Province of KwaZulu-Natal

Provincial Treasury

IMES Unit

ESTIMATION OF THE SPATIAL AUTOCORRELATION FUNCTION FOR KWAZULU-NATAL[1]

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[1] The views expressed in this working paper are the views of the author and might not necessarily reflect the views of the Provincial Treasury.

Introduction

The first law of geography, according to Tobler (1976), states that everything is related to everything else, but near things are more related than distant things. LeSage (2009) points out that it is commonly observed that sample data collected for regions or points in space are not *independent*, but rather *spatially dependent*, which means that observations from one location tend to exhibit values similar to those from nearby locations. Spatial dependence in a collection of sample data means that observations at location *i* depend on other observations at locations $j \neq i$. Formally LeSage (2009) state:

$$y_i = f(y_j) \quad i = 1,\dots,n \quad j \neq i$$

LeSage (2009) states that there are predominantly two reasons why sample data observed at one point in space will be dependent on values observed at other locations. First, data collection of observations associated with spatial units such as zip-codes, countries, states, census tracts and so on might reflect measurement error. This would occur if the administrative boundaries for collecting information do not accurately reflect the nature of the underlying process generating the sample data.

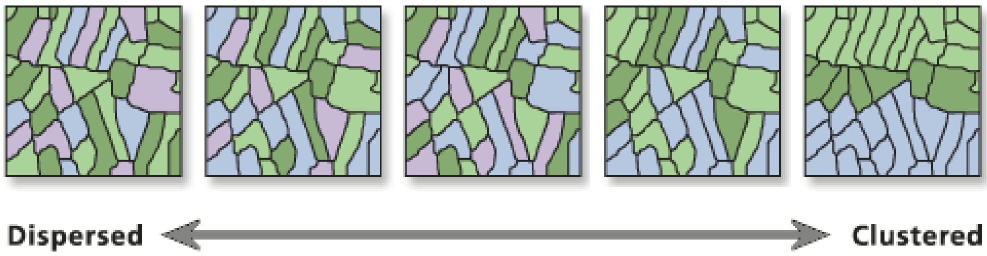
A second and perhaps more important reason, according to LeSage (2009) is that the spatial dimension of socio-demographic, economic or regional activity may truly be an important aspect of a modelling problem. Regional science is based on the premise that location and distance are important forces at work in human geography and market activity. All of these notions have been formalized in regional science theory that relies on notions of spatial interaction and diffusion effects, hierarchies of place and spatial spillovers.

Spatial autocorrelation is the formal property that measures the degree to which near and distant things are related, i.e., it measure the degree to which a set of spatial features and their associated data values tend to be clustered together in space. If there is any systematic pattern in the spatial distribution of a variable, it is said to be spatially autocorrelated, i.e.,

- If nearby or neighboring areas are more alike, this is positive spatial autocorrelation
- Negative autocorrelation describes patterns in which neighboring areas are unlike

On the other hand random patterns exhibit no spatial autocorrelation. The degrees of spatial autocorrelation is illustrated in the below illustration

Illustration 1: Degrees of Spatial Autocorrelation



The Provincial Point of Reverence

The province of KwaZulu-Natal is located in the southeast of South Africa; it borders three other provinces and the countries of Mozambique, Swaziland, and Lesotho, along with a long shoreline on the Indian Ocean. The province covers a land area of 93,378km² or 7.65 per cent of the total land area of South Africa. There are at present about 10.7 million people residing in the province or about 19.8 per cent of the total national population. The province has a population density of almost 110 people per km², significantly less than the 602 people per km² recorded in the Gauteng province, but significantly greater than the 48 people per km² recorded in the Mpumalanga province (data supplied by Global Insight, Coetzee unpublished report, own calculations).

In 2014, KwaZulu-Natal's GDP was estimated at about R480 billion (constant 2010 prices). Provincial output increased from R420 billion during 2009 to R434 billion, R449 billion, R461 billion and R470 billion in 2010, 2011, 2012 and 2013, respectively (constant 2010 prices). Economic activity picked up robustly from 2000 to 2008 (4.45 percent average annual growth), thereafter growth moderated and ultimately decreased (-1.78 percent) in 2009 due to the global financial crisis. Positive growth resumed during 2010 albeit at a very modest pace. The growth trend since 2010 has consistently been disappointing, averaging a mere 2.9 per cent per annum. The province contributes on average between 16 per cent and 17 per cent to the national gross domestic product, significantly less than the 35 per cent of the province of Gauteng but slightly more than the 15 per cent of the province of the Western Cape (data supplied by Stats SA, Coetzee unpublished report, own calculations).

The province of KwaZulu-Natal consists of 52 local economic regions. These local economic regions are demarcated by the Municipal Demarcation board (http://www.demarcation.org.za/). The province of KwaZulu-Natal also seems to be a fairly concentrated province, for example:

- About 52 per cent of the provincial population resides in the five main local economies.
- About 77 per cent of the provincial GDP is produced in the five main local economies.
- Personal per capita income is more than double in the five main local economies compared to the rest of the province.
- Poverty levels are almost half in the five main local economies compared to the rest of the province.
- The five main local economies cover only about 9.5 per cent of the total provincial land cover.
- Population density levels are more than 13 times higher in the five local economies compared to the rest of the province.
- The five local economies account for about 89 per cent, 80 per cent and 79 per cent of all new Office & Banking Space, Shopping Space and Industrial & Warehouse Space from 2001 to 2012.

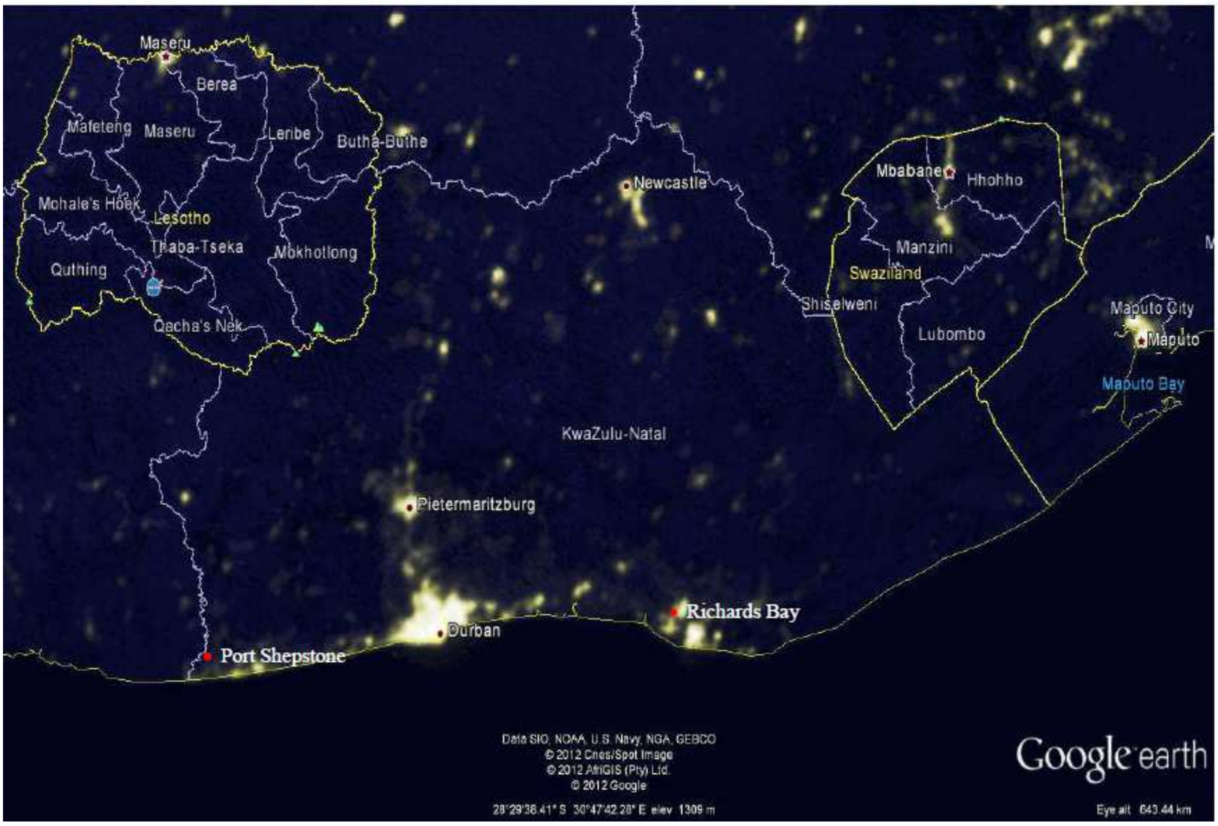
(data supplied by Stats SA and Global Insight, Coetzee unpublished report, own calculations).

The five local economies which are also the major municipal regions are:

- Ethekwini Municipality (Durban). It is the economic hub of KwaZulu-Natal and the major import/export center in South Africa.
- Msunduzi Municipality (Pietermaritzburg). It is the second largest city within KwaZulu-Natal and is the capital city of the province of KwaZulu-Natal.
- Umhlathuze Municipality (Richards Bay, Empangeni). It is the home of manufacturing in the province, boasting two world class aluminium smelters and the world's largest export coal terminal.
- Hibiscus Coast Municipality (Port Shepstone). It covers an area of approximately 90 km of coastline, comprising of 21 beaches, not surprisingly the premier tourism destination in the South Africa.
- Newcastle Municipality (Newcastle). Situated in the northern corner of the province, it is has significant coal deposits and agricultural land.

The location and economic dominance of the five local economies are clearly displayed in the night satellite map (figure 1) of the province below. It is evident that the economic activity of the province is located (with the exception of Newcastle) along the N2 from Port Shepstone to Richards Bay and along the N3 from Pietermaritzburg to Durban. In-land or rural KwaZulu-Natal seems relatively starved of economic activity.

Figure 1: Night Satellite Map of the Province - 2012

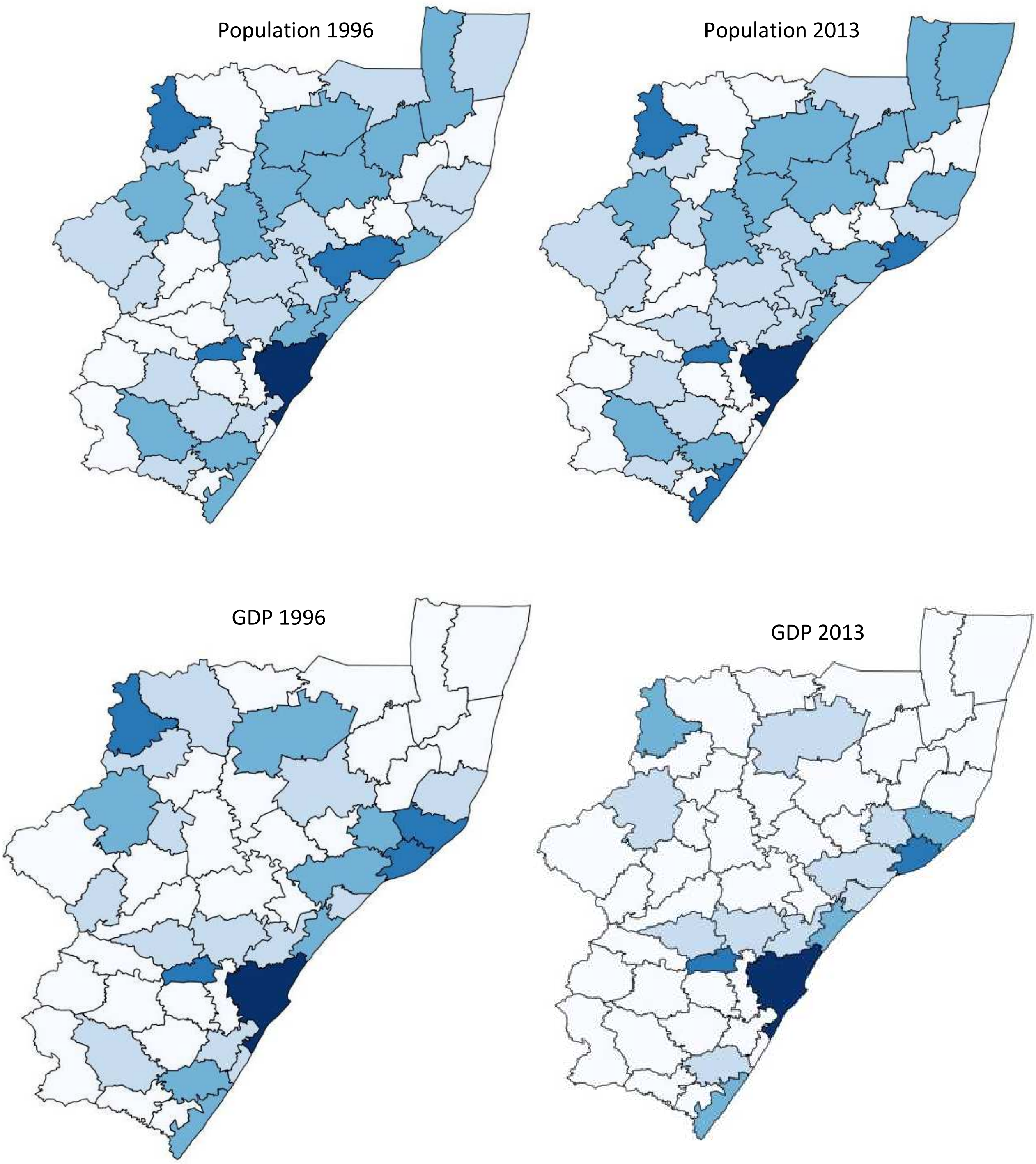


(Source: Google Earth)

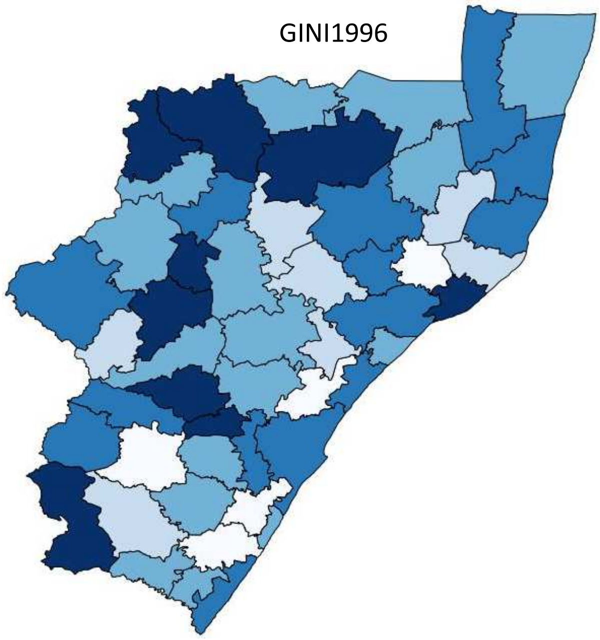
Visualizing the Data

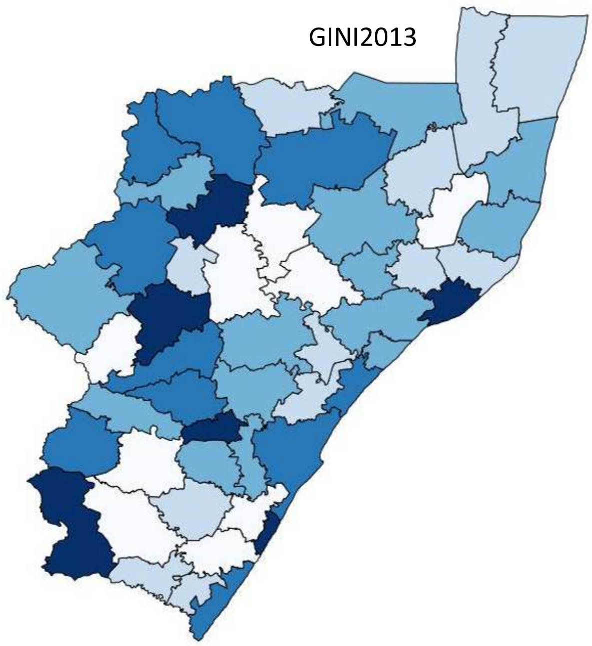
Geographical clusters and/or regions can be analyzed and described by a number of different spatial association statistics as well as visually (quickly and intuitively when the eye and brain look at the map). Each of the 18 graphs below presents a colored map that allows the visualization of the spatial pattern of each of the provincial economic variables. The GIS (geographical information system) programme QGIS was used for the analysis. Data was sourced from various sources including Statistics SA, Global Insight and own sources. Dark areas indicate high levels or concentration of the particular variable in that municipality whilst light areas indicate low levels or concentration of the particular variable in that municipality.

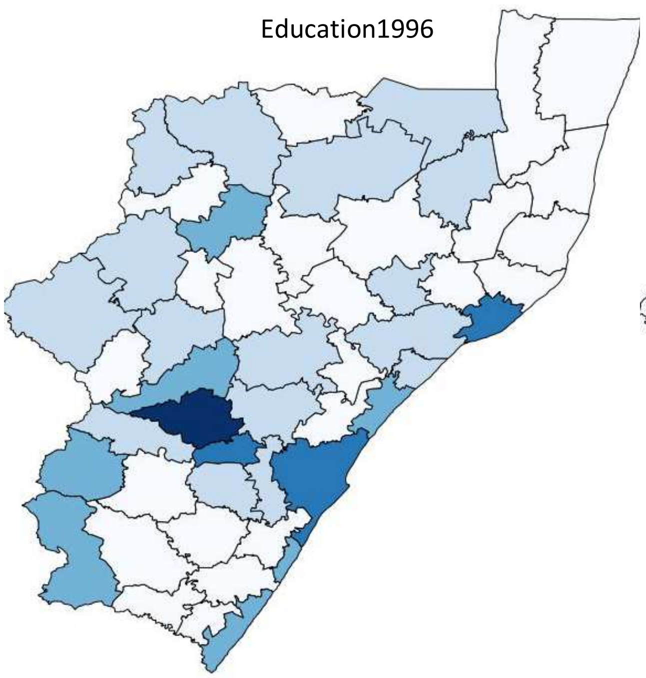
The population graphs display the population (number of people) properties during 1996 and 2013 in the province. It seems evident that the majority of the population resided near the coast and in the north of the province. There also seems to be some spatial association especially around the Abaqulusi, Ulundi, Nongoma and Jozini municipalities. However, it seems that the population in KZN has been fairly randomly distributed and has changed very little from 1996 to 2013.

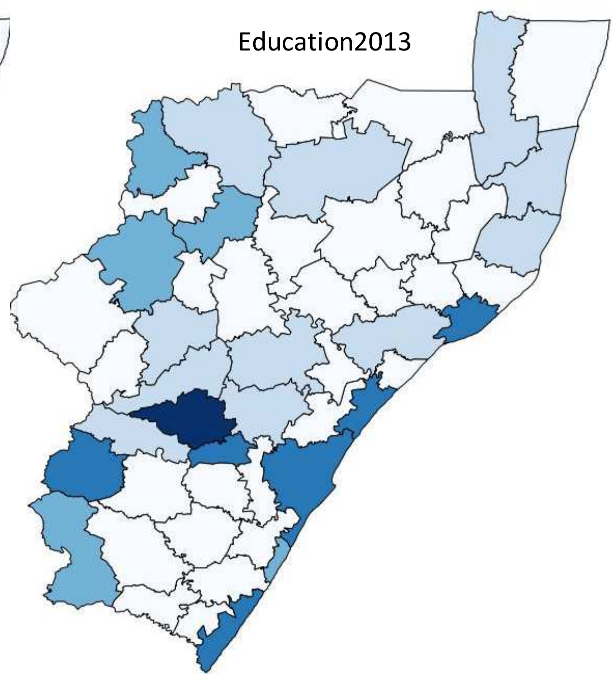


On the other hand the provincial gross domestic product (GDP) properties (above) suggests that economic activity in the province has become more concentrated since 1996 with the majority of economic activity located in the Richards Bay, Durban, Pietermartizburg and Port Shepstone corridor (some spatial association). The population and GDP properties seem to suggest some disjuncture between the location of the population and economic activity in the province.

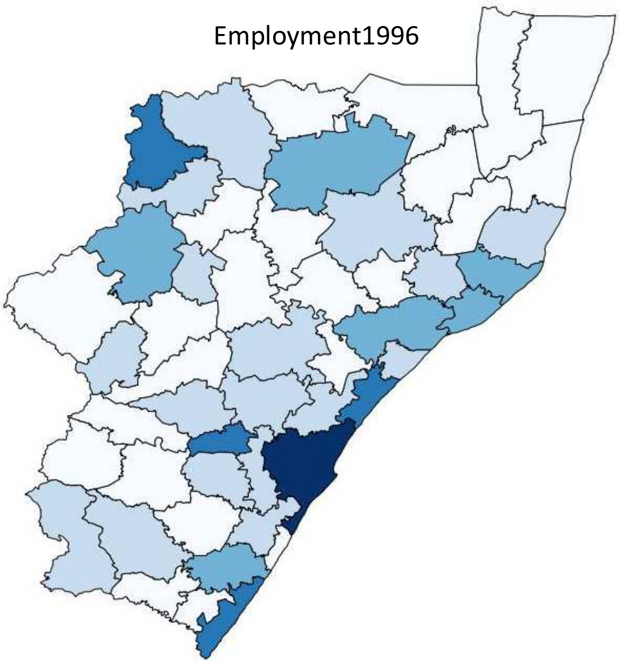


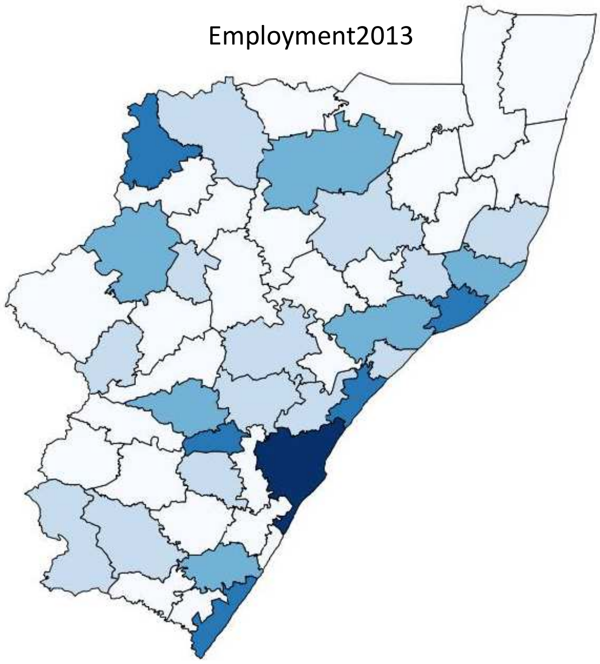


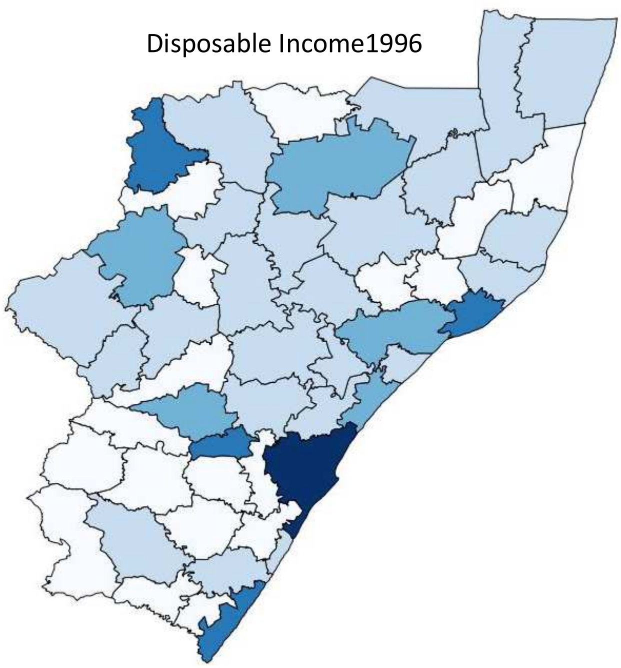


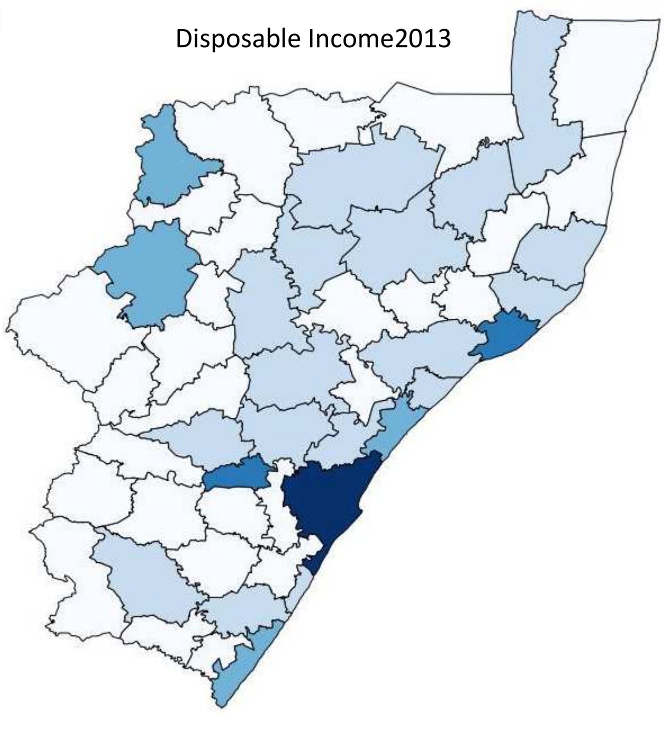


The above GINI coefficient properties suggest a fairly random distribution of in-equality in the province that has marginally improved over time. The education properties also seem fairly randomly distributed, but with some concentration along the coast.

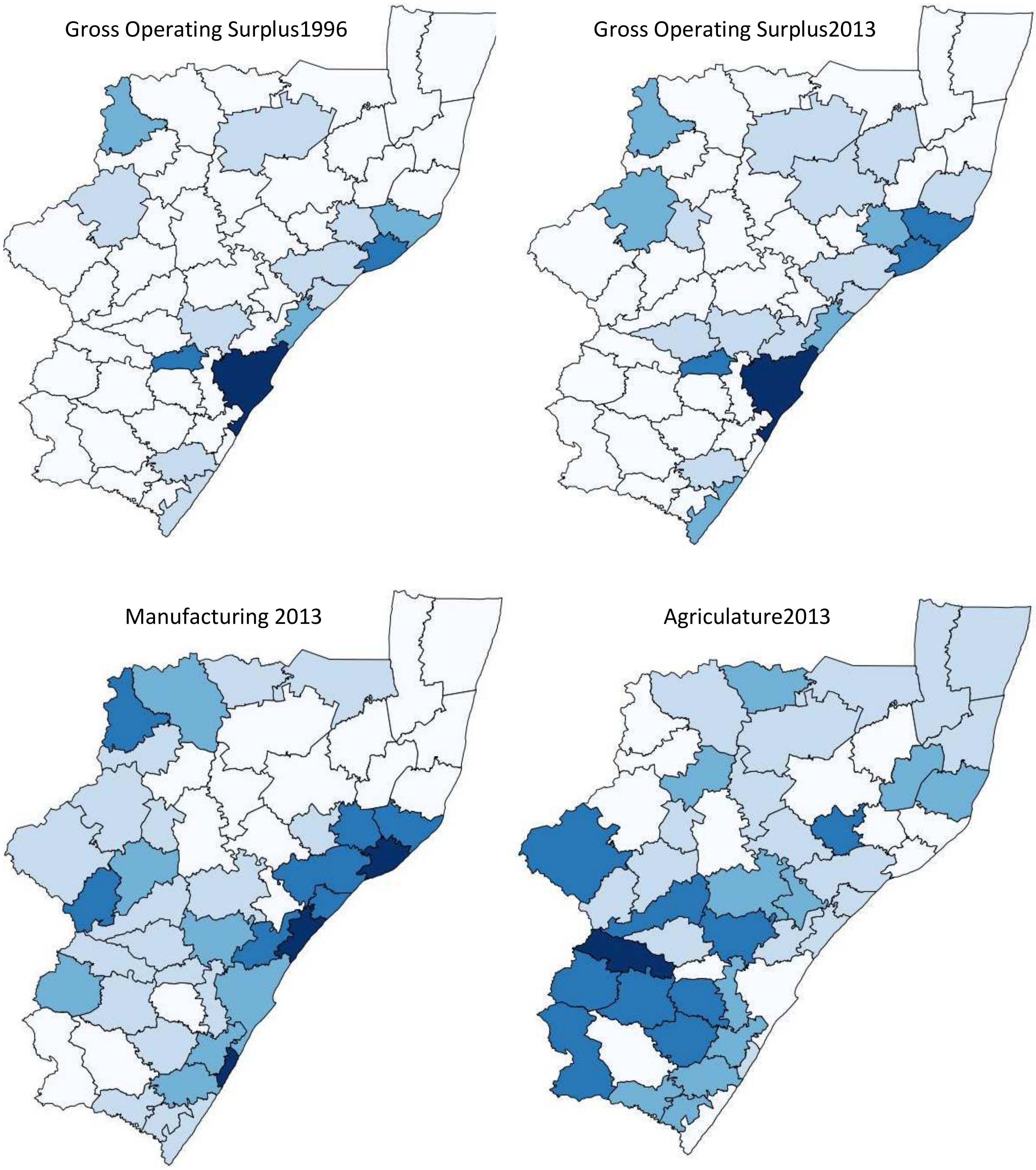




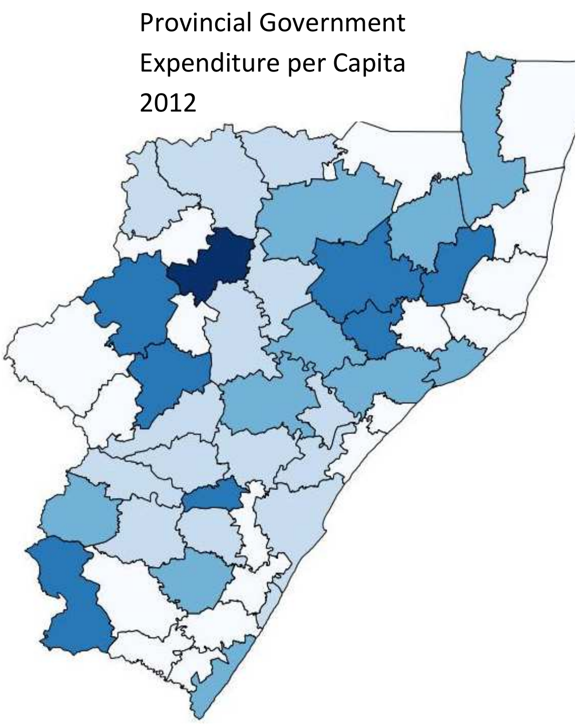


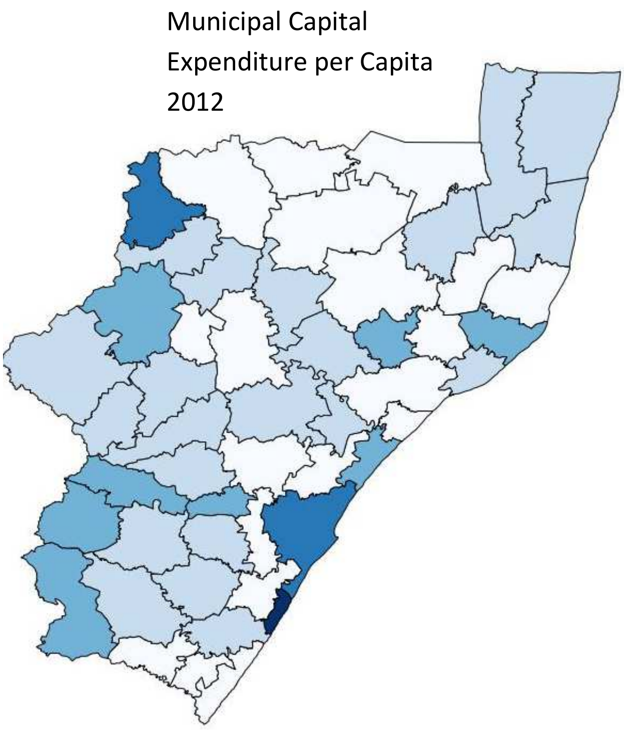


Employment seems fairly randomly distributed in the province, again with some concentration along the coast. Unfortunately employment does not seem to have improved much since 1996 in the province. Disposable income distribution in the province seems very similar to employment distribution.



The gross operating surplus properties (measure of profitability) suggest a high level of concentration of profitability in the province. Fortunately it seems that profitability has become a bit more dispersed in the province since 1996. Manufacturing and agriculture during 2013 in the province seems fairly concentrated in certain municipalities.





Provincial government expenditure and municipal capital expenditure per capita seems fairly randomly distributed during 2012.

The above GIS generated maps seem to suggest that the province is in general characterized by spatial randomness. There are however some indications that concentration levels in the province have been increasing and have been clustering around the coastal areas. The Richards Bay, Durban, Port Shepstone and Pietermaritzburg corridor seems in particular very attractive from a clustering point of view. There also seems to be some spatial disjuncture between purely economic and so-called socio-economic variables in the province, for example the poverty seems fairly randomly distributed whilst disposable income is fairly concentrated.

Determination of the spatial weights matrices

Before constructing a spatial weights matrix, we must make a spatial contiguity matrix by using weight function (Smith, 2009). A *spatial weight matrix* summarizes potential spatial relations between *n* spatial units. Here each *spatial weight*, w_{ij}, typically reflects the "spatial influence" of unit *j* on unit *i*. For *n* elements in a geographical system, a spatial contiguity matrix, *C*, can be expressed in the form:

$$C= \begin{pmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ c_{n1} & c_{n2} & \cdots & c_{nn} \end{pmatrix}$$

where *cij* is a measurement used to compare and judge the degree of nearness or the contiguous relationships between region *i* and region *j*. Thus a spatial weights matrix can be defined as:

$$W= \frac{C}{C_o} = \begin{pmatrix} w_{11} & w_{12} & \cdots & w_{1n} \\ w_{21} & w_{22} & \cdots & w_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ w_{n1} & w_{n2} & \cdots & w_{nn} \end{pmatrix}$$

where

$$C_0 = \sum_{i=0}^{n} \sum_{j=0}^{n} Cij \quad , \quad \sum_{i=0}^{n} \sum_{j=0}^{n} wij = 1$$

Spatial contiguity weights - The simplest of these weights simply indicate whether spatial units share a boundary or not. If the set of boundary points of unit i is denoted by bnd(i) then the so-called queen contiguity weights are defined by:

$$W_{ij} = \left\{\frac{1, \quad bnd(i) \cap bnd(j) \neq \emptyset}{0, \; otbnd(i) \cap bnd(j) = \emptyset}\right\}$$

k-Nearest Neighbor weights - Let centroid distances from each spatial unit *i* to all units *j* ≠ *i* be ranked as follows: $dij_{(1)} \leq dij_{(2)} \leq --- \leq dij_{(n\ 1)}$. Then for each *k* =1,..,*n* - 1, the set $N_k(i)$ = { j(1), j(2),..,j(k)} contains the *k* closest units to *i* (where for simplicity we ignore ties). For each given *k* , the *k-nearest neighbor* weight matrix, *W* , then has spatial weights of the form:

$$W_{ij} = \left\{\frac{1, \quad j \in Nk(i)}{0, \; otherwise}\right\}$$

Radial distance weights - If distance itself is an important criterion of spatial influence, and if *d* denotes a *threshold distance* (or *bandwidth*) beyond which there is no direct spatial influence between spatial units, then the corresponding *radial distance* weight matrix, *W* , has spatial weights of the form:

$$W_{ij} = \left\{\frac{1, \; 0 \leq dij \leq d}{0, \quad dij > d}\right\}$$

Actual distance values - If distance itself is an important criterion of spatial influence, and if *d* denotes the actual *distance* (1/d = inverse of the distance) then the corresponding *actual distance* weight matrix, *W* , has spatial weights of the form:

$$W_{ij} = \{1, 1/dij > 0\}$$

Applying Moran's I statistic

In statistics, Moran's I is a measure of spatial autocorrelation developed by Patrick Alfred Pierce Moran (Ward and Gleditsch, 2007). Moran's I takes the form of a classic correlation coefficient in that the mean of a variable is subtracted from each sample value in the numerator. This results in coefficients ranging from (–1) to (+1), where values between (0) and (+1) indicate a positive association between variables, values between (0) and (-1) indicate a negative association, and (0) indicates there is no correlation between variables. The expected value of Moran's I under the null hypothesis of no spatial autocorrelation is E(I) = {-1}/ {N-1}.

Moran's I:

$$I(d) = \frac{\frac{1}{W}\sum_{h=1}^{n}\sum_{i=1}^{n} w_{hi}(y_h - \bar{y})(y_i - \bar{y})}{\frac{1}{n}\sum_{i=1}^{n}(y_i - \bar{y})^2} \quad \text{for} \quad h \neq i$$

where:

$I(d)$ = Moran's I correlation coefficient as a function of distance

w_{hi} = a matrix of weighted values, where elements are a function of distance

1 = y_h and y_i are within a given distance class, for $y_h \neq y_i$

0 = all other cases

y_h, y_i = values of variables at locations h and I

W = sum of the values of the matrix w_{hi}

n = sample size

(Wikipedia, http://en.wikipedia.org/wiki/Moran's_I)

The results using a number of different economic variables (1996, 2004 and 2014) for each weight matrix are displayed below.

Table 1: Moran I statistics

Moran I	Spatial Contiguity Weights	k-Nearest Neighbor Weights	Radial distance = 100km radius	Inverse distance	Average
GovExp12	-0.101	-0.015	-0.038	-0.027	-0.045

Pop04	-0.052	-0.018	-0.026	-0.020	-0.029
Tourism13	-0.045	-0.017	-0.031	-0.021	-0.028
Tourism04	-0.048	-0.019	-0.025	-0.020	-0.028
Pop13	-0.047	-0.018	-0.025	-0.019	-0.027
Pop96	-0.043	-0.018	-0.023	-0.018	-0.026
DwellingM	-0.012	-0.009	-0.052	-0.026	-0.025
Urban96	-0.039	-0.019	-0.024	-0.018	-0.025
Toilet13	-0.002	-0.020	-0.043	-0.027	-0.023
ShoppingSpace	-0.030	-0.018	-0.024	-0.020	-0.023
Urban04	-0.031	-0.020	-0.023	-0.018	-0.023
Schools	-0.027	-0.019	-0.026	-0.020	-0.023
GDP96	-0.028	-0.020	-0.025	-0.018	-0.023
GDP04	-0.028	-0.020	-0.025	-0.018	-0.023
Empl04	-0.031	-0.021	-0.022	-0.017	-0.023
GOS04	-0.026	-0.020	-0.026	-0.018	-0.022
Refuse13	-0.017	-0.019	-0.024	-0.029	-0.022
Urban13	-0.030	-0.020	-0.022	-0.017	-0.022
DispInc96	-0.031	-0.021	-0.020	-0.016	-0.022
GOS13	-0.025	-0.020	-0.025	-0.018	-0.022
DispInc04	-0.030	-0.021	-0.020	-0.017	-0.022
GOS96	-0.025	-0.020	-0.025	-0.018	-0.022
GDP13	-0.026	-0.020	-0.024	-0.018	-0.022
Empl13	-0.029	-0.021	-0.021	-0.016	-0.022
Empl96	-0.028	-0.021	-0.021	-0.016	-0.022
Churches	-0.025	-0.018	-0.022	-0.021	-0.021
Office	-0.024	-0.018	-0.023	-0.020	-0.021
DispInc13	-0.028	-0.021	-0.020	-0.016	-0.021
Industrial	-0.024	-0.022	-0.017	-0.017	-0.020
Gini13	-0.010	-0.026	-0.020	-0.019	-0.019
Incom96	-0.005	-0.027	-0.017	-0.023	-0.018
OtherRes	0.008	-0.022	-0.020	-0.014	-0.012
Townhouses	-0.004	-0.030	0.006	-0.013	-0.010
DwellingL	0.006	-0.028	-0.006	-0.013	-0.010
Gini04	0.033	-0.017	-0.020	-0.033	-0.009
Refuse96	0.027	-0.025	-0.014	-0.019	-0.008
Edu04	0.029	-0.037	0.003	-0.002	-0.002
Edu13	0.025	-0.042	0.016	-0.006	-0.002
Gini96	0.055	-0.035	-0.002	-0.006	0.003
Flats	0.051	-0.029	-0.002	-0.007	0.003
Edu96	0.048	-0.039	0.002	0.004	0.004
Unemp96	0.042	-0.028	0.024	-0.018	0.005
Toilet96	0.075	-0.041	0.003	0.003	0.010
Unemp04	0.043	-0.035	0.042	-0.008	0.010
Water13	0.101	-0.017	-0.043	0.003	0.011
Water04	0.100	-0.033	-0.021	0.005	0.013
Unemp13	0.055	-0.042	0.059	-0.002	0.017
Incom04	0.092	-0.051	0.030	0.013	0.021
Agri04	0.084	-0.068	0.067	0.033	0.029
House96	0.167	-0.026	-0.024	0.005	0.030
Elec96	0.167	-0.034	-0.024	0.015	0.031
Elec13	0.177	-0.037	-0.019	0.008	0.032
Elec04	0.188	-0.038	-0.027	0.018	0.035
House04	0.196	-0.026	-0.041	0.012	0.035

Agri96	0.113	-0.077	0.079	0.046	0.040
Agri13	0.124	-0.084	0.099	0.048	0.047
PerCap96	0.232	-0.029	-0.043	0.033	0.048
PerCap04	0.223	-0.036	-0.021	0.030	0.049
PerCap13	0.228	-0.041	-0.016	0.033	0.051
Water96	0.217	-0.064	0.036	0.037	0.056
House13	0.283	-0.060	0.015	0.041	0.070
Man13	0.339	-0.047	0.009	0.071	0.093
Man96	0.358	-0.043	-0.008	0.073	0.095
Man04	0.370	-0.039	-0.012	0.068	0.097
Incom13	0.290	-0.085	0.105	0.077	0.097

The summary statistics are displayed in the table below:

Table 2: Moran I statistics – Summary statistics

Moran I	Spatial Contiguity Weights	k-Nearest Neighbor Weights	Radial distance = 100km radius	Inverse distance	Average
Average	0.055	-0.031	-0.008	-0.001	0.004
Median	0.006	-0.025	-0.021	-0.016	-0.010
St Dev	0.114	0.017	0.032	0.027	0.036
Min	-0.101	-0.085	-0.052	-0.033	-0.045
Max	0.370	-0.009	0.105	0.077	0.097
Positive Numbers	33	0	16	22	27
Negative Numbers	32	65	49	43	38

There seems to be some fairly big differences between the four weight matrices, i.e., the average Moran I statistics being 0.055 using the spatial contiguity weight matrix versus -0.031 using the k-nearest neighbor weight matrix. It's also interesting to note that the vast majority of the Moran I statistics are close to zero, i.e., spatial randomness. Overall there are much more negative Moral I statistics (38) than positive Moran I statistics (27). However, it does seem that the Moran I statistic of many of the variables have increased (positive spatial autocorrelation) over the period, for example agriculture increased from 0.04 in 1996 to 0.047 in 2013, income increased from -0.018 to 0.097 and unemployment increased from 0.005 to 0.017. Manufacturing had the highest Moran I statistic (0.37) whilst provincial government expenditure had the lowest Moran I statistic (-0.1).

The results seem to suggest that the province experienced almost no, or very little, spatial dependence from 1996 to 2013, i.e., the economic outcomes/indicators from a particular region have been very much autonomous or independently generated from a provincial spatial point of view.

Applying Geary's C statistic

Geary's C is defined as:

$$C = \frac{(N-1)\sum_i \sum_j w_{ij}(X_i - X_j)^2}{2W\sum_i (X_i - \bar{X})^2}$$

where N is the number of spatial units indexed by i and j; x is the variable of interest; x̄ is the mean of x; w_{ij} is a matrix of spatial weights; and w is the sum of all w_{ij}. The value of Geary's C lies between 0 and 2. 1 means no spatial autocorrelation. Values lower than 1 demonstrate increasing positive spatial autocorrelation, whilst values higher than 1 illustrate increasing negative spatial autocorrelation (Sawada, 2009).

The results using a number of different economic variables (1996, 2004 and 2014) for each weight matrix are displayed below.

Table 3: Geary's C statistics

Moran I	Spatial Contiguity Weights	k-Nearest Neighbor Weights	Radial distance = 100km radius	Inverse distance	Average
GovExp12	1.152	0.917	1.168	1.074	1.078
Pop04	1.177	0.922	1.138	1.040	1.069
Tourism13	1.174	0.922	1.141	1.040	1.069
Tourism04	1.175	0.923	1.135	1.039	1.068
Pop13	1.172	0.922	1.137	1.040	1.068
Pop96	1.167	0.922	1.136	1.039	1.066
Urban96	1.163	0.922	1.137	1.039	1.066
ShoppingSpace	1.166	0.921	1.134	1.038	1.065
GDP96	1.162	0.923	1.137	1.037	1.065
GDP04	1.162	0.923	1.136	1.036	1.064
GDP13	1.161	0.923	1.136	1.036	1.064
Urban04	1.161	0.923	1.135	1.037	1.064
Office	1.162	0.921	1.135	1.038	1.064
GOS13	1.160	0.923	1.136	1.036	1.064
Empl04	1.161	0.924	1.134	1.036	1.064
Schools	1.160	0.922	1.136	1.037	1.064
GOS04	1.159	0.924	1.136	1.036	1.064
DispInc96	1.161	0.924	1.133	1.037	1.064
GOS96	1.158	0.923	1.136	1.036	1.064
Empl13	1.160	0.924	1.134	1.036	1.063

Urban13	1.158	0.923	1.135	1.037	1.063
DispInc04	1.160	0.924	1.133	1.036	1.063
Churches	1.160	0.921	1.133	1.038	1.063
Empl96	1.158	0.924	1.134	1.036	1.063
DispInc13	1.157	0.925	1.131	1.036	1.062
Industrial	1.158	0.926	1.127	1.035	1.061
OtherRes	1.115	0.925	1.128	1.033	1.050
DwellingM	1.104	0.935	1.108	1.029	1.044
Townhouses	1.098	0.945	1.086	1.025	1.038
DwellingL	0.988	0.941	1.121	1.047	1.024
Gini13	1.034	0.995	1.046	1.010	1.021
Flats	1.013	0.932	1.103	1.027	1.019
Toilet13	1.027	1.015	0.985	0.992	1.005
Edu04	0.784	0.940	1.216	1.069	1.002
Edu96	0.772	0.942	1.214	1.061	0.997
Gini96	0.987	1.005	0.983	1.010	0.996
Edu13	0.790	0.954	1.178	1.062	0.996
Refuse13	0.956	0.990	1.021	1.009	0.994
Gini04	0.997	1.007	0.956	1.012	0.993
Incom96	0.906	0.986	1.042	1.030	0.991
Water04	0.912	0.996	1.044	1.002	0.989
Unemp96	0.981	1.004	0.972	0.995	0.988
Refuse96	0.915	0.993	0.999	1.007	0.978
House04	0.834	0.987	1.077	1.000	0.975
Water13	0.879	0.985	1.037	0.996	0.974
House96	0.839	0.982	1.058	0.998	0.969
Agri04	0.917	1.038	0.960	0.960	0.969
Unemp04	0.942	1.021	0.921	0.971	0.964
Toilet96	0.867	1.011	0.992	0.981	0.963
Agri96	0.896	1.042	0.955	0.953	0.961
Unemp13	0.933	1.020	0.915	0.973	0.960
Agri13	0.889	1.048	0.951	0.948	0.959
Incom04	0.776	1.002	1.034	1.003	0.954
Water96	0.783	1.035	0.976	0.953	0.937
Elec04	0.755	1.016	1.012	0.963	0.936
House13	0.743	1.037	0.985	0.967	0.933
Elec96	0.758	1.018	0.992	0.960	0.932
Elec13	0.768	1.044	0.944	0.943	0.924
PerCap13	0.752	1.025	0.952	0.932	0.915
PerCap96	0.719	1.019	0.969	0.926	0.908
PerCap04	0.722	1.035	0.924	0.921	0.900
Incom13	0.652	1.056	0.882	0.905	0.874
Man96	0.575	1.031	0.947	0.904	0.864
Man13	0.564	1.024	0.953	0.905	0.862
Man04	0.553	1.031	0.939	0.893	0.854

The summary statistics are displayed in the table below:

Table 2: Geary's C statistics – Summary statistics

Moran I	Spatial Contiguity Weights	k-Nearest Neighbor Weights	Radial distance = 100km radius	Inverse distance	Average
Average	0.980	0.969	1.063	1.006	1.005
Median	0.997	0.945	1.103	1.029	1.005
St Dev	0.187	0.048	0.087	0.045	0.063
Min	0.553	0.917	0.882	0.893	0.854
Max	1.177	1.056	1.216	1.074	1.078
>1	32	23	43	43	34
<1	33	42	22	22	31

There don't seem to be large differences between the four weight matrices, i.e., the average Geary C statistics being 0.98 using the spatial contiguity weight matrix versus 1.06 using the radial distance weight matrix. It's also interesting to note that the vast majority of the Geary C statistics are close to 1, i.e., spatial randomness. Overall there are more less than 1 Geary C statistics (34) than more than 1 Geary C statistic (31). However, it does seem that the Geary C statistic of many of the variables have decreased (positive spatial autocorrelation) over the period. Manufacturing had the lowest average Geary C statistic (0.854) whilst provincial government expenditure had the highest average Geary C statistic (1.078).

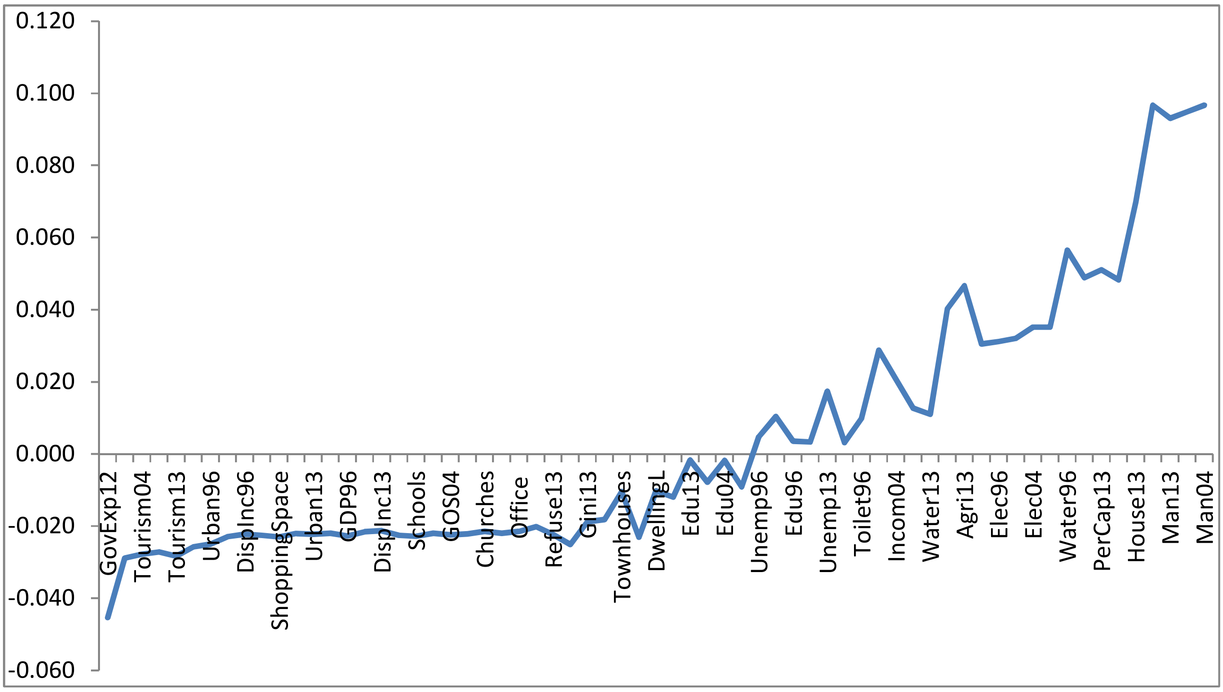
The results of the Geary C statistics support the results of the Moran I statistics, i.e., the economic outcomes/indicators from a particular region have been very much autonomous or independently generated from a provincial spatial point of view.

Comparison of Moran's I and Geary's C

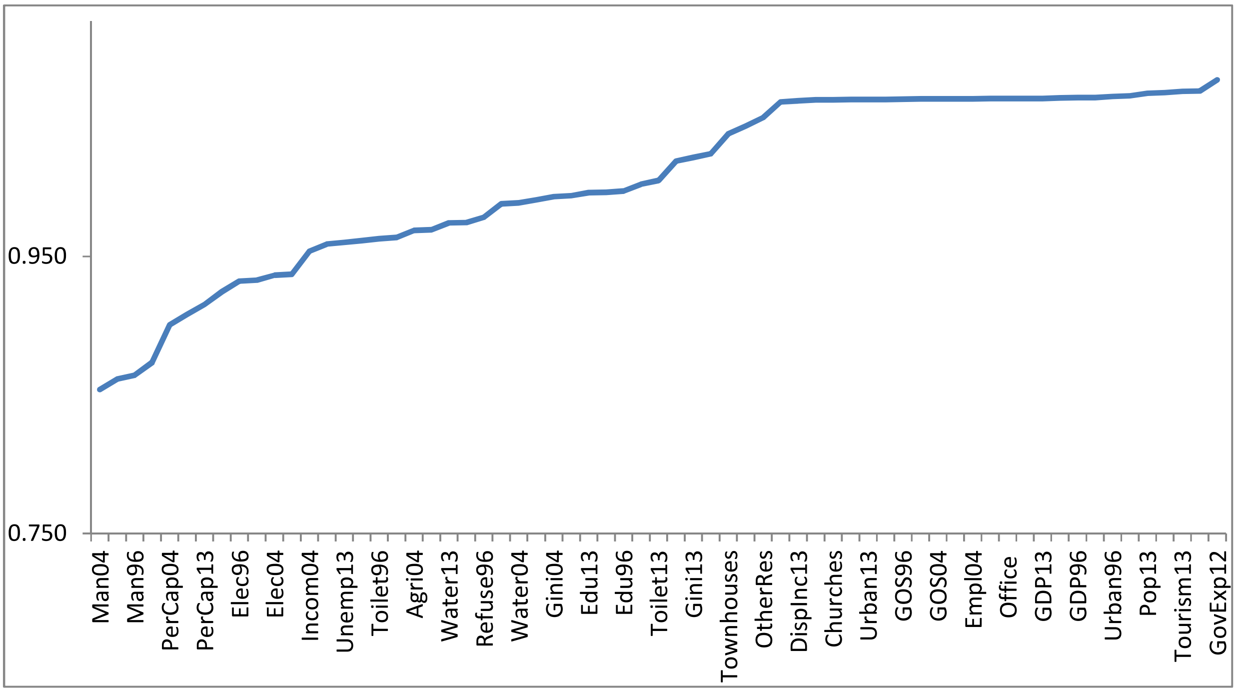
Griffith (1987) notes that simulation experiments suggest that the inverse relationship between Moran's I and Geary's C is basically linear in nature. Departures from linearity are ascribed to differences in what each of the two indices measure, that is, Geary's C deals with paired comparisons and Moran's I with covariations (Sawada, 2009).

Graph 1 display the average (of the four weight matrices) Moran's I statistic for the 65 economic variables. The values are ranked from smallest to largest. Graph 2 display the average (of the four weight matrices) Geary's C statistic for the 65 economic variables. The values are also ranked from smallest to largest.

Graph 1: Average (of the four weight matrices) Moran's I statistic for 65 statistics

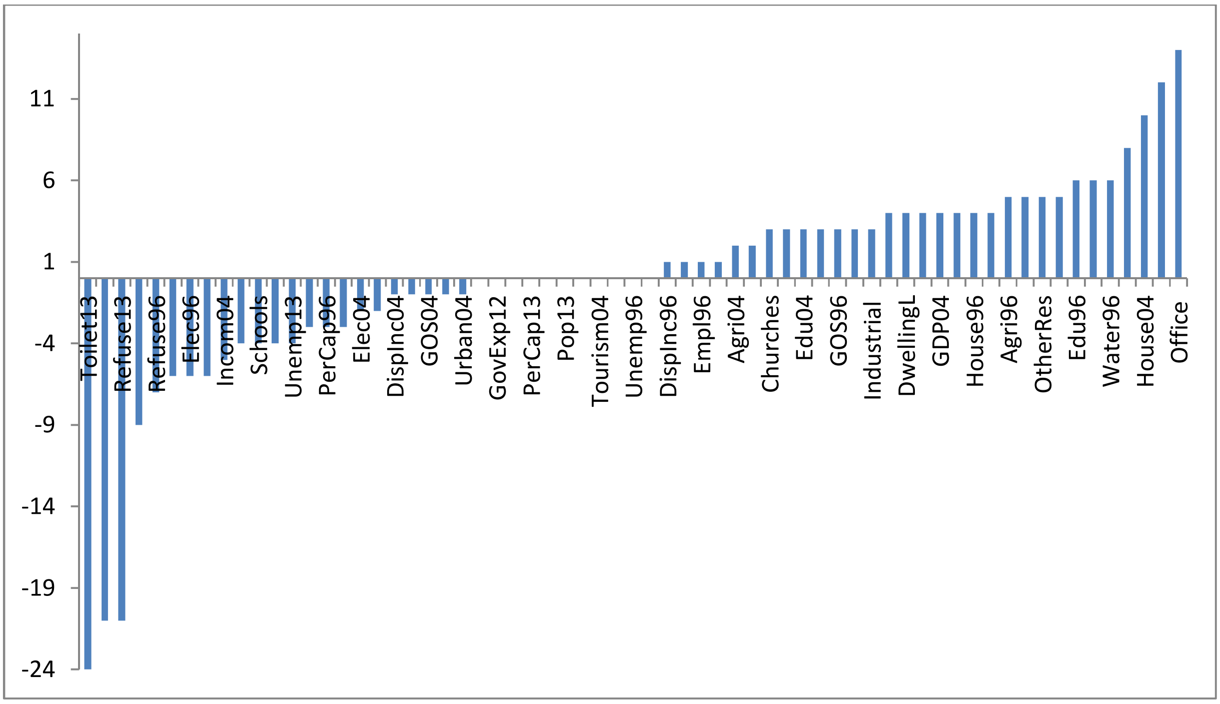


Graph 2: Average (of the four weight matrices) Geary's C statistic for 65 statistics



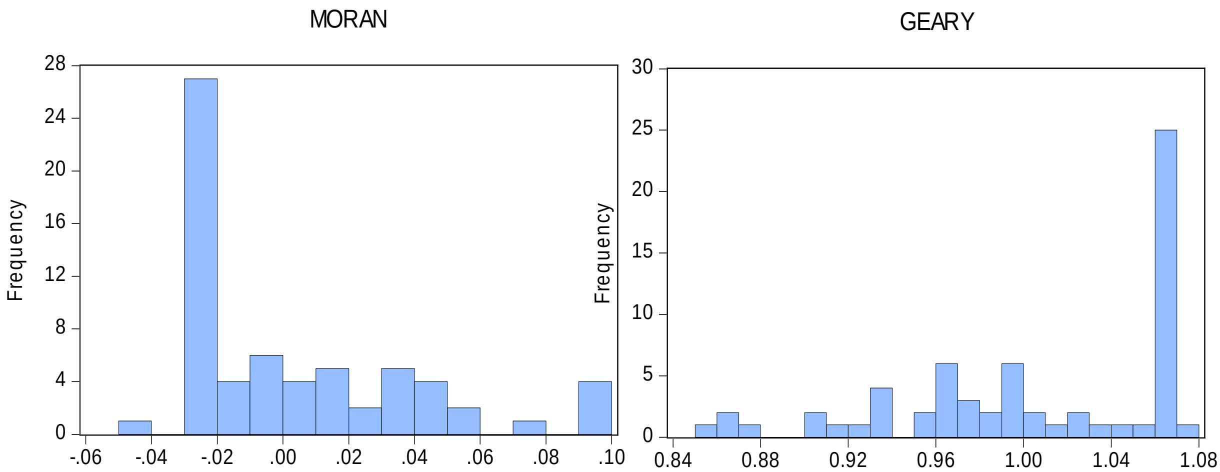
Graph 3 displays the rank difference for each of the 65 economic variables, i.e., the Moran I statistic and Geary's C statistic were ranked (smallest to largest and largest to smallest) for the 65 economic variables and the difference in rank was calculated for each economic variable.

Graph 3: Rank Difference (Moran I rank vs Geary's C rank) for 65 statistics



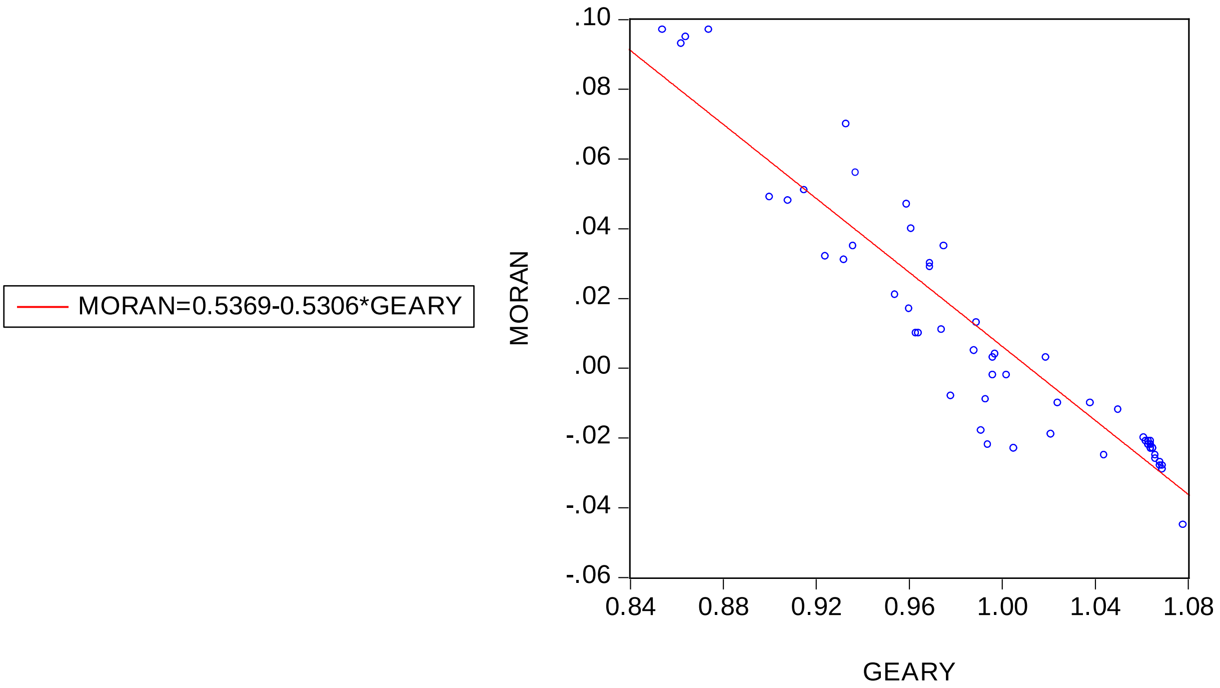
The ranked correlation coefficient is -0.94, i.e., inverse and very strong as expected. The Moran I and Geary C histograms are displayed in the exhibit below. It essentially indicates that distribution of the Moran I and Geary C statistics suggests no-spatial autocorrelation or spatial randomness.

Exhibit 1: Moran I and Geary C histograms for 65 statistics



Graph 4 suggests that the relation between Moran's I and Geary's C is linear and either statistic will essentially capture the same aspects of spatial autocorrelation.

Graph 4: Relation between Moran's I and Geary's C for 65 statistics



The adjusted R is estimated at 0.88 and the t-statistics is estimated at -21.9.

Spatial Significance

The below table suggests that its only Manufacturing that has a statistically significant Moran I statistics from the included economic variables. It is therefore possible to argue that the province has experienced very little if any spatial autocorrelation.

Table 3: Test of Statistical Significance

	Moran I	p-value
Population 1996	-0.044	0.16
Population 2013	-0.042	0.22
GDP 1996	-0.025	0.39
GDP 2013	-0.022	0.48
GINI 1996	0.03	0.28
GINI 2013	-0.032	0.43

Education 1996	0.087	0.1
Education 2013	0.052	0.17
Employment 1996	-0.025	0.48
Employment 2013	-0.026	0.49
Disposable Income 1996	-0.028	0.41
Disposable Income 2013	-0.023	0.47
GOS 1996	-0.021	0.46
GOS 2013	-0.02	0.43
Manufacturing 2013*	0.42	0.01
Agriculture 2013	0.099	0.11
Provincial Government Expenditure per Capita 2012	-0.045	0.4
Municipal CAPEX per Capita 2013	0.027	0.23

(* statistically significant at 5%)

Summary and Conclusions

Spatial statistics are used to analyse data which have a spatial location. Spatial statistics give explicit consideration to spatial properties like location, spatial patterns, spatial arrangement, distance etc. This spatial dimension tends to make spatial statistics more complex than 'ordinary' non-spatial statistics.

It is suggested that spatial phenomena often exhibit a high degree of spatial correlation, i.e., sample data collected for regions or points in space are not independent, but rather spatially dependent, which means that observations from one location tend to exhibit values similar to those from nearby locations.

The aim of this paper was therefore to test the hypothesis of spatial correlation using four different weight matrices. The Moran I and Geary C methods were applied to 65 economic variables to estimate the levels of spatial correlation in the province.

The results suggest that the province has experienced very little (if any at all) spatial correlation from 1996 to 2013. The results strongly suggest spatial heterogeneity. However the results also suggest that concentration/dependence levels in the province have increased especially around the coastal regions.

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