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SPATIAL CLUSTERS OF LOGISTICS-RELATED EMPLOYMENT – A CASE STUDY OF BRISBANE-SOUTH EAST QUEENSLAND, AUSTRALIA

Prem Chhetri and Shams Rahman

School of Management
RMIT University
Melbourne, Victoria,
Australia.
e-mail: shams.rahman@rmit.edu.au

ABSTRACT

The purpose of this paper is two-fold. First it maps the spatial distribution of logistics-related employment (LRE) and second it identifies the spatial clusters and patterns of LRE across a large urban region – South East Queensland in Australia. The results from the Gini Coefficient and Lorenz Curve indicate the presence of spatial inequality in the distribution of LRE; however this inequality has stabilised over the last decade. Use of Global Moran indicates the spatial dependency in the distribution (i.e. suburbs with high values are surrounded by high value suburbs); whilst the measure of local Moran has identified three main spatial clusters of the LRE around major activity hubs such as the Brisbane airport, Port and the CBD.

Key words: Logistics Related Employment, spatial econometrics, spatial autocorrelation, and GIS.

INTRODUCTION

With the advent of globalisation, and the concomitant change in the pattern of international trade, national firms are increasingly been transformed into international and global co-operations and alliances. Under the global business environment, the role of geographically localised processes on locational behaviour of firms appears to become less significant. It has been argued that the greater connectivity, telecommuting, and improved transportation provisions might have further changed the way multinational and trans-national co-operations manage their global trade in the international market (Rodrigue et al. 2005). Globalisation and internet technologies might have reduce the importance of localised geographical factors in the location decision choices as *places* are increasingly becoming more connected to global business around the world and *people* and their mobility patterns are now more likely to be liberated from spatial constraints such as distance and proximity.

Contrary to this view, the agglomeration and cluster theories (Porter 2000; Rosenthal et al. 2003; Van Soest et al. 2006) argue that the process of globalisation has in fact accelerated the clustering tendency of firms around those areas that have comparative and competitive advantage. Globalisation has made the businesses more 'location dependent' rather than 'location free'. The localised geographical processes such as accessibility have further reinforced this tendency of co-location (Woundsma et al. 2008) wherein firms are clustered to take advantage of economies of scale, low transport costs, and closeness to larger corporations for business. These theories were predicated on the basis of the assumption that employment generally exhibits a tendency to cluster in

specific areas that have relative advantage of offering 'optimal' outcomes in terms of profits, cost, or other criteria depending upon the type of industry. The theory of clustering is now well established in regional science literature. Porter (2000) defines a 'cluster' as a group of interrelated companies and associated institutions that cooperate and compete to generate wealth located within a geographic area. Cluster theory establishes that competitive advantage may arise from agglomeration economies – co-location of buyers, sellers and relevant others that minimise operating cost structures, encourage sharing technology, and develop business networks (Porter 1998).

The distributional aspect of logistics and supply chains is a geographic phenomenon (Rodrigue et al. 2005). It holds explicit locational attributes (e.g. geographic references) as passengers or freight is to be transported across a given geographic space. The movement of freight and the resulted spatial interactions vary due to the relative differences in resources distribution; the location of logistics provisions such as storage and warehousing facilities thus tends to adjust according to the accessibility to transportation hubs and ports (Woundsma et al. 2008) so that the areas of production and consumption can be linked more economically. The question to what extends logistics firms and companies exhibit the clustering tendency around areas of comparative advantage has however attracted very little attention. A number of studies (Waddell and Shukla 1993; Szivas et al. 2003; Chhetri et al. 2008) have investigated location choices for retail and business services employment, however the industry that manages supply chain networks and provides infrastructure support (e.g. storage and transport provisions) on which other types of industry are directly and indirectly dependent for resource acquisition and distribution has largely been ignored in the literature.

It is evident in several studies (Waddell and Shukla 1993; Woundsma et al. 2008; Chhetri et al. 2008) that the tendency of clustering often encourages firms to co-locate along major activity centres such as CBD, urban corridors and transport hubs so that the economies of scale can be achieved and transport costs can be reduced. Since there is so much of spatial heterogeneity embedded within any supply chain between the origin and the destination or multiple destinations, unevenness in the distribution of LRE across a geographic area is expected to exist. This paper purports to address the distributional aspects of logistics-related employment for one of the rapidly growing city regions in Australia – the South East Queensland region; thus aims to fill this gap in the literature. The nature, location and relationships of spatial clusters, particularly for logistics related employment, in the information or knowledge driven economy, will be evaluated before the cluster theory can be more widely transmuted into policy and action.

There are three main objectives set out for this paper.

- First, we will describe the distribution of logistics-related employment across the SEQ region including the identification of areas that are either emerging or declining in transport and warehousing industries over the last decade (between 1991-2001). The number of people employed in those industries is considered as a surrogate measure for logistics related industries. That means, higher the employment, greater the number of firms and companies.

- Second, we will quantify the degree of inequality in the distribution of these jobs at a global level using measures of inequality such as the Gini coefficient and Moran's I.
- Third, the spatial association and clustering of jobs will be identified using the measure of the measure of local Moran so that spatial patterns and structures of the LRE can be quantified.

The novelty of this research is two fold. First, it investigates logistics related employment at a spatially disaggregate level (e.g. suburb) to provide a local perspective to decision choice process. Second, a number of techniques including more advanced methods of spatial econometric are applied to analyse the spatial dependence of the LRE.

The remainder of this paper is structured into four sections. The next section introduces the study area, which is then followed by section three that describes the datasets to be used for the analysis. Results of statistical analysis are presented in section four, and the paper concludes with a summary of the major findings in section five.

STUDY AREA

The South East Queensland (SEQ) region of Australia, which includes the Brisbane, Gold Coast and Sunshine Coast, has been experiencing rapid socio-economic and demographic changes (e.g. inter-state migration, tourism growth) over the last two decades. The growth in population combined with burgeoning economic activity has placed considerable stress on the modal and Intermodal infrastructure facilities. The ability of the metropolitan road network to meet growing demand for cross-town movement of freight, commercial and commuter traffic is critical to the region's long-term development. Congestion is more increasingly impacting the network efficiency and performance and this problem is expected to increase over the next 20-25 years as the population and commercial activities increase (Queensland Government 2006). Freight across Queensland is also forecasted to double by 2020 (Queensland Government 2006). With the expanding import and export activities around the Port of Brisbane, the road and rail transport corridors that service the Australia Trade Coast area might struggle to manage the anticipated flow and volume of traffic in the future.

DATASETS

The employment data used for the analysis have been extracted using Census Journey to Work (JTW) dataset (ABS 2001). The JTW data provide information about where people live and work, what industry they work and what transport modes they use. The types of industry in the JTW data were classified using the Australia and New Zealand Standard Industrial Classification (ANZSIC). ANZSIC codes were used to identify logistics-related employment. As it is difficult to identify logistics-related employment on the standard ANZSIC classification, therefore one-digit industry sector '*Transportation and Warehouse*' has been used as a surrogate measure for representing logistics-related employment. The data comprises 289 Statistical Local Areas (referred as suburbs in this paper), which hold information about the number of people employed in the transportation and warehouse industry.

STATISTICAL ANALYSIS

Two sets of methods are applied to employment data in this paper; the first relates to the measurement of the spatial distribution and the associated patterning of TRE using the Lorenz Curve and the Gini Coefficient, and the second set of methods employed are applied to measure the spatial autocorrelation to reflect both global and local patterning and clustering of jobs.

Lorenz Curve and Gini Index

The degree of inequality in the distribution of a phenomenon such as wealth can be measured using the Lorenz Curve and the Gini Coefficient. To calculate the Lorenz curve, the data on employment in logistics sector were first ordered and then proportionally cumulated by their size. Since the Lorenz Curve is a comparative measure, the distribution of all jobs is used as a comparative scale to measure the degree of inequality. In terms of interpretation of the curve, if all observations (e.g. suburbs) are of the same size (e.g. the number of people employed in the logistics sector), the curve will form a straight diagonal line that is termed 'the line of equality'. In case of unequal distribution of employment in a sector, the curve will either be over or under the line of equality.

The Lorenz Curve and the Gini Coefficient were calculated for three census time intervals: 1991, 1996 and 2001. The results indicate that the LRE across the SEQ region is unequally distributed (see figure 1). The distribution depicts a high spatial concentration of LRE in suburbs that are either located in close proximity to industrial areas or the Brisbane Port. City – Inner, Pinkenba-Eagle Farm, City Remainder, Acacia Ridge and Ipswich were among the top five suburbs in 1991, whilst the order and ranking have changed slightly with the Pinkenba-Eagle Farm leading the list of top performers with others being City – Inner, Hemmant-Lytton, Acacia Ridge and Bowen Hills in a descending order in 2001. The suburbs with high concentration of LRE are either located in close proximity to Brisbane Port and CBD or they are industrial areas (e.g. Acacia Ridge, Archerfield and Rocklea). The concentration of logistics-related employment is also evidenced in the Lorenz Curve. In 1991, for example, 50 percent of the total jobs in the logistics related sector were located only in 56 suburbs out of a total of 289; while the degree of job concentration didn't change much in 2001 with a total of 57 suburbs accounting for 50 percent of the LRE employment.

Figure 1 shows the relationship between the cumulative proportion of logistics-related employment and total employment using the Lorenz Curve. Each year (1991, 1996 and 2001) displays a wide disparity in the distribution of LRE; however, over the three census periods there is an indication of the degree of inequality in the distribution of LRE across the SEQ region has not changed much. While a stable pattern over the last decade is evidenced on the Lorenz curves, the magnitude of that inequality is still unknown. Using the Gini Coefficient measure, the magnitude of the inequality can be further explored through a single measure of the distribution.



Figure 1: Lorenz curves for three census periods: a) 1991, b) 1996, and c) 2001)

The degree of inequality (e.g. the extent to which the curve deviates from the line of equality) can be computed using the Gini Coefficient, which is the ratio between the area enclosed by the Lorenz curve and the line of equality, and the area under the line of equality within the given triangle. Since the data is arranged by the size of the observations in ascending order, the Gini Coefficient is computed as:

$$G = \frac{\sum_{i=1}^n (2i - n - 1)x'_i}{n^2\mu} \quad (1)$$

Where, μ is the mean size, n is the number of observations.

The Gini coefficient ranges between 0 and 1, where 0 reflects complete equality (every suburb has equal number of jobs) whilst 1 corresponds to a perfect inequality (a single location/suburb has all the jobs).

The results show that the Gini Coefficient has slightly increased from 0.33 in 1991 to 0.35 in 1996 and remain the same (0.35) in 2001, indicating the large disparities in the distribution of LRE inequality over the last 10 years. Despite the existence of inequality across the region, there is indication that the gap between the core and peripheral areas has remained unchanged. The spatial pattern (e.g. distinct pockets of low and high concentrations) and dispersion of logistics-related employment and the underlying clustering at the local level however could not be explored through the global measure of Gini Coefficient. Further investigation is thus needed that provides insights into the growth patterns that then may enable the identification of 'hotspots' and 'coldspots' of logistics led employment for the region.

Spatial autocorrelation methods

One commonly used technique to calculate the degree of spatial autocorrelation in the observations is the Moran's I statistic (1950). This index can be based on binary contiguity between spatial units. In the binary weight matrix spatial connectivity is expressed as either a 1 or 0. That is, if two spatial units have a common border of non-zero length then they are considered to be 'neighbours' and assigned a value of 1, otherwise attributed a value of 0 (not neighbours).

This idea of a binary weight matrix can be extended to a more general spatial weight matrix. A general spatial weight matrix uses a combination of distance measures to express the proximity between spatial units. For instance, one such method is to define W where the i, j th element is defined as follows:

$$w_{ij} = \begin{cases} \exp(-cd_{ij}), & \text{for } d_{ij} \leq D_{\max}, \\ 0, & \text{otherwise,} \end{cases} \quad (2)$$

where d_{ij} is the distance between unit i and unit j D_{\max} is the maximum allowable distance between any i and j before spatial proximity becomes redundant, c is the decay parameter. A high value of c indicates that regional

interactions are very proximate whilst a lower value would suggest that interactions are more spread out over the state space.

Once the potential spatial interactions are defined, the next step is then to detect any global and local patterns of spatial autocorrelation.

The Moran's I statistic (Moran 1950) is the most common test to measure global spatial autocorrelation by combining each observation over all pairs of locations, this test statistic takes the form:

$$I = \frac{N}{(N-1)S^2} \sum_{i=1}^N \sum_{j=1}^N w_{ij} (x_i - \bar{x})(x_j - \bar{x}), \quad (3)$$

where w_{ij} is an element of the spatial weight matrix W , x_i is observation $i=1, \dots, N$ and $S^2 = (N-1)^{-1} \sum_{i=1}^N (x_i - \bar{x})^2$. Moran's I is positive when there exists a positive correlation between sites, negative for a negative correlation and zero when no spatial autocorrelation exists. Inference from this statistic can proceed via permutation tests, such as Monte-Carlo test. Furthermore, by using the asymptotic distribution of I , a normal test for the null hypothesis of no spatial autocorrelation can be performed on the standardised test statistic. It must be noted that Moran's I is quite sensitive to changes in the mean, and Moran's I can only be reasonably interpreted when there is a globally constant variance.

Localized Indicators of Spatial Autocorrelation (LISA) statistics are another useful diagnostic tool (Anselin 1995). LISA statistics enable the detection of: regions where autocorrelation is unusually different; clusters of positive or negative autocorrelation; and abnormal observations in the data.

A common measure of localised spatial autocorrelation is the local Moran's I statistic which is defined as:

$$I_i = \frac{N}{(N-1)S^2} (x_i - \bar{x}) \sum_{j=1}^N w_{ij} (x_j - \bar{x}). \quad (4)$$

As with the global statistic, a value close to one indicates positive spatial autocorrelation, a negative value suggests negative correlation and zero indicates no autocorrelation.

Spatial patterning, in terms of clustering, randomness or dispersal of employment, can be quantified using the bi-variate measure of Moran's (I). To calculate the Moran's I , the spatial interconnectedness of regions has been calculated. A spatial weighting matrix was computed using the 'first-order contiguity', where areas (i.e. suburbs) with common borders are defined as neighbours.

The significant Moran's I index evidenced the presence of positive spatial autocorrelation for the logistics-related employment for all three census periods. In other words, the suburbs that are close together have similar values to those that are located further apart. The Z scores indicate that there is less than 1 percent likelihood that these clustering could be the result of random chance. The Moran's I index calculated for TRE for 1991 is 0.482 without the outliers

(City-Inner and Pinkenba-Eagle Farm). For 1996, the Moran's I decreased to 0.453 excluding the outliers. The Moran's I for the 2001 census period continued to decline to 0.442 ($p < 0.001$).

From the results two main conclusions can be drawn from the spatial dependence of TRE for the region. First, the jobs across the region are not randomly distributed as the spatial pattern emerged to be spatially correlated with the presence of spatial clusters. Second, since 1991 the clustering pattern has not changed much. Suburbs with high values (i.e. the number of jobs) are surrounded by high values; whilst suburbs with low values have neighbours with low values.

The Moran's I index is a global measure (i.e. measures which assess the whole dataset) and therefore it does not indicate the local specific change or association of LRE processes on logistics related employment at a particular locality. To explore this, the Local Indicators of Spatial Association (LISA) is applied that decomposes the global measure into contributions for each suburb. The Local Moran I statistics enable the spatial clustering of similar or dissimilar values to be mapped for every observation across a geographic space. Using the outputs from LISA, spatial clusters can be identified and their significance mapped at a smaller unit of analysis.

The relationships has also been explored using the Moran's scatter plot (Anselin 1995) that maps the difference from the average number of jobs for each suburb against the number of jobs of its nearest geographic neighbour. The plot illustrates each suburb's difference from the average number of employment against their spatial lag, - that is a weighted average of the total employment of neighbouring suburbs. Four quadrants can be conceptualised to interpret the results. *Quadrant 1* represents those suburbs that have low concentration of logistics-related employment surrounded by suburbs with high concentration of jobs. These are: Corinda, Herston, Kangaroo Point, Moggill, Kelvin Grove, Labrador and Broadbeach. *Quadrant 2* consists of those suburbs with high concentration of LRE surrounded by suburbs with high values. These include: Acacia Ridge, Archerfield, Bowen Hills, City-Remainder, Fortitude Valley; Hendra; Hamilton, Wacol, Ipswich, and Hendra. *Quadrant 3* contains low concentration of LRE in suburbs as well as in their neighbours. The quadrat 3 consists a large number of Brisbane suburbs (Fig Tree Pocket, Highgate Hill, Indooroopilly, Kenmore, Keperra, Kilcoy, Laidley, Caloundra, Noosa). *Quadrant 4* encompasses high concentration suburbs with low concentration of LRE neighbours. Suburbs in this quadrant are Darra-Summer, East Brisbane, Geebung, Toowong, Upper Mount Gravatt, Gatton, and Capalaba, to name a few.

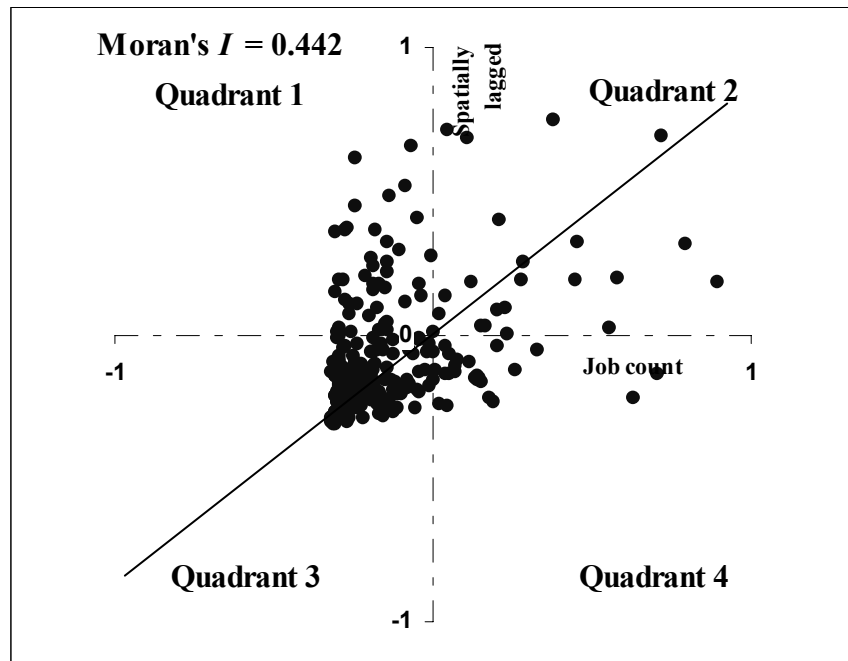


Figure 2: The Moran scatter plot

Figure 3 depicts the results of local indicators. Suburbs depicted in darker shades are statistically significant 'hot spots' wherein areas with high (above average) concentration of LRE are surrounded by areas with similar high values. Three major hotspots are identified on the map, they include:

- **CBD-based cluster** includes City-Inner, City-Remainder, Fortitude Valley, Milton and Spring Hill.
- **Port-based cluster** comprises areas such as Banyo, Hamilton, Hendra, and Northgate.
- **Industry-based cluster** consists Acherfield and Coopers plains.

Poorly performing suburbs are those situated in cold spots where they have low (below average) concentration of jobs surrounded by similarly low values. These suburbs with low-low concentration of logistics-related jobs are typically located in outer suburban area of Brisbane. The pockets include suburbs of high socio-economic status with low concentration of manufacturing industries (e.g. Pullenvale, Bellbowrie, Chapel Hill, Kenmore Hills, Pinjara Hills, Upper Brookfield and The Gap).

The two other types of clusters (i.e. high-low and low-high) have negative spatial autocorrelation where suburbs with low or high values surround suburbs with high or low concentration of jobs respectively. Few suburbs (i.e. Nudgee Beach, Nudgee, Nundah, Wynnum, Herston, Ascot and Newstead) have emerged as areas of statistically significant low-high concentration. They have relatively low values of job concentration though suburbs with relatively high values surround them. These suburbs are close to either Brisbane Port (with direct access to a beach or coast) or are situated close to Brisbane CBD.

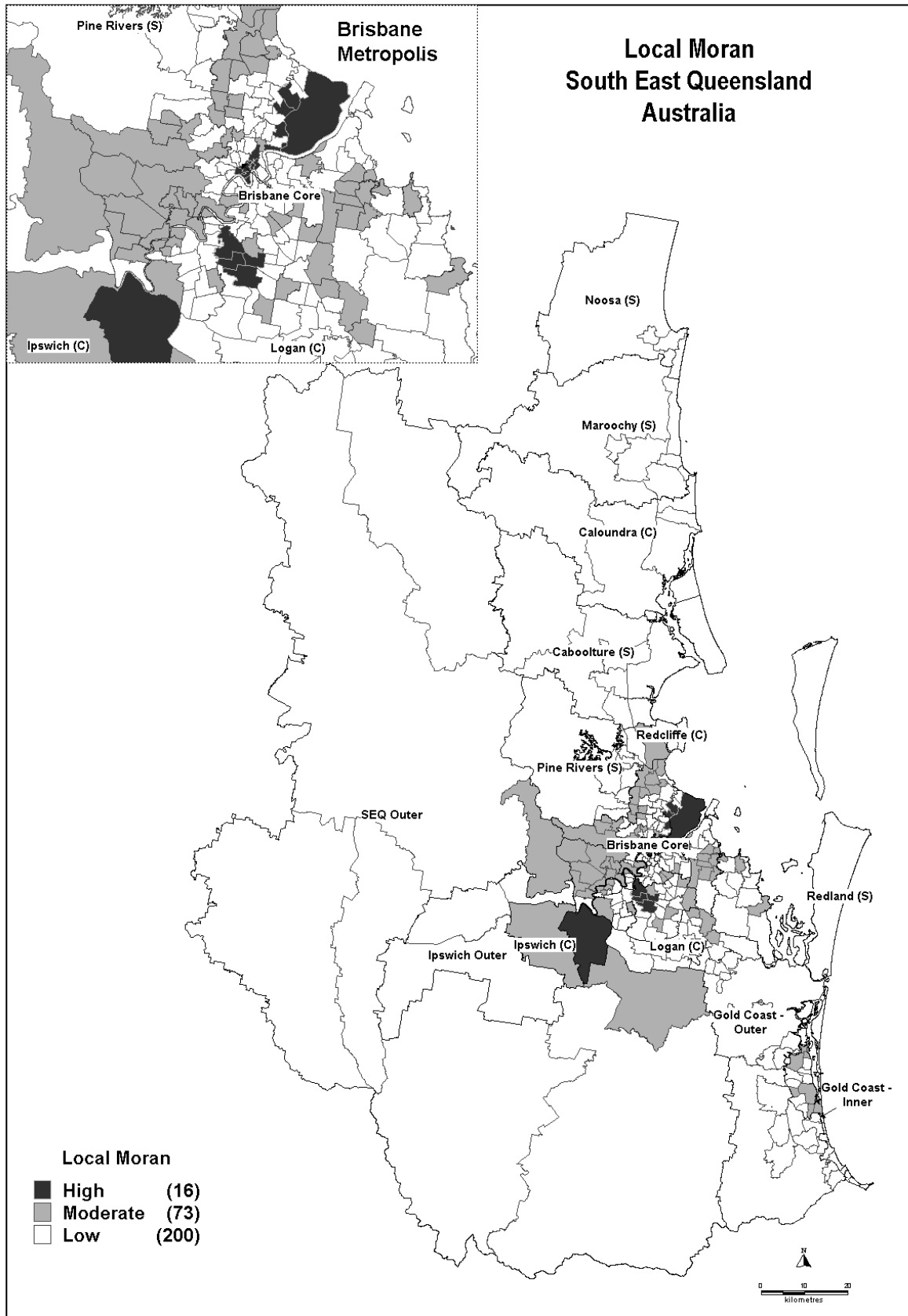


Figure 3: The local Moran score

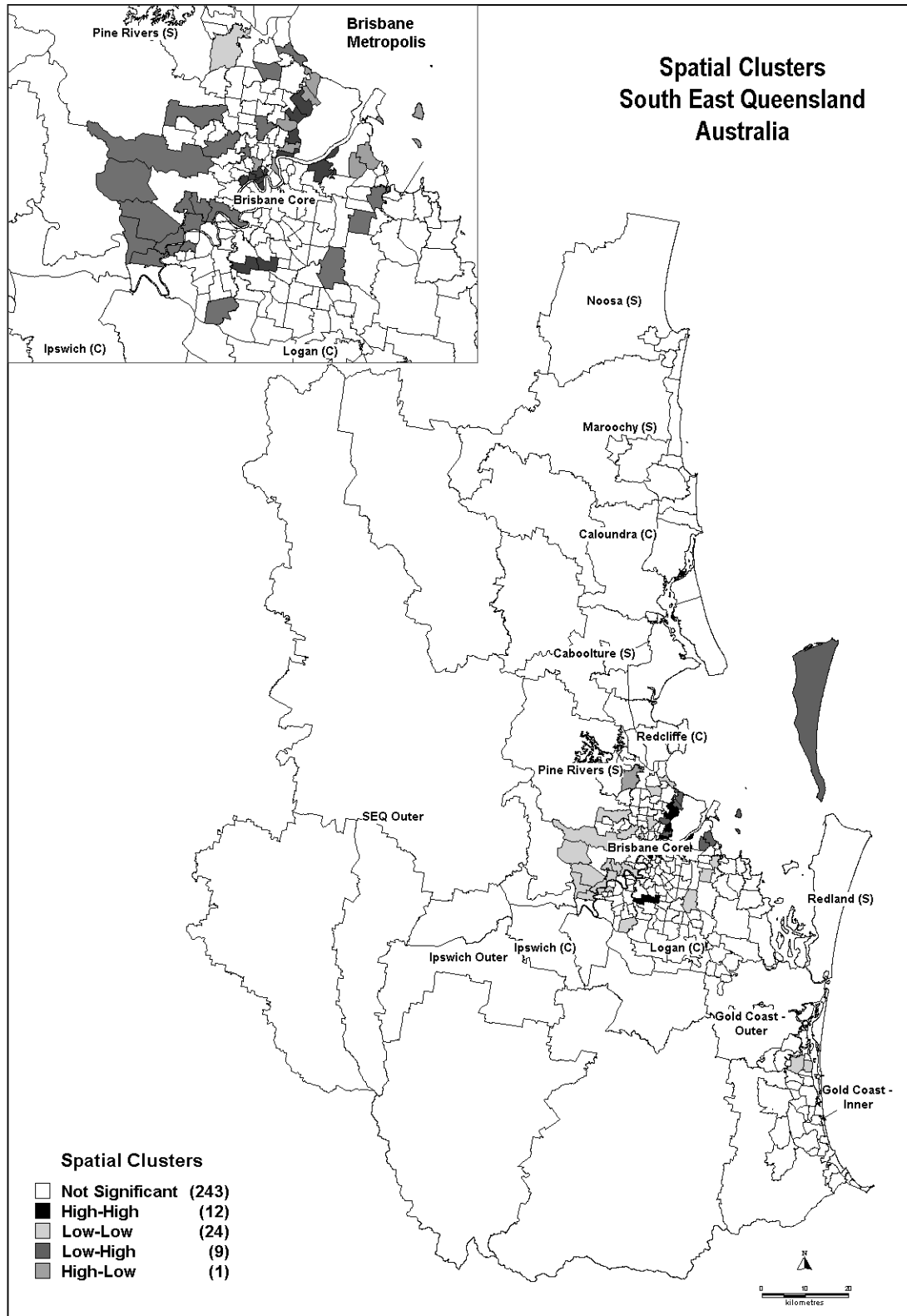


Figure 4: The spatial clusters of spatial association

CONCLUSIONS

This paper applied a number of techniques to explore the distribution and spatial reflection of the logistic related employment. The main findings of this paper can be summarised as following. First, the Lorenz Curve and the Gini Coefficient show that the degree of inequality in the distribution of LRE does exist. Over the last decade, this inequality however has been not changed. The results indicate that the gap between the core areas of logistics and warehousing and peripheral areas has remained stable, which may suggest that logistics-led employment might not have started to permeate across less developed parts of the region. The clustering and agglomeration effect might have encouraged the disparity in the distribution of LRE. Second, using measures of spatial autocorrelation both global and local indicators, spatial dependency of LRE whereby areas with high values (i.e. the number of jobs) are surrounded by high values and suburbs with low values have neighbours with low values has been detected. Significant spatial clustering across the metropolis was identified whereby LRE tends to congregate around transport terminals such as Brisbane airport and port. Three major spatial clusters were identified when the local Morans were mapped. These include the Port-based, CBD-based, industry-based clusters. Closer examination of the last two clusters indicates the 'supportive role' of logistics in facilitating the administrative (CBD based) and circulation (i.e. transportation and storage based) of goods and services for other industries. For the Port-based Cluster, logistics related employment might be considered as 'core activity' in terms of providing freight movement and transshipment facilities.

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