest: (1) a strong existence of agglomeration economies, (2) an emerging multinucleated urban form and (3) that the changing urban form affects travel behavior in Hamilton.

1. Introduction:

Throughout the twentieth century cities around the world underwent dramatic changes. In the North American context, automobile dependency and continuous investment in road infrastructure projects are widely considered to have fueled such changes. Locations previously inaccessible became part of the urban landscape, leading to gradual changes in the spatial pattern of where people live and work. This shift is usually characterized by the decentralization of population and employment from the traditional urban core to the suburbs, transforming the cities from monocentric to polycentric. Over time, the newly formed suburban centers tend to diminish the importance of the Central Business District (CBD), creating new waves of population and employment decentralization.

The change in urban form has a profound influence on the flows of goods and people within a city, both from the point of view of the number as well as the length of trips that take place. The relative location of land uses alone, however, does not in itself determine the flows (Anderson et al., 1996). Although commercial and industrial development in the emerging subcenters are likely to attract more trips to far locations, the level of interaction is determined by a set of organizing principles that defines the relation between the different types of interacting land uses. For example, people can choose to live close or far from their place of work, which defines the relation between housing and employment locations. The level of spatial interaction that reflects the journey to work is determined by the collective “place of residence-place of work” pairs for all the workers who work at a particular node. The key point here is that changes in urban form can and will influence travel patterns in the city. Studying the change of urban form is therefore important from the sustainability and planning perspective.

Over the past three decades, a significant portion of the literature on urban form has examined the degree of spatial concentration of urban population and employment to describe the regularities in urban structure. A review to this literature by Anas et al (1998) distinguishes two general approaches. The first operates at the citywide level and is concerned with the overall decentralization trends in monocentric cities. The second

approach, on the other hand, focuses on the local variability of activities that lead to the formation of a polycentric or dispersed pattern in the city. These approaches build on a number of statistical methods to describe emerging urban form from employment and population data. A detailed description of these statistical methods is provided in the next section.

The goal of this paper is to examine the recent changes in the form of the City of Hamilton in Canada. Following Giuliano and Small (1991), who claim that the location of employment is the key to understanding the formation of urban subcenters, we use firm micro data to examine the types of economic clustering and their influence on urban form in Hamilton. We also devise an explanatory multivariate statistical method to examine the existence of agglomeration economies and to identify and highlight the importance of economic nodes in the city.

Here is a brief description of the remainder of this paper. In the next section we provide an overview of agglomeration economies and the role of economic clustering in reshaping cities. We also highlight the various statistical methods that has been used to study the evolution of urban form. Following in section three, we introduce the methods of analysis that are used to explore and model economic clustering in our study. Accordingly, we highlight the methods that were used to explore the existence of localization economies and discuss the geo-statistical method we formulated to test for the inter-industry linkages. We also discuss the explanatory approach we devised to study the emerging urban form in the City of Hamilton. In section four, we provide an overview of the study area and then highlight the data used in the empirical analysis. In section five, we present and discuss the empirical results from the analysis. The last section identifies important findings and provides a conclusion of our study.

2. Agglomeration economies and methods to study urban form

Agglomeration refers to the clustering of firms at a particular location in urban space. It is widely accepted that firms do not locate randomly but according to economic criteria related to profit maximizing. The resulting economic clusters become employment nodes in the city, giving rise to the multinucleated urban form. Barf (1987) argues that such clusters are vital for the local economy and stimulate the growth of urban areas. The benefits of agglomeration economies and the role they play in the growth of the city were first highlighted in Marshall's (1920) benchmark theory. He argued that external economies such as labor market pooling, input sharing and technological spillovers enhance the productivity level of the city, leading to economic growth. Recent empirical work by Glaeser et al. (1992), Hanson (1996), Rigby and Essletzbichler (2002), and Rosenthal and Strange (2003) support Marshall's theory.

The economic force created when firms cluster together in space, also known as agglomeration economies force, is a prerequisite for the survival and success of firms in an urban area. The reasons for this, as Anas et al. (1998) point out, are spatial

inhomogeneities, internal scale economies, external scale economies and imperfect competition. All of these factors are known to be critical for the successful operation of a firm and for all of them the co-location of firms is a necessary condition. In turn, firms value the benefits of agglomeration economies in their locational decision. The empirical literature supports this assertion. Several studies refer to agglomeration economies as the heart of the urban processes and argue that their use in explaining the intra-urban firm location is instrumental (see for example Erickson and Wasylenko, 1980; Ihlanfeldt and Raper, 1990; Shukla and Waddell, 1991; Waddell and Shukla, 1993; Smith and Florida, 1994; Waddell et al., 2003, Frenkel, 2001, Wu, 1999 and Maoh et al., 2002).

In this paper, we refer to two types of agglomeration economies: (1) localization economies and (2) inter-industry linkages. The forces that lead to localization may be a combination of shared labor pool, intermediate inputs and technological spillovers (Krugman, 1991). Waddell et al (2003) argue that localization could result from comparison-shopping in the case of retail and the co-location at a site with highly desirable characteristics or benefiting from reducing the cost of production. Inter-industry linkages refer to agglomeration economies that result from the co-location and clustering of firms of different industries. An example of inter-industry linkages as noted by Waddell et al (2003) may be distribution companies locating where they can readily service retail outlets or manufacturers locating near concentrations of suppliers in different industries.

A number of statistical methods in the literature studied and described the regularities of urban form. Anas et al (1998) highlight these methods and classify them into two main approaches. The first approach operates at the citywide level and makes use of Clark's negative exponential density function to determine the pattern of activity relative to the CBD. This function connects population and employment density at different points (usually different zones) in urban space with distance from the CBD. When used with temporal data, Clark's density function can depict the way the density gradient changes over time with respect to distance from the CBD. A decline in density at short distances from the CBD accompanied with an increase at long distances suggests decentralization in the urban area. An example of this approach is Bourne's (1989) study of the decentralization of population and employment in the 27 largest urban areas in Canada. Cuthbert and Anderson (2002), however, argue that while the negative exponential density function has been valuable in understanding trends in monocentric cities, it is less useful for the study of urban form in contemporary polycentric cities.

The second approach, discussed by Anas et al (1998), focuses on the local variability of activities that lead to the formation of a polycentric or dispersed pattern. Three methods are commonly used to describe urban structure: (a) polycentric density functions, (b) fractal geometry and (c) point pattern analysis. The polycentric density function approach extends Clark's negative exponential density function to accommodate the multinucleated urban form. In this context, urban residents and firms value access to all employment subcenters and not only the CBD. This implies that employment and population densities

are functions of distances to all these subcenters. Examples of studies making use of this approach are Small and Song (1994) and McMillen and McDonald (1998). With regards to fractal geometry, when a geometric element is repeatedly replicating itself at smaller and smaller scale, the end result is a geometric element called fractal. The objectives of the approach are to present the two-dimensional development patterns in the city and to examine the irregularities of the line marking the outer edge of urban development. Frankhauser (2000) provides an overview on the fractal geometry concept and highlights the most recent literature that applied it to the study of urban development patterns in cities around the globe.

Point pattern analysis is a branch of spatial statistics and consists of methods that purport to examine if the distribution of events over an urban area is clustered, dispersed or random. Events could be households or firms, provided by their location coordinates in space and potentially over several time periods. The objective of the analysis is to identify high density spatial clusters and to trace their evolution over time. A limited number of studies have applied the point pattern approach to study the change in the structure of urban form (Getis, 1983; Cuthbert and Anderson, 2001) or the clustering of economic activities in urban areas (Barf, 1987; Barf and Hewitt, 1989 and Feser and Sweeney, 2000).

3. Methods of Analysis

In the following two subsections, we will provide a description of the methods we used to explore and model agglomeration economies, firm clustering and urban form.

3.1 Exploring firm clustering

One of the first tasks in explaining urban spatial structure is to examine the existence of agglomeration economies. This requires statistical testing for localization economies and inter-industry linkages. An approach for the first is to consider the firm population of an industrial sector and to test for firm clustering (or spatial dependency), considering complete spatial randomness (CSR) as the alternative hypothesis. Using as input the location coordinates of the firms, the method commonly used for such analysis is to estimate an empirical univariate K function. Intuitively, this function provides the expected number of firms within a given distance from a randomly selected firm. The estimated K function is then compared to a set of simulated K functions for the same number of firms that are constructed under the CSR assumption. The test is simple in its conception but computationally intensive. Details for the estimation of the K function are provided in Bailey and Gatrell (1995) and Cuthbert and Anderson (2002). Several studies have employed the K function in the analysis of urban form (See Getis, 1983; Barf, 1987 and Cuthbert and Anderson, 2002)

While the univariate K function provides an explicit test for the spatial dependence among firms of the same type, it is not useful in explaining the co-location of firms that belong to different sectors. An extension of the univariate K-function is the bi-variate function, which tests for the inter-dependence in clustering between two event patterns in space.

The function provides the expected number of events of one type from a randomly selected event of the other type within a specified distance. For a more detailed description readers are referred to Bailey and Gatrell (1995). Examples of using the bivariate K-functions in urban economic applications can be found in Barf and Hewitt (1989), Feser and Sweeney (2000) and Cuthbert and Anderson (2002).

In the context of this paper, the bivariate K-function can be useful in testing the interdependence between two economic sectors at a time. However, the locational decision of a firm is likely to be influenced by more than one type of industry when considering the benefits of agglomeration economies. Based on this, we abandon the bivariate K-function approach in favor of a multivariate approach which accounts for the multiple dependencies that might exist between the different industries in space. This approach depends on kernel estimation and will be discussed in detail in the next section.

Kernel estimation and the resulting maps constitute another powerful tool for the exploration of the spatial and temporal characteristics of firm and population clustering. Torrens and Alberti (2000) emphasize the role of kernel estimation as a useful technique in evaluating urban sprawl. The method requires as input a point pattern, such as the location of individual firms, or count data at the zonal level, such as the number of firms per census tract in an urban area. In the latter case, the centroids of the zones constitute a point pattern with each centroid associated with the corresponding count as a weight. The outcome of the process is a continuous surface that for each point in the study area provides the intensity of event appearance. In the case of firms, the outcome for every point in the study area is the number of firms per unit area. The process works by summing the number of events within a specified radius from the point of interest and dividing by the area of the circle. Each event enters the summation with an assigned weight, which is inversely related to the distance from the point of interest. The weights are determined by a function that resembles a bivariate probability density function, known as the kernel. For details on the method readers may consult Bailey and Gatrell (1995). There are numerous applications of the kernel estimation in exploratory analysis. Bracken and Martin (1989), however, provided a different type of application that is useful for bringing together data from different sources, known as cross area interpolation. A spatial population distribution from census centroid data is transformed into a continuous surface of population intensity and superimposed on a grid to make it compatible with other GIS data.

For the purposes of this study kernel estimates were obtained with the help of the Spatial Analyst module of ArcView GIS. The estimated kernel surfaces allowed visualizing and exploring the decentralization of firms and population between any two time periods. Moreover, when produced at the same spatial resolution, a difference surface of these kernel maps for two time periods allows the identification of spots that were experiencing a decrease or increase in firms and population over time.

3.2 Multivariate Explanatory Approaches to Agglomeration

In this section, we formulate a multivariate model to investigate the level of inter-industry linkages between the 13 major sectors of the economy. We also devise an explanatory approach to investigate and quantify the extent of decentralization and multinucleation patterns in the City of Hamilton. The proposed explanatory approach is conducted on 1157 grid cells (1 x 1 km), which make up the city. At this spatial resolution, spatial autocorrelation in the observations is likely to occur and should be explicitly captured to avoid estimation bias. Therefore, we make use of a simultaneous autoregressive (SAR) model.

The investigation of inter-industry linkages is based on the generated kernel surfaces, which depicts the expected number or intensity of firms per grid cell for the different economic sectors. Our first attempt was to regress the 1157 intensity measures of a particular sector n against the intensity of the other 12 sectors to identify the level of inter-industry linkages between sector n and the other 12 sectors. The specification of such a model will be misleading due to potential multicollinearity among some of the 12 independent variables in the SAR model. Therefore, we employ factor analysis to extract a reduced number of non-correlated (orthogonal) factors that could be employed in the SAR models to quantify the level of inter-industry linkages. Factor analysis is a statistical technique used to reduce a set of observable variables into a small number of latent factors (Bailey and Gatrell, 1995). These unobserved latent factors account for the correlation among the observed variables such that if the latent variables are held constant then the partial correlations among the observed variables all become zero.

In our context, factor analysis is used to account for the intercorrelations among the firm intensity variables to come up with a set of k latent variables that explain why the firm intensity variables are correlated with each other. The outcome factors will enable us to identify those sectors that are more likely to cluster together in space. These could be depicted from a factor pattern matrix that provides the individual and non-redundant contribution that each factor is making to predict a firm intensity variable. Therefore, each factor is interpreted based on the significant amount of loads that each firm intensity variable has on that factor. Accordingly, the level of inter-industry linkages for a particular economic sector n is tested using a SAR model of the form:

$$\lambda = F \beta + \rho W \lambda - \rho W F \beta + \varepsilon \quad (1)$$

Where λ is a (1157 x 1) vector with elements λ^i reflecting the expected number or intensity of firms of economic sector n in grid cell i as depicted from an estimated kernel surface, F is a (1157 x k) matrix with the values of the extracted k latent factors achieved from running the factor analysis over the 12 intensity variables excluding the one of sector n , β is a (k x 1) vector of parameters to be estimated, ρ is a spatially lag parameter to be estimated, W is a (1157 x 1157) row standardized *first order rook weighted* matrix and ε is (1157 x 1) vector of zero mean random variables. A significant and positive parameter β_k would suggest a positive correlation between the clustering patterns of sector n and factor

k . In other words, this will suggest the existence of inter-industry linkages between sector n and the sectors that have the highest loads in factor k .

In the second part of the multivariate analysis, we define a number of nodes at various locations in the city and test how they contribute to explaining the emerging urban form. Table 1 presents the categorical variables that are created to reflect these nodes in the city. The definition of these variables is based on the recent layout of the city and the general firm-clustering pattern that will be described in more details later in this paper. They intend to account for the monocentric effect via the CBD node variable, the radial effect via the Highways and expressway (Hwy & Expwy) variable and the multicentric effect via the rest of the specified variables. A number of SAR models are estimated using these categorical variables. For a given sector, the dependent variable is measured as the difference in the spatial intensity of firms between 1990 and 1997, reflecting for all locations the gains or losses in business establishments over time.

Table 1 here

The last part of the analysis uses a SAR model to investigate if changes in urban form influence travel behavior. The dependent variable in this model is constructed by subtracting the number of work trips that have as a destination a given grid cell within a typical 24 hour day in 1991 from the same number in 1996. This variable is regressed against the change in the spatial intensity of firms by grid cell between 1990 and 1997.

4. Study area and data sets

The City of Hamilton, Ontario, located approximately 75 Km south-west of Toronto, has evolved around the south-west harbor of lake Ontario as shown in Figure 1. The Niagara escarpment separates the city into a lower coastal area between the escarpment and the harbor to the north and a highland beyond the escarpment to the south. While early urban development took place on the lower city, the continuous population and economic growth over time led to urban development above the escarpment. Recently, the city expanded its boundaries by annexing the municipalities of Ancaster, Dundas, Flamborough, Glanbrook and Stoney Creek. The city's population has increased from 451,685 in 1991 to 467,799 in 1996 (Statistics Canada, 1991 and 1996), as shown in Table 2.

Table 2 here

Figure 1 here

The total number of firms in the region has grown from 11,587 in the year 1990 to 12,065 in the year 1997. The economic base of the city has traditionally been the heavy steel industry, making Hamilton one of the major steel producing cities in Canada. In recent years, however, retailing and services play a major role in the local economy. Regional malls and retailing complexes continue to grow in the region especially above the escarpment.

Table 3 provides summary information on the employment and firms in the city by economic sector. The services and retail trade establishments retain the highest proportion of firms in 1990 and 1997, accounting for 31.13% and 48.67%, respectively, in 1990. The 1997 figures indicate that the total number of establishments in retailing has declined by 2.73%, whereas services have grown by 3.72%. Manufacturing ranks third in terms of number of establishments. Services, retail trade and manufacturing firms effectively constitute the economy of the city providing 87.8% of the job opportunities.

Table 3 here

The exiting jobs generated 133,414 and 131,370 work trips per day in 1991 and 1996, respectively. While the overall work trips have declined by 1.53% between 1991 and 1996, Table 4 indicates a clear decentralization in these trips. The percentage change suggests a significant increase in the outer municipalities of the region except for Ancaster. The results show a clear shift of work trips from the core of the city to the outer suburbs. Accordingly, the old city has the highest amount of work trip losses. In contrast, the area known as the mountain above the escarpment experienced an increase in the generated work trips.

Table 4 here

The analysis in this paper relies heavily on firm micro data for the years 1990 and 1997, collected by the city through surveys. The 1990 survey was conducted over a seven months period between May and December and aimed at identifying the type of business activities in the region and the number of people employed in these activities. Each firm was surveyed at the establishment level and its geographic coordinates were coded in the database. The survey categorized each establishment according to the 1980 Standard Industrial Classification (SIC) code. The city repeated the survey of firms in 1997, but the new database did not include the number of employees in each firm. Otherwise, the 1997 dataset has the same characteristics as that of 1990. Additional data sets used in this study include work trip and population data, obtained from the Transportation Tomorrow Survey (TTS) and Statistics Canada, respectively.

5. Results and discussion

The next two subsections will be dedicated to discuss the empirical results we achieved from the discussed analysis.

5.1. Exploring economic clustering

The general pattern of results through kernel estimation suggests clustering of firms and population in the region. The generated maps indicate that population density is highest at the city core. However, the general pattern of population distribution does not suggest a monocentric urban form. The difference of the population density surfaces for 1991 and

1996 shows a number of residential foci at the outer-skirts of the city. The map in Figure 2 indicates that residential development continues to grow in the south above the escarpment, Stoney Creek, Dundas and northwestern part of Ancaster. The map also shows that the population intensity in the core continues to decline, suggesting a decentralizing trend.

Figure 2 here

To explore firm clustering, we started with the whole firm population and estimated two kernel surfaces for the years 1990 and 1997, respectively. The resultant kernel maps provide evidence of firm clustering. Although the largest cluster appears to be at the city core, Figure 3 points to a decentralizing trend over time. Kernels and the univariate K-function were also used to evaluate the clustering of firms by sector. The K-functions were estimated using the SPLANCS library of the S-plus statistical package. As deduced by the K curves, all sectors tend to cluster in the range of 20 to 25 kilometers, with exception of business firms that cluster to a range of up to 16 kilometers. Since all curves look similar, in the interest of brevity a sample graph is presented in Figure 4. Results from the K-function estimation provide clear evidence on the presence of localization economies in Hamilton.

Figure 3 here
Figure 4 here

Spatial variation in the clustering patterns of the different types of firms is present in the region as depicted from the estimated kernel surfaces. Following is a summary of the 1997 clustering patterns identified for the different sectors:

- Manufacturing, wholesale trade and construction firms show a similar clustering pattern. Clusters appear in the harbor, northern part of Stoney Creek and southeastern part of Hamilton municipality.
- Transportation firms cluster in the northern part of Hamilton especially in the northeastern part close to the Q.E.W highway.
- Communication firms cluster in the municipality of Hamilton, especially the CBD.
- Retail Trade firms show high affiliation with the core of the city. However, the clustering pattern is apparent in populated areas
- FIRE, Business, Government and education firms are highly clustered in the CBD. However, the clustering pattern of FIRE, business and education firms is also prominent in populated areas.
- Health and Social insurance, Accommodation, food and beverage and the rest of services firms cluster at the core of the city and in close proximity to it

In general, findings from the kernel maps support the hypothesis of the presence of agglomeration economies in the City of Hamilton.

5.2 The multivariate analysis results

Factor analysis enabled us to explore and quantify the level of inter-industry linkages in the city of Hamilton. Data exploration was achieved by running the factor analysis on the 13 firm intensity variables that correspond to the 13 economic sectors. The exploration enabled us to identify which industries are more likely to co-cluster in space. The results from the factor pattern matrix in Table 5 suggest that finance insurance and real estate (FIRE) firms and business service (BS) firms cluster together given their significant loads on Factor 1. We categorize these establishments as high ordered services. The manufacturing (M) and wholesale trade (WT) sectors have significant loads on Factor 2, which imply that establishments of these two industries cluster together in space. These establishments are categorized as goods based industries. The loads on Factor 3 suggest that Accommodation food and beverages services (AF&B) and other services (OS) tend to cluster together in space. We labeled these establishments as population oriented services. Figures 5a to 5c present the clustering pattern for these three groups of industries. Figure 5a indicates that FIRE and Business services firms are central and their intensity decays as we move away from the CBD. Manufacturing and wholesale trade firms are highly clustered on the harbor to the North and in scattered nodes in the suburbs near highways as shown in Figure 5b. Figure 5c indicates that Accommodation food and beverages (AF&B), and other services (OS) firms are mainly located in the old part of the city and in areas in close proximity to regional malls. The above results are consistent with the kernel estimation results highlighted in the previous section.

Table 5 here

Figure 5 here

Factor analysis was also used in the exploratory analysis to create the variables in matrix F in equation (1) for the different modeled sectors. Except for minor differences, the results from running the factor analysis with 12 of the 13 firm intensity variables by excluding one of the 13 variables at a time generated similar results to those reported in Table 5. Factor 1 in all models except for those from FIRE, BS and GS has its significant loads from FIRE and BS firm intensity variables. In the case of the BS and GS model, the significant loads on factor 1 are generated by the FIRE firm intensity variable whereas it is generated by the AF&B intensity variable in the case of the FIRE model. Factor 2 has significant loads from wholesale trade (WT) and manufacturing (M) firm intensity variables in all the specified models except for the manufacturing and wholesale trade SAR models. In the manufacturing model, the wholesale trade and business services intensity variables generates the highest loads on factor 2. The manufacturing and business services intensity variables generated the significant loads on factor 2 in the wholesale trade model. The significant loads on factor 3 are generated by the Accommodation food and beverages (AF&B) and other services intensity variables in all the models except for the FIRE, BS, AF&B and OS SAR models. The significant load on factor 3 in the case of FIRE and AF&B models is generated by the Other Services (OS) firm intensity variable. In the business services model, the significant loads on factor 3 is generated by the construction, retail

trade and other services whereas the significant loads on this factor in the other services model is generated by the accommodation food and beverage (AF&B) and retail trade (RT) intensity variables.

Table 6 provides the estimated parameters for the SAR models of equation (1). Spatial autocorrelation in the data is present, as indicated by the statistical significance of the spatial lag parameter ρ in all the estimated SAR models of table 6. The estimation results indicate that inter-industrial linkages are strong between manufacturing, wholesale trade, construction, and transportation and storage firms. Communication and utilities show affiliation with both goods based industries and high ordered services as depicted from the sign and significance level of factor 1 and factor 2 of the C&U model. On the other hand, manufacturing and construction seems to repel high ordered services as inferred from the sign of factor 1 for these two sectors. Transportation and storage and wholesale trade firms avoid population-oriented services as shown from the sign and significance of factor 3 in the models of these two sectors. The retail trade model shows affiliation with high ordered services, goods based industries and the population oriented services establishments. However, the inter-industrial linkages between retail trade and high ordered services tend to be the most significant among the three groups of industries. Population oriented services rank second and the linkages tend to fade with basic good producers.

Table 6 here

FIRE and AF&B firms show strong linkages as depicted from the sign, magnitude and significance level of factor 1 in the models of these two sectors. However, FIRE firms repel goods based industries and other services firms. Business services and government services firms show strong linkages with FIRE firms. Businesses firms locate on land far away from construction, retail and other services firms. Also, government services firms and population oriented firms repel each other. The estimated parameters show strong linkages between Education services firms and high ordered services and population oriented services firms. The results also suggest strong linkages between health and social services firms and population oriented services firms. Both education services firms and health and social services firms avoid co-locating with goods based industries. Accommodation food and beverages firms and other services firms are strongly affiliated with each other and with high ordered services firms. They also show some spatial linkages with retail trade firms. In short, although inter-industry linkages exist in the region, the analysis suggests specialization in land use activities. This is evident from the different clustering pattern shown by goods based, population-oriented and high ordered industries.

The results in Table 7 provide an inference on the growth and decline of the economic nodes shown in Figure 6. These estimation results suggest an evident and strong overall decentralization in the region. This is clear from the sign, magnitude and statistical

significance of the “CBD node” variable of the pooled model. A comparison of this variable across the different industries suggests that decentralization is due to the loss of retail trade, other services, FIRE, wholesale trade and construction firms. On the other hand, the CBD node shows gaining of firms in business services, Accommodation food and beverages, Health and social services and education service industries. The pooled model also indicates that highway and expressway proximity is important for the location of firms as portrayed in the “Hwy & Expwy node” variable. The results suggest that firms in the business services, accommodation food and beverages services and government services are more likely to favor land close to highways and expressways.

Table 7 here

Figure 6 here

The results in the pooled model suggest that the Ancaster node is gaining more firms than any of the other nodes as depicted from the sign, magnitude and statistical significance of the “Ancaster node” variable. A comparison across the different models indicates that retail trade, Accommodation food and beverages, FIRE and business services industries contribute to this gain. The Rymal node ranks second in terms of firm gains as indicated from the magnitude of its estimated parameter in the pooled model. These gains arise from the location of manufacturing, wholesale trade, retail trade, FIRE, business services, education services, accommodation food and beverages and other services firms in that node. The estimation results also suggest a loss of construction firms at this node. Dundas node also shows an overall gaining of firms. These gains are due to the location of Transportation and storage firms as well as services firms. The Dundas node also suffered a loss of construction firms as shown in the construction industries model.

Limeridge node and Upper James node exhibit an equivalent level of firm gains between 1990 and 1997 as shown by the results of the pooled model. However, there is a variation among the different industries that contributed to this gain at these nodes. In the “Upper James node” case, these gains arise from the location of communication and utilities, retail trade and all services firms except for FIRE firms. This gain is faced with a loss that arises from the death or relocation of construction, transportation and utilities and FIRE firms. The Limeridge node gains, on the other hand, arise from the location of communication and utilities, FIRE, health and social services and accommodation food and beverages firms. These gains are confronted by a loss that arises from the death or relocation of construction and transportation and utilities. The Central Mall node shows an overall loss as depicted from the negative sign of this variable in the pooled model. The results from the different models suggest that retail trade and FIRE firms are mainly responsible for this loss. In comparison, the Central Mall node experienced gains in construction and education services firms. The East Gate Square node parameter from the pooled model suggests a weak gain in the number of firms between 1990 and 1997. These gains are due to the location of manufacturing, communication and utilities, government services and

health and social services firms in that part of the city. These gains were faced by losses from construction and wholesale trade firms.

The above findings suggest a dynamic surface of the economy in the City of Hamilton. This dynamics influences the urban form and is likely to impact the generated travel over time. The results in table 8 depict the relation between the change in firm clustering and work trip pattern. The estimated parameters meet our a priori expectation on the relation between the losses and gains of firms and how it would influence the trip patterns in the region. The estimated parameters suggest that those areas that lost firms have lost trips as depicted from the negative sign of the estimated parameter. Moreover, areas that gained firms have gained trips between 1991 and 1996. These results imply that decentralization and suburbanization influence the generated flows in our urban area. Therefore, trips are more likely to decline in the core and increase in the outer suburbs as firms continue to suburbanize.

Table 8 here

6. Conclusion

This paper explores economic clustering and urban form in the City of Hamilton. Using a number of geo-statistical techniques and methods, we examine the existence of localization economies and inter-industry linkages and find a strong presence of agglomeration economies in the region. We estimate univariate K functions and kernel surfaces to examine the range and shape of firm clustering in the region. The estimates indicate the presence of localization economies and portray a clustering pattern to a range of 25 km for all types of firms except for business services firms, which cluster to a range of 16 km. The kernel surfaces reveal spatial variations in the clustering pattern among the different types of firms in the different economic sectors. These kernels also show decentralization in both population and firms between 1990 and 1997. This central decay is accompanied with a wave of suburbanization that is pushing the boundaries of urban development outwards and causing urban sprawl. We also estimate a number of SAR models to identify the existence of inter-industry linkages. Our estimated models suggest the presence of geographical clustering among the different types of industries with some being more influential than others on the location decision of particular types of firms.

We investigate the emerging urban form in the region and come across some rather interesting results. In this context, we identify a number of economic foci to quantify the growth and decline of firms. Our estimates show an overall decentralization trend with retail trade firms having the highest share of outflow from the CBD. While most of the firms are decentralizing, business services firms are very central in the region. The same could be said about firms in the accommodation, food and beverages sector, the educational services sector and health and social services sector. Along with the CBD, the Central Mall area near the harbor is losing most of the businesses in the region. In comparison, other nodes above the escarpment and in the outer suburbs are gaining most

of the firms. Nodes above the escarpment include the Upper James node and Limredge node while the outer suburb node includes the Rymal node, Ancaster node, and Dundas node. It becomes obvious that the urban form in the City of Hamilton is not monocentric despite the fact that the core is still the heart of the region's economy. Given the recent trends we have observed, an inevitable multinucleated urban form is likely to emerge in the near future.

The work presented in this paper emphasizes the potential use of spatial statistics in explaining the form and spatial structure of cities. It also provides a valuable tool to measure the extent and shape of agglomeration economies at the micro level. While our findings present interesting results on economic clustering in space and its influence on urban form, extension of this research to other regions is of interest to determine whether the findings have generic trends or specific to the Hamilton economy and geography.

Table 1: Explanatory variables of economic activity nodes

Variable Name	Description
Hwy & Expwy Node	1 if grid cells are within 1000 meter from a highway or an express way; 0 otherwise
CBD Node	1 if grid cells are located in the Central Business District area; 0 otherwise
Limridge Node	1 if grid cells are located in the Limredge mall area; 0 otherwise
Upper James Node	1 if grid cells are located on the Upper James road; 0 otherwise
Central Mall Node	1 if grid cells are located in the Central mall area; 0 otherwise
EGS Node	1 if grid cells are located in the East Gate Square and Queens mall area; 0 otherwise
Dundas Node	1 if grid cells are located in downtown Dundas; 0 otherwise
Ancaster Node	1 if grid cells are located in Meadowlands Center in Ancaster; 0 otherwise
Rymal Node	1 if grid cells are located in the Rymal area; 0 otherwise

Table 2: Population distribution by municipality, City of Hamilton (1991 and 1996)

Municipality	1991 Population	1996 Population
Ancaster	29,530	31,242
Dundas	13,800	14,809
Flamborough	30,145	34,514
Glanbrook	9,730	10,564
Hamilton	324,600	328,279
Stoney Creek	43,880	48,391
Total	451,685	467,799

Table 3: Business establishments and employment by economic sector

Sector code	Industrial Sector	Emp. 1990	% Emp. 1990	Firms 1990	% Firms 1990	Firms 1997	% Firms 1997
M	Manufacturing	51309	27%	905	8%	928	8%
C	Construction	6782	4%	633	6%	509	4%
T&S	Transportation & Storage	4054	2%	157	1%	152	1%
C&U	Communication & Utilities	4886	3%	118	1%	145	1%
WT	Wholesale trade	6830	4%	445	4%	462	4%
RT	Retail trade	29826	15%	3604	31%	3421	29%
	Finance Insurance and Real Estate						
FIRE	Estate	9831	5%	640	6%	593	5%
BS	Business services	7620	4%	756	7%	899	8%
GS	Governmental services	9849	5%	155	1%	234	2%
E	Education services	16506	9%	343	3%	435	4%
H&SS	Health and Social Services	21755	11%	951	8%	1118	9%
	Accommodation food and beverages services						
AF&B		12329	6%	907	8%	1046	9%
OS	Other services	11551	6%	1885	16%	1994	17%
	Total	193128	100%	11499	100%	11936	100%

Table 4: Typical day work trips by destination municipality

Municipality	1991 work trips	1996 work trips	Difference 96 - 91	% Change
Ancaster	5790	5197	-593	-10.24%
Dundas	1971	3412	1441	73.11%
Flamborough	3406	4714	1308	38.40%
Glanbrook	918	1336	418	45.53%
Upper Hamilton (mountain)	20972	23167	2195	10.47%
Lower Hamilton (Below escarpment)	90456	82905	-7551	-8.35%
Stoney Creek	9901	10639	738	7.45%
Total	133414	131370	-2044	-1.53%

Table 5: Factor pattern matrix for the 13 firm intensity variables

Firm intensity variables	Factor 1	Factor 2	Factor 3
M	-0.04	0.31	0.08
C	-0.05	0.05	0.17
T&S	0.04	0.06	-0.05
C&U	0.02	0.08	-0.02
WT	0.04	0.51	-0.12
RT	-0.08	0.15	0.25
FIRE	0.48	-0.27	0.07
BS	0.36	0.22	-0.71
GS	0.06	0.08	-0.07
E	0.05	0.06	0.11
H&SS	-0.01	-0.06	0.14
AF&B	0.05	-0.09	0.43
OS	0.10	-0.06	0.53

Table 6: Parameter estimates of inter-linkages agglomeration economies models

	M	C	T&S	C&U	WT	RT	FIRE	BS	GS	E	H&SS	AF&B	OS
Spatial Lag (ρ)	0.28 (15.42)	0.43 (19.44)	0.34 (11.79)	0.39 (14.05)	0.17 (9.08)	0.13 (5.81)	-0.19 (-13.80)	0.21 (13.16)	0.19 (9.18)	0.48 (22.56)	0.36 (10.99)	0.09 (5.72)	0.29 (20.54)
Constant	0.57 (17.64)	0.24 (12.45)	0.08 (7.48)	0.08 (8.76)	0.33 (19.94)	2.56 (20.24)	0.61 (32.78)	0.61 (13.58)	0.16 (16.04)	0.19 (13.06)	0.56 (6.13)	0.82 (29.09)	1.23 (28.73)
Factor 1	-0.09 (-2.33)	-0.09 (-3.75)	0.04 (2.61)	0.21 (20.12)	0.01 (0.65)	6.26 (42.13)	3.86 (123.11)	5.61 (80.36)	0.85 (58.05)	0.46 (28.15)	-0.27 (-2.28)	2.50 (74.54)	3.08 (64.24)
Factor 2	2.38 (49.77)	0.76 (29.31)	0.42 (26.12)	0.19 (18.14)	1.51 (56.94)	1.48 (11.69)	-0.28 (-13.98)	0.37 (7.39)	0.02 (1.51)	-0.07 (-4.94)	-0.28 (-2.77)	-0.04 (-1.32)	0.33 (7.88)

Factor 3	0.26	0.17	-0.12	0.00	-0.19	5.18	-0.78	-2.44	-0.25	0.36	2.28	1.71	2.49
	(5.89)	(6.16)	(-7.65)	(-0.21)	(-8.50)	(28.62)	(-39.38)	(-48.31)	(-24.57)	(17.83)	(15.38)	(35.77)	(39.20)
Pseudo-R²	0.90	0.81	0.66	0.73	0.91	0.90	0.97	0.95	0.90	0.87	0.52	0.96	0.96

Note: *t*-Statistics in parenthesis

Table 7: Parameter estimates of economic activity nodes in the City of Hamilton (1990 – 1997)Note: *t*-Statistics in parenthesis

Variables	All firms	M	C	T&S	C&U	WT	RT
Spatial Lag (ρ)	0.54 (18.45)	0.51 (16.29)	0.57 (20.09)	0.52 (16.18)	0.48 (14.80)	0.66 (26.01)	0.46 (15.04)
Constant	-0.05 (-0.33)	-0.01 (-0.64)	-0.03 (-2.02)	-0.01 (-0.97)	0.00 (0.33)	0.01 (0.45)	-0.07 (-0.83)
Hwy & Expwy Node	0.52 (1.77)	0.03 (0.72)	0.03 (1.15)	0.02 (1.12)	0.01 (0.51)	0.02 (0.79)	0.14 (0.93)
CBD Node	-23.19 (-11.73)	-1.21 (-4.71)	-1.24 (-7.56)	0.02 (0.18)	-0.19 (-2.39)	-1.37 (-7.69)	-18.83 (-17.06)
Limeridge Node	3.21 (1.57)	-0.19 (-0.67)	-0.01 (-0.07)	-0.08 (-0.78)	0.33 (3.72)	-0.13 (-0.68)	-2.17 (-2.05)
Upper James Node	3.06 (1.78)	-0.11 (-0.45)	-0.95 (-6.35)	-0.21 (-2.36)	0.29 (3.92)	-0.54 (-3.33)	1.57 (1.75)
Central Mall Node	-3.68 (-2.54)	-0.22 (-1.10)	0.30 (2.37)	-0.09 (-1.22)	-0.06 (-0.97)	0.00 (-0.03)	-3.08 (-4.05)
EGS Node	0.52 (0.40)	0.71 (3.93)	-0.68 (-5.89)	0.10 (1.48)	0.48 (8.14)	-0.44 (-3.57)	-0.74 (-1.08)
Dundas Node	8.16 (4.03)	0.48 (1.72)	-1.13 (-6.41)	0.28 (2.67)	0.09 (1.04)	0.22 (1.16)	1.66 (1.57)
Ancaster Node	15.10 (4.72)	-0.01 (-0.03)	0.05 (0.20)	-0.01 (-0.06)	-0.01 (-0.06)	0.33 (1.12)	6.22 (3.72)
Rymal Node	9.06 (7.11)	1.21 (6.95)	-0.30 (-2.80)	0.00 (-0.03)	0.06 (1.11)	0.39 (3.36)	4.37 (6.66)
Pseudo-R²	0.38	0.23	0.34	0.11	0.23	0.31	0.46

...Table 7 continued.

Variables	FIRE	BS	GS	E	H&SS	AF&B	OS
Spatial Lag (ρ)	0.50 (16.59)	0.47 (15.24)	0.45 (13.71)	0.56 (19.45)	0.39 (11.63)	0.56 (20.52)	0.49 (15.54)
Constant	0.00 (-0.17)	-0.03 (-1.24)	0.02 (1.89)	0.01 (1.26)	0.03 (0.98)	0.00 (0.21)	0.03 (0.92)
Hwy & Expwy Node	-0.01 (-0.14)	0.14 (2.96)	0.04 (2.16)	0.01 (0.83)	0.04 (0.83)	0.05 (1.74)	0.05 (0.74)
CBD Node	-4.06 (-14.27)	4.42 (14.01)	-0.91 (-7.39)	0.61 (5.60)	1.54 (5.06)	2.40 (13.12)	-5.81 (-12.57)
Limeridge Node	1.06 (3.74)	0.22 (0.70)	0.22 (1.63)	0.28 (2.32)	3.58 (10.51)	1.25 (6.60)	-0.78 (-1.65)
Upper James Node	-0.40 (-1.68)	1.08 (4.02)	0.21 (1.85)	0.72 (7.11)	0.59 (2.09)	0.47 (2.94)	0.72 (1.81)
Central Mall Node	-1.01 (-4.93)	0.12 (0.53)	-0.07 (-0.79)	0.44 (5.22)	-0.25 (-1.08)	-0.05 (-0.35)	-0.22 (-0.65)
EGS Node	0.00 (-0.01)	0.05 (0.22)	0.41 (4.70)	0.05 (0.69)	1.00 (4.64)	-0.14 (-1.17)	0.23 (0.76)
Dundas Node	0.96 (3.40)	0.80 (2.53)	0.22 (1.71)	0.74 (6.27)	2.19 (6.61)	0.87 (4.65)	1.19 (2.53)
Ancaster Node	3.11 (6.95)	1.09 (2.19)	-0.06 (-0.31)	-0.13 (-0.70)	0.43 (0.84)	3.27 (11.07)	1.02 (1.37)
Rymal Node	0.35 (2.04)	1.13 (5.82)	0.06 (0.74)	0.17 (2.44)	0.36 (1.82)	0.56 (4.95)	1.47 (5.12)
Pseudo-R²	0.41	0.39	0.18	0.31	0.27	0.46	0.31

Note: *t*-Statistics in parenthesis

Table 8: Parameter estimates of trip change patterns 1991 – 1996

Variables	Parameters
Spatial Lag (ρ)	0.67 (25.84)
Constant	-1.69 (-0.83)
Change in Firm intensity	2.50 (7.54)
Pseudo-R²	0.27

Note: *t*-Statistics in parenthesis

Figures

Fig1. The city of Hamilton in the regional context

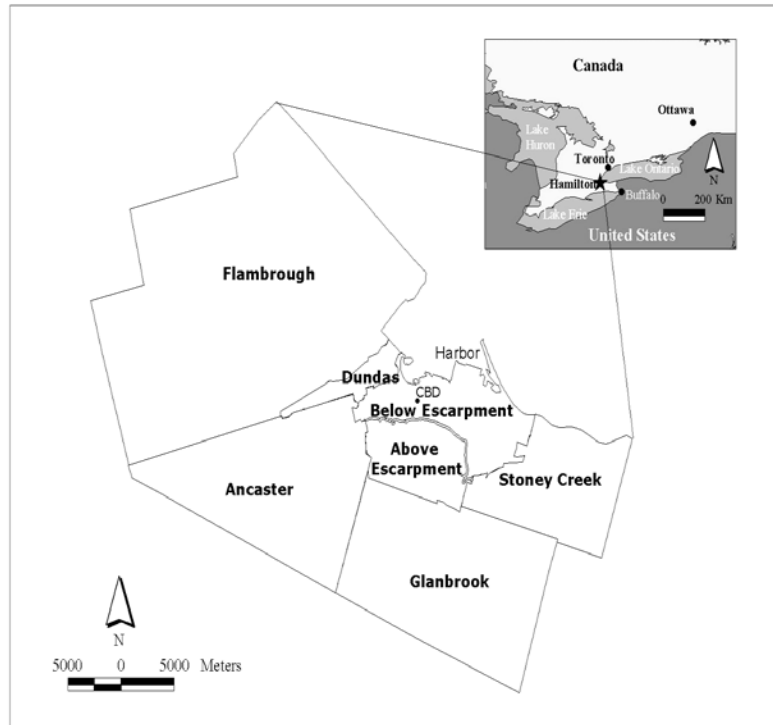
Fig2. 1991 and 1996 difference surface of population density

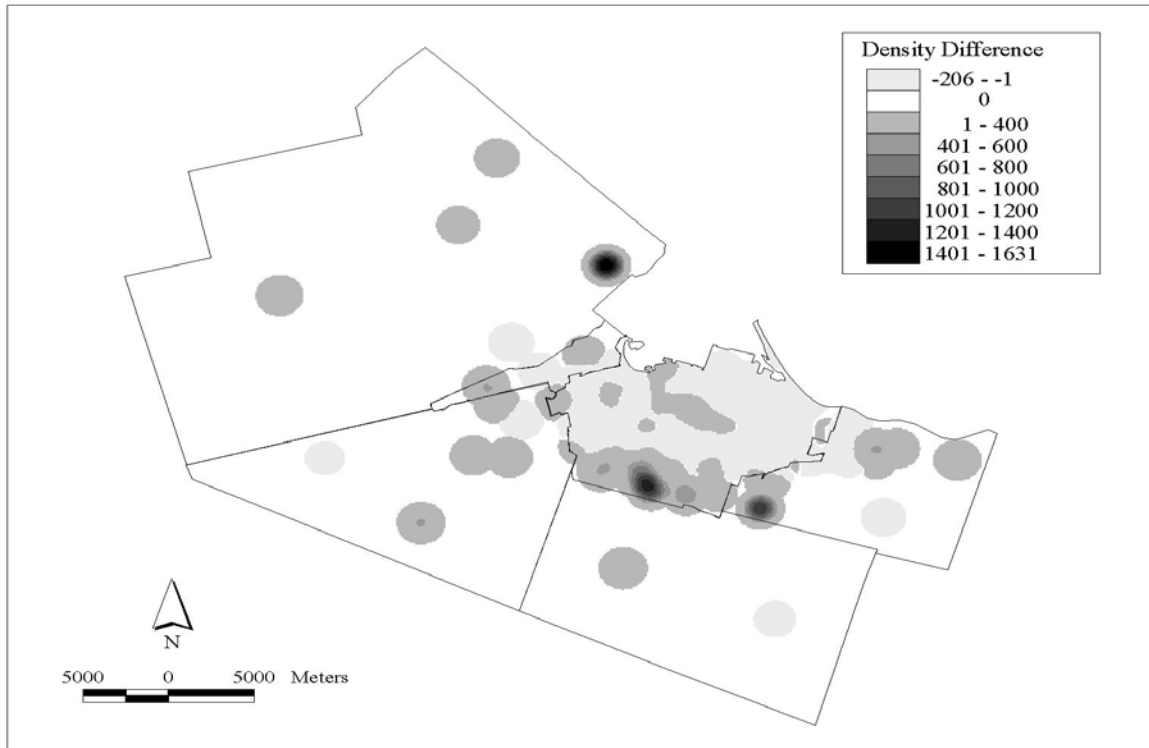
Fig3. 1990 and 1997 difference surface of firm intensity

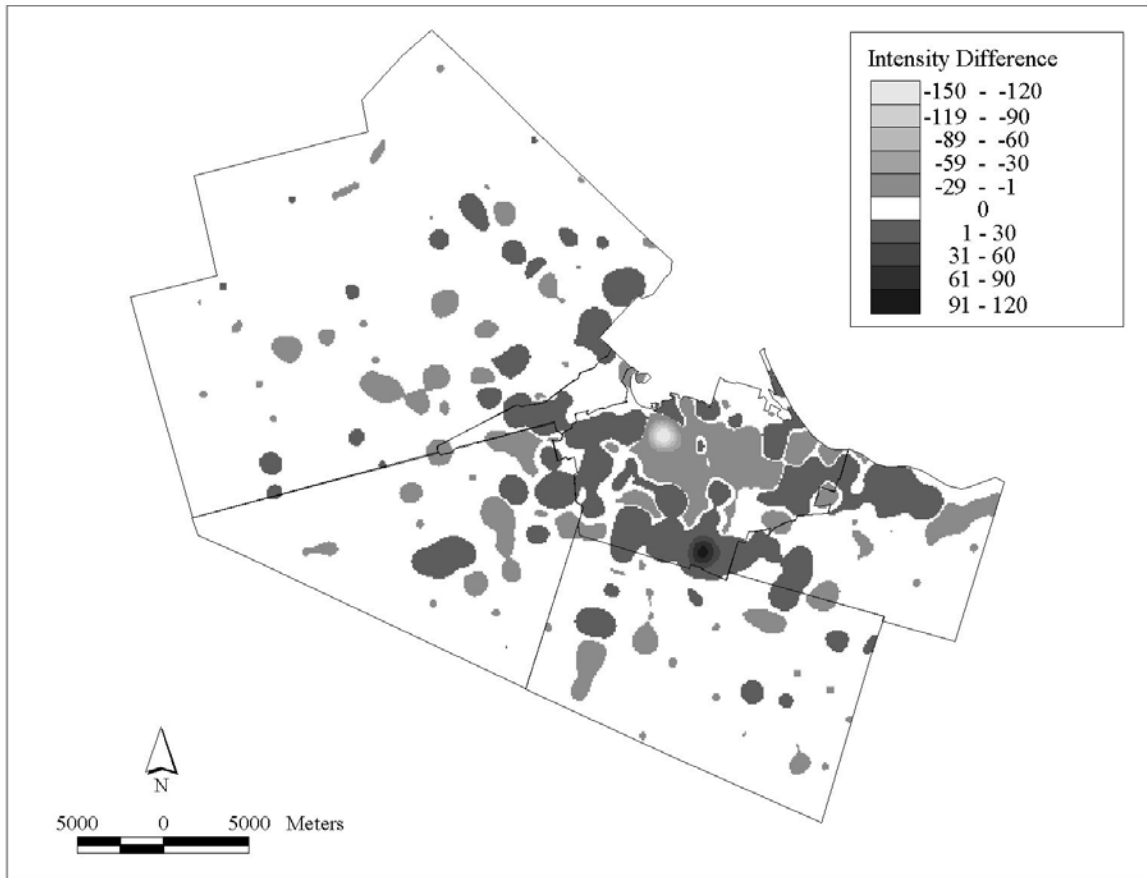
Fig4. A sample of the K-hat estimation for business services firms in 1997

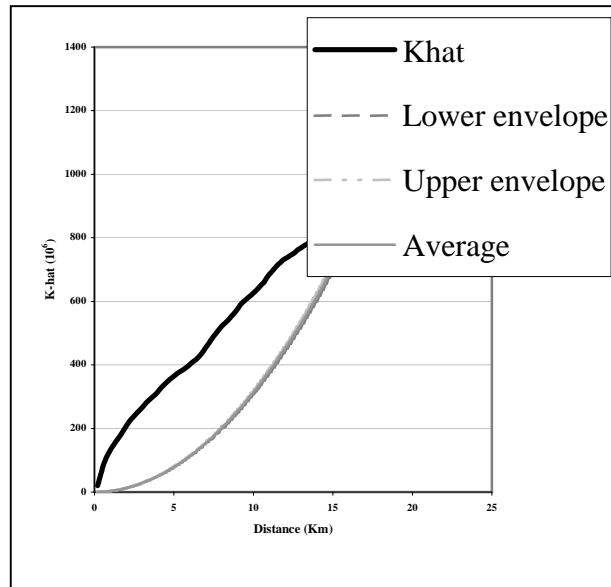
Fig5. Clustering pattern of goods based industries, high ordered services and population-oriented firms, 1997 trends

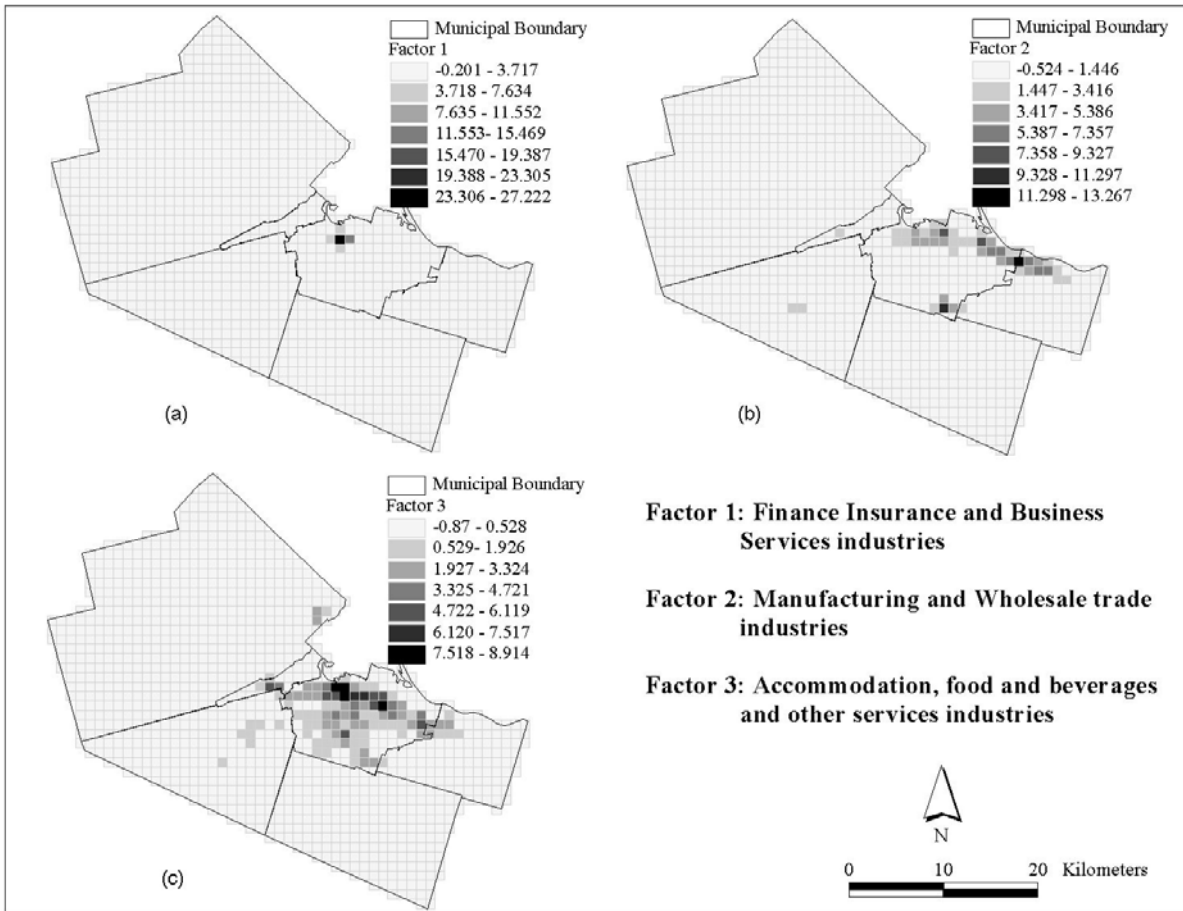
Fig6. The economic nodes in the city of Hamilton

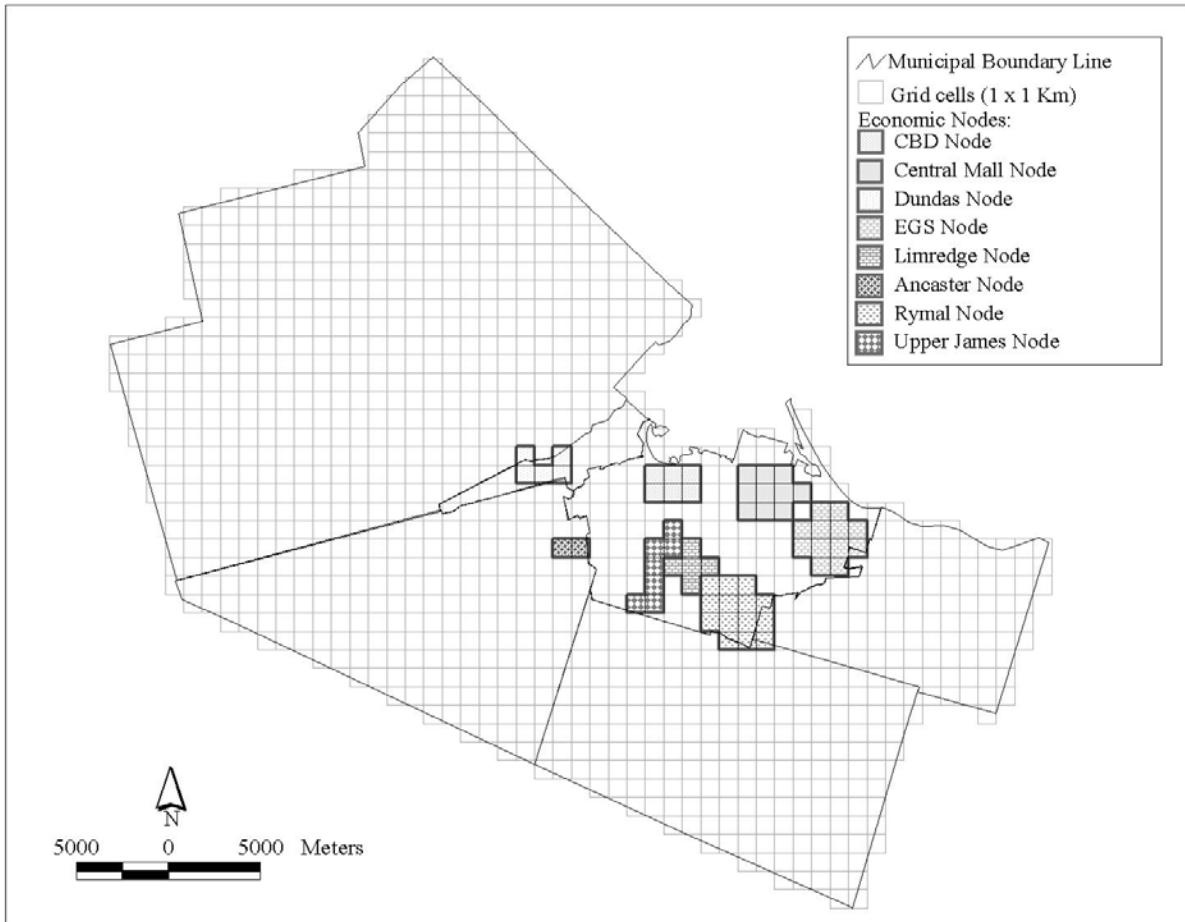












References

- Anas, A., Arnott, R. and Small, K.A. (1998) Urban Spatial Structure, *Journal of Economic Literature*, XXXVI, pp. 1426-1464.
- Anderson, W.P., Kanaroglou, P.S. and Miller, E.J. (1996) Urban form, energy and the environment: A review of issues, evidence and Policy, *Urban Studies*, 33, pp. 7-35.
- Bailey, T.C. and Gatrell, A.C. (1995) *Interactive spatial data analysis*, Harlow, Addison Wesley Longman Limited.
- Barff, R. A. (1987) Industrial clustering and the organization of production: A point pattern analysis of manufacturing in Cincinnati, Ohio, *Annals of the Association of American Geographers*, 77, pp. 89-103.
- Barff, R.A. and Hewitt, D.E. (1989) Second-order analysis of bivariate point pattern, *Professional Geographer*, 41, pp. 183-189.
- Bourne, L.S. (1989) Are new urban forms emerging? Empirical tests for Canadian urban areas, *The Canadian Geographer*, 33, pp. 312-328.
- Bracken, I. and Martin, D. (1989) The generation of spatial population distribution from census centroid data, *Environment and Planning A*, 21, pp. 537 – 543
- Cuthbert, A. and Anderson, W. (2002) Using spatial statistics to examine the pattern of urban land development in Halifax-Dartmouth, *The Professional Geographer*, 54, pp. 521-532
- Erickson, R. and Wasylenko, M. (1980) Firm relocation and site selection in suburban municipalities, *Journal of Urban Economics*, 8, pp. 69-85.
- Feser, E.J. and Sweeney, S.H. (2000) A test for the coincident economic and spatial clustering of business enterprises, *Journal of Geographical Systems*, 2, pp. 349-373.
- Frankhauser, P. (2000) GIS and fractal formalization of urban patterns: towards a new paradigm for spatial analysis?, in A.S. Fotheringham and M. Wegener (Eds.) *Spatial Models and GIS: New Potential and New Models*, pp. 121-141, London: Taylor & Francis.
- Frenkel, A. (2001) Why high technology firms choose to locate in or near metropolitan areas, *Urban Studies*, 38, pp. 1083--1102.
- Glaeser, E.L., Kallal, H.D, Scheinkman, J.A and Shleifer, A. (1992) Growth in cities, *The Journal of Political Economy*, 100, pp. 1126-1152

Getis, A. (1983) Second order analysis of point patterns: the case of Chicago as a multi-center urban region, *Professional Geographer*, 35, pp. 73-80.

Giuliano, G. and Small, K.A. (1991) Subcenters in the Los Angeles region, *Regional Science and Urban Economics*, 21, pp. 163-182.

Hanson, G.H. (1996) Agglomeration, dispersion and the pioneer firm, *Journal of Urban Economics*, 39, pp. 255 – 281

Ihlanfeldt, K.R. and Raper, M.D. (1990) The intrametropolitan location of new office firms, *Land Economics*, 66, pp. 182-198.

Krugman, P. (1991) *Geography and trade*, MIT press, Cambridge, MA

Maoh, H.F., Kanaroglou, P.S. and Buliung, R. (2002) Modeling the location of firms within an integrated transport and land-use model for Hamilton, Ontario. Paper presented at *the International Colloquium: The Behavioural Foundations of Integrated Land-Use And Transportation Models: Assumptions and New Conceptual Frameworks*, Quebec, June.

Marshall, A. (1920) *Principles of economics*, London, McMillan

McMillen, D.P. and McDonald, J.F. (1998) Suburban subcenters and employment density in metropolitan Chicago, *Journal of Urban Economics*, 43, pp. 157-180.

Rigby, D. and Essletzbichler, J. (2002) Agglomeration economies and productivity differences in US cities, *Journal of Economic Geography*, 2, pp. 407 - 432

Rosenthal, S.S. and Strange, W.C. (2003) Geography, industrial organization and agglomeration, *The Review of Economics and Statistics*, 85, pp. 377-393

Shukla, V. and Waddell, P. (1991) Firm location and land use in discrete urban space: A study of the spatial structure of Dallas-Fort Worth, *Regional Science and Urban Economics*, 21, pp. 225-253.

Small, K.A. and Song, S. (1994) Population and employment densities: structure and change, *Journal of Urban Economics*, 36, pp. 292-313.

Smith, D.F. and Florida, R. (1994) Agglomeration and industrial location: An econometric analysis of Japanese-affiliated manufacturing establishments in automotive-related industries, *Journal of Urban Economics*, 36, pp. 23-41

Torrens, P. and Alberti, M. (2000) Measuring sprawl. Paper presented to *the Association of collegiate schools of planning conference*, Atlanta, November.

Waddell, P. and Shukla, V. (1993) Manufacturing location in a polycentric urban area: a study in the composition and attractiveness of employment subcenters, *Urban Geography*, 14, pp. 277 - 296

Waddell, P., Borning, A., Noth, M., Freier, N., Becke, M. and Ulfarsson, G. (2003) Microsimulation of urban development and location choices: design and implementation of UrbanSim, *Networks and spatial economics*, 3, pp. 43-67

Wu, F. (1999) Intrametropolitan FDI firm location in Guangzhou, China: a poisson and negative binomial analysis, *The Annals of Regional Science*, 33, pp. 535-555.