Urban Design

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Abstract

This paper gives an exploratory description of the regional growth pattern in Sweden during the period 1981-1999. The main issue is to test the hypothesis that municipalities with high average income growth rates are more spatially clustered than could be caused by pure chance. The paper is purely descriptive where we make use of two statistical tests for spatial correlation as well as maps to identify what we reefer to as 'regional Hot Spots'. Irrespective of the definition of neighbors, our results support, at the 95-percent level of significance, the hypothesis that municipalities with similar average growth rates are more clustered than could be expected from pure chance. In particular, regional Hot Spots are found near the major city of Stockholm and in the Gislaved/Gnosjö region.

Keywords: Regional growth, Spatial autocorrelation, Moran's I, New G_i^*-statistic

JEL classification: O15, O18, R11.

1. Introduction

This paper concern spatial clusters of average income growth rates at the local level of government in Sweden during the period 1981-1999. The main purpose is to identify what we refer to as Hot Spots. That is, to test the hypothesis that municipalities with high average income growth rates are more spatially clustered than would be expected from merely a coincidence. The analysis of average income growth is motivated from a local public finance perspective, as local income taxes constitute the major source of funds for the Swedish municipalities. Hence, changes in average income levels is one component[1] of the local tax base that, in turn, affect the local public sector's ability to provide services imposed on them by the central government. The analysis is based on two commonly used test statistics for spatial cluster, the Moran's I and the new $G_i^*(d)$-statistic proposed by Ord and Getis (1995). These two test statistics complement each other and are, according to Ord and Getis, preferably used in combination. The Moran's I is a global test for spatial correlation and tells us if high or low values are more clustered than would be expected by pure chance (positive spatial correlation). If the Moran's I reveals a negative spatial correlation, the data is organized as a checkerboard pattern. The new $G_i^*(d)$-statistic, which is a local test for spatial correlation, complement the Moran's I in at least two ways: 1) it reveals if there is a cluster of high or low values, not only that there is a cluster of similar values, and 2) it reveals where these clusters are located. Hence, the combination of these two tests may deepen the analysis in that the new $G_i^*(d)$-statistic may show local patterns that are not detected by the Moran's I.

Before we proceed, let us discuss some stylized facts regarding the regional growth pattern in

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[1] The other component relates to population growth and the age distribution.

Sweden. During the last decades, there has been a tendency that individuals move from the sparsely populated areas in the northern and middle western parts of the country to more densely populated areas, preferably the major cities and university towns. At the same time, the local public sector, which is mainly financed through a local personal income tax, has expanded quite dramatically both in terms of expenditures per capita and in local income tax rates.[2] This expansion has mainly been driven by decisions made at the national level of government as they has to an increasing extent delegated and also imposed new obligations on the local public authorities. The combination of a receding population base and an expanding local public sector may put a lot of economic stress on local public governments. However, this effect could be neutralized by a higher average income growth.

Much of the empirical literature on regional growth has taken the so-called convergence hypothesis as point of departure, e.g. that initially 'poor' regions tend to grow faster and eventually catch up with 'richer' regions. This hypothesis is predicted by neoclassical growth theory as presented by Solow (1956) and Swan (1956). For instance, Barro and Sala-i-Martin (1992, 1995) find support for the convergence hypothesis for the U.S. states. In an application using data on Swedish counties, Persson (1997) reports similar results. However, some authors have taken the lack of convergence as evidence against the neoclassical growth model; see for instance Romer (1986) and Lucas (1988). Still other studies has focused attention on a broader set of possible determinants of regional growth, such as human capital, labor market characteristics, local public expenditures and investments, intergovernmental grants, demographic characteristics and measures of political stability and leadership. One example is Aronsson *et al.* (2001) who, besides convergence, also find labor market characteristics to be important factors of regional growth in Sweden. Using data on Swedish municipalities during the period 1981-1990, Lundberg (2003a) finds, in addition to support for the convergence hypothesis, local public expenditures and income tax rates to be important determinants of average income growth and net migration. The spatial pattern of regional growth has recently achieved quite much attention; see for instance Nijkamp and Poot (1998), Bal and Nijkamp (1998), Rey and Montouri (1999), Wheeler (2001) and Lundberg (2003b).

This paper complements previous studies of average income growth using Swedish data in that we do not try to explain the causes of regional growth. Instead, this paper focus attention on which regions that has experienced a relatively large average income growth and to what extent these regions are more spatially clustered than could be expected from pure chance. In addition, we consider the importance of the specification of neighbors, an issue that we often find neglected, or at least not sufficiently discussed in previous papers which makes use of spatial econometric methods or tests for spatial correlation. Therefore, we make use of a large set of different and, as we regard, from a theoretical perspective reasonable definitions of neighbors based on traveling time by car between municipal centers and on the criterion that the municipalities share a common border. The purpose

[2] The local income tax rate has increased from an average of 16.68-percent in 1981 to 20.55-percent in 1999. During the same period, the average income level has, measured in 1999 money value, increased from 130 000 SEK to 184 000 SEK. The local public expenditures has increased from 35 000 SEK in 1981 to 44 000 SEK per capita in 1996.

is to analyze if, and if, to what extent the results differ depending on the weights matrix used.

The remaining of this paper is organized as follows. The two test statistics used, the Moran's I and the new $G_i^*(d)$-statistic, are described in Section 2. The data set used and definitions of the concept 'neighbors', e.g. the definition of the different weights matrices are discussed in Section 3. This section is followed by the empirical results presented in Section 4. Concluding remarks are given in Section 5.

2. Statistical tests for spatial correlation

2.1. Moran's I

The Moran's I, which builds on the work by Moran (1948), is probably the most frequently used test for spatial correlation. This test statistic has been generalized by Cliff and Ord (1972) in order to derive a test for spatial correlation in linear regression models. Burridge (1980) demonstrated that the Moran's I test statistic is equivalent to a Lagrange multiplier test statistic derived from a linear regression model without a spatial lag. Its large sample properties and asymptotics have recently been analyzed by Pinkse (1999) and Keleijan and Prucha (2001).

Consider a data set on average income growth rates (y) covering n Swedish municipalities. Assume that $\mathbf{W}$ is a weighting matrix of dimension $(n \times n)$ whose elements assigns the neighbors to each municipality. The weighting matrices used here can be characterized as $\mathbf{W} = \{w_{ij}\}$ such that $0 < w_{ij} \leq 1 \; \forall \; i \neq j$ if i and j are neighbors, otherwise $w_{ij} = 0$. Note that $w_{ii} = 0$. Using row-standardized weights, which is the preferable way of interpreting this test, $\sum W_i = 1$. Then, the Moran's I is calculated as

$$I = \sum_i \sum_j w_{ij} \left(y_i - \mu\right) \left(y_j - \mu\right) \times \frac{1}{\sum_i \left(y_i - \mu\right)^2} \tag{1}$$

where y_i and y_j are observations for locations i and j with mean μ. The test statistic is compared with its theoretical mean, $E\left(I\right) = -1/\left(n-1\right)$, where $E\left(I\right) \to 0$ as $n \to \infty$. The null hypothesis $H_0 : I = -1/\left(n-1\right)$ is tested against the alternative $H_a : I \neq -1/\left(n-1\right)$. If H_0 is rejected then there are two alternative interpretations depending on whether the test statistic I is significantly larger or lower than its expected value. If H_0 is rejected and $I > -1/\left(n-1\right)$, this indicates a positive spatial correlation meaning that municipalities with similar values are more spatially clustered than could be caused by chance. If H_0 is rejected and $I < -1/\left(n-1\right)$ this indicates a negative spatial correlation, municipalities with high and low values are mixed together. A perfect negative spatial correlation is characterized by a checkerboard pattern of high and low values. As the test statistic is to be compared to its theoretical mean, inferences is often based on the z-statistic

$$z = \left[I - E\left(I\right)\right] / SD\left(I\right) \tag{2}$$

where $SD(I)$ is the theoretical standard deviation of I. If $z > |2.57|$, I is at the 99-percent level of significance different from $-1/(n-1)$ indicating either a negative or a positive spatial correlation.[3]

2.2. *The new $G_i^*(d)$-statistic*

The other test for spatial correlation to be used here is the new $G_i^*(d)$-statistics developed by Ord and Getis (1995) which build on the 'old' $G_i^*(d)$-statistics suggested by Getis and Ord (1992). Like the Moran's I, the basic idea behind this test is to define a set of neighbors for each municipality, i.e. municipalities that fall within a specified distance, d, from the municipality in which we are interested. The new $G_i^*(d)$-statistic then indicates whether a particular municipality is surrounded by a cluster of other municipalities with equivalent growth rates. Hence, a test statistic is computed for each location, in our case for each municipality. The new $G_i^*(d)$-statistic differ from the 'old' version in that the new $G_i^*(d)$-statistic allow for nonbinary weights and the weights matrix do not necessarily have to be symmetric. In addition, the new $G_i^*(d)$-statistic differ from the new $G_i(d)$-statistic in that y_i is included in the calculation of the new $G_i^*(d)$.

To be more specific, the new $G_i^*(d)$-statistic is calculated as

$$G_i^*(d) = \frac{\sum_j w_{ij} y_j - (W_i + w_{ii})\,\mu}{s\left\{\left[\left(\left(n\sum_j w_{ij}^2 - (W_i + w_{ii})^2\right)/(n-1)\right)\right]\right\}^{1/2}}, \text{for all } j \tag{3}$$

where s is the standard deviation of y. Here $H_0 : G_i^*(d) = 0$ is tested against the alternative $H_a : G_i^*(d) \neq 0$ where H_0 is the absence of spatial clustering. If H_0 is rejected, two possible interpretations arise. A positive and significant test statistic indicates that other municipalities with high growth rates surround the municipality, a negative and significant test statistic indicates the opposite while $G_i^*(d) = 0$ indicate no spatial correlation. Assuming that $G_i^*(d)$ is approximately normally distributed, inferences is often based on the z_i-statistic

$$z_i = \frac{\{G_i^*(d) - E[G_i^*(d)]\}}{\sqrt{Var\ G_i^*(d)}} \tag{4}$$

If $z > |2.57|$, the particular municipality i is at the 99-percent level of significance surrounded by other municipalities with either high $(z > 0)$ or low $(z < 0)$ average income growth rates.

3. Data and definition of neighbors

3.1. *Data*

The data set used in this study originates from two sources. Information on average income growth is based on the official statistics provided by Statistics Sweden and refers to the Swedish municipalities during the period 1981-1999. During this period, the number of municipalities varied between 279 in

[3] Most commonly, the 95-percent level of significance is used to evaluate the significance of econometric test statistics. However, as we will later use the 99-percent level of significance when calculating the new $G_i^*(d)$-statistics in order to single out the most significant regions, we use the same level of significance when evaluating the Moran's I.

1981 and 288 in 1999. Those municipalities whose borders have been changed during this period are excluded from the analysis. The reason is that it is difficult to obtain comparable data on average income growth for those municipalities. In addition, the municipality of Gotland is excluded due to the fact that there is no road connection between Gotland and the main land. This leaves us with a data set covering 269 Swedish municipalities and their average income growth rates during the period 1981-1999. The growth rate of the average income level is calculated as $y_i = \ln(Y_{i,t}/Y_{i,t-T})$ where Y is the average income level for the subpopulation aged 20 or above.

The exclusion of some municipalities from the analysis is unfortunate, as it will automatically induce spatial 'holes' in the data set. We are aware of this problem. Yet, instead of manipulating the data and try to construct comparable figures for these municipalities we choose to exclude them from the analysis. In addition, on average, the municipalities excluded from the analysis are quite small both in geographic and population terms.

The weighting matrices used are based on the travel time by car between municipal centers. This information has been provided by The Swedish Road Administration and is based on the road network and speed limits in 1985. Descriptive statistics are presented in Table 1. To clarify Table 1, the average income growth has on average been 42-percent during this period and the average traveling time between municipal centers are 330.74 minutes, or 5 hours and 30 minutes.

Table 1. Descriptive statistics.

Variable	Mean	Standard deviation	Min	Max
y_i	1.42	0.08	1.25	2.06
w_{ij}	330.74	-	5.87	1 212.00

3.2. Definition of neighbors

One of the more crucial and delicate problems in most empirical studies where the spatial dimension in the data is an issue is the specification of the weights matrix, here denoted $\mathbf{W}$. As, in this case, $\mathbf{W}$ is an $n \times n$ matrix it is not possible, or at least in most cases very difficult, to estimate its elements. This means that the elements in $\mathbf{W}$ have to be specified a priori from some criteria. The definition of the elements in $\mathbf{W}$ is of great importance as $\mathbf{W}$ may be crucial for the results. So, the question is which municipalities are to be considered as neighbors and, if they are, are some neighbors to be considered as more closely related than others?

As we focus attention on geographical clusters, it seems natural to base the definition of neighbors on some geographical criteria.[4] One obvious definition of neighbors is municipalities that share a common border. However, consider the situation where municipality i border on j and k, and l border on k while neither i nor j. There are no roads directly connecting i and j while there is a

[4] Closeness could of course also be based on distance in population size, local public expenditures, local income taxes etc.

highway connecting i and k. Should i and j be regarded as close neighbors as i and k? Should i and j be considered as neighbors at all? Furthermore, assume that you are traveling by car and have to pass through k to get from i to j. This trip takes 30 minutes. Instead, if you are to take the car between i and l it takes 20 minutes even though i and l do not share a common border. Then, are i and l to be considered as more closely related compared to i and j?

Using a large set of different weights matrices reduces the risk for misinterpretations due to the fact that the weights matrix is incorrectly specified. In the following, we elaborate with 14 different weights matrices where the definition of neighbors are based on two criteria; 1) two municipalities who share a common border, or 2) the traveling time by car between municipal centers. To be more specific, the weights matrices used here are row-standardized and could be grouped into five different categories:

1. $\mathbf{W1}, \mathbf{W2}, \mathbf{W5}, \mathbf{W10}$: These weights matrices are based on the traveling time by car between municipal centers. Neighbors are defined as the nearest ($\mathbf{W1}$), the two nearest ($\mathbf{W2}$), the five nearest ($\mathbf{W5}$) and the 10 nearest ($\mathbf{W10}$) municipalities respectively. Binary weights where each municipality are assigned the same number of neighbors.

2. **WInv**: The elements in $\mathbf{W}$ are defined as $w_{ij} = 1/d_{ij}$ where d_{ij} is the traveling time by car between municipalities i and j. Each municipality is assigned the same number of neighbors.

3. **WB**: Neighbors are defined as those municipalities who share a common border. Binary weights.

4. **WBin30**, **WBin45**, **WBin60**, **WBin75**: Neighbors are defined as those municipalities located within the range of 30 (**WBin30**), 45 (**WBin45**), 60 (**WBin60**) and 75 (**WBin75**) minutes travel time by car. Binary weights.

5. **WInv30**, **WInv45**, **WInv60**, **WInv75**: The elements in $\mathbf{W}$ are defined as $w_{ij} = 1/d_{ij}$ where d_{ij} is the traveling time by car between municipalities i and j with cut off values of 30 (**WInv30**), 45 (**WInv45**), 60 (**WInv60**) and 75 (**WInv75**) minutes respectively.

Many of the Swedish municipalities, especially those located in the very north of the country, could be characterized as very large and sparsely populated where the majority of the inhabitants live in the center of the municipality. In some cases, the traveling time by car to the nearest municipality is longer than 75 minutes. Consequently, when using the definitions of neighbors corresponding to categories 4 and 5 some municipalities are not assigned any neighbors which means that neither the Moran's I nor the new $G_i^*(d)$-statistic could reveal any spatial clusters within these areas. However, the use of the matrices defined under categories 4 and 5 may reveal a different pattern within the regions where the traveling time between municipal centers are less than 30, 45, 60 or 75 minutes respectively, compared to the results using categories 1, 2 and 3. Descriptive statistics of the elements in the different weights matrices are presented in Table 2.

Table 2. Descriptive statistics of the elements in the W matrices.

Weights matrix	Mean	Min	Max	Weights matrix	Mean	Min	Max
$W1$	1.00	0.00	1.00	WB	0.21	0.10	1.00
$W2$	0.50	0.00	0.50	$WInv$	0.00	0.00	0.02
$W5$	0.20	0.00	0.20				
$W10$	0.10	0.00	0.10				
$WBin30$	0.27	0.06	1.00	$WInv30$	0.05	0.03	0.17
$WBin45$	0.16	0.05	1.00	$WInv45$	0.04	0.02	0.17
$WBin60$	0.10	0.04	1.00	$WInv60$	0.03	0.02	0.17
$WBin75$	0.07	0.03	1.00	$WInv75$	0.02	0.01	0.17

4. Results

4.1. Moran's I

If the variable that is to be tested follows a normal distribution, the Moran's I-statistic is compared with its theoretical mean, $-1/(n-1)$. However, if this is not the case, the reference distribution for the Moran's I should be generated empirically. This is done by randomly reshu- ing the observed values over all locations. A Wald test statistic of 3 238 with 2 degrees of freedom reveals non-normality in the variable y.[5] Consequently, the reference distribution of the Moran's I is generated using the permutation approach.

The z-value for the Moran's I for different weighting matrices are presented in Table 3. With two exceptions (**WBin30** and **WBin45**), the results suggest a positive and at the 99-percent level significant spatial correlation indicating that high and low values are spatially clustered. However, using the weights matrices **WBin30** and **WBin45**, the Moran's I is significant at the conventional 95-percent level of significance. What differs is the level of significance, which, with one exception (**W5**), tend to increase with the number of neighbors assigned to each municipality.

[5]The Wald statistic is χ^2-distributed and calculated as $W = n\left[b_1^2/6 + (b_2-3)^2/24\right]$ where $b_1 = (1/n)\sum_i (y_i-\mu)^3 / \left(\sigma^2\right)^{3/2}$ (skewness), $b_2 = (1/n)\sum_i (y_i-\mu)^4 / \left(\sigma^2\right)^2$ (kurtosis) and σ is the standard deviation of y.

Table 3. Moran's I

Weights matrix	z-value	Mean	Weights matrix	z-value	Mean
$W1$	3.20	-0.018	WB	6.31	-0.009
$W2$	4.87	-0.011	$WInv$	7.84	-0.004
$W5$	4.54	-0.006			
$W10$	6.67	-0.005			
$WBin30$	2.26	-0.006	$WInv30$	2.60	-0.006
$WBin45$	2.40	-0.009	$WInv45$	2.62	-0.010
$WBin60$	2.84	-0.006	$WInv60$	3.27	-0.007
$WBin75$	3.94	-0.007	$WInv75$	4.24	-0.008

From the results presented in Table 3 above, we conclude that there exists a positive spatial correlation indicating that municipalities with similar average income growth rates are more spatially clustered than could be expected from pure chance. Using the conventional level of significance of 95-percent, we also conclude that this result holds irrespective of the choice of weights matrix. However, the Moran's I give no guidance regarding if these clusters consist of municipalities with high or low average income growth rates.

4.2. The new $G_i^*(d)$-statistic

In order to make the results from the new $G_i^*(d)$-statistic easier to overview and interpret, they are presented in map-form. Regions marked dark blue indicate significant clusters (at the 99-percent level of significance) of municipalities with low average income growth rates, while regions marked dark red indicate significant clusters (also at the 99-percent level of significance) of municipalities with high average income growth rates, so called Hot Spots. The colors light blue and light red indicate non-significant clusters of low and high average income growth rates respectively and those municipalities excluded from the analysis are marked in white.

Let us go through the maps and discuss how the clustering pattern change as we elaborate with different weights matrices. Figure 1 shows the results based on the weights matrix **W1**, which is based on traveling distance by car between municipality centers where each municipality is only assigned one neighbor, the nearest one.

Using this definition of neighbors, a significant cluster of municipalities with high average income growth rates are found in the Stockholm region only (Täby, Danderyd and Lidingö). Among these three municipalities, Täby have also experienced a relatively large in migration during this period, which indicate that Täby is attractive to migrants, which is also positive from the perspective of being able to finance local public services through the local income tax.[6] However, Figure 1 does not display

[6] Lidingö and Danderyd have experienced a negative net migration during this period, which in part could be one of the explanations for their high average income growth rates if those with relatively low average income levels tend to move out from these municipalities.

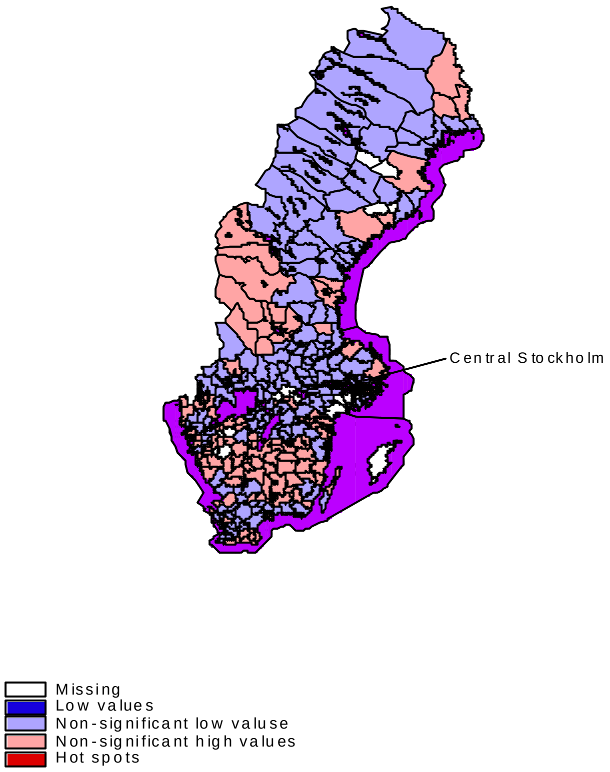

Figure 1: Regional disparities in new G*-statistic using weights matrix **W1**.

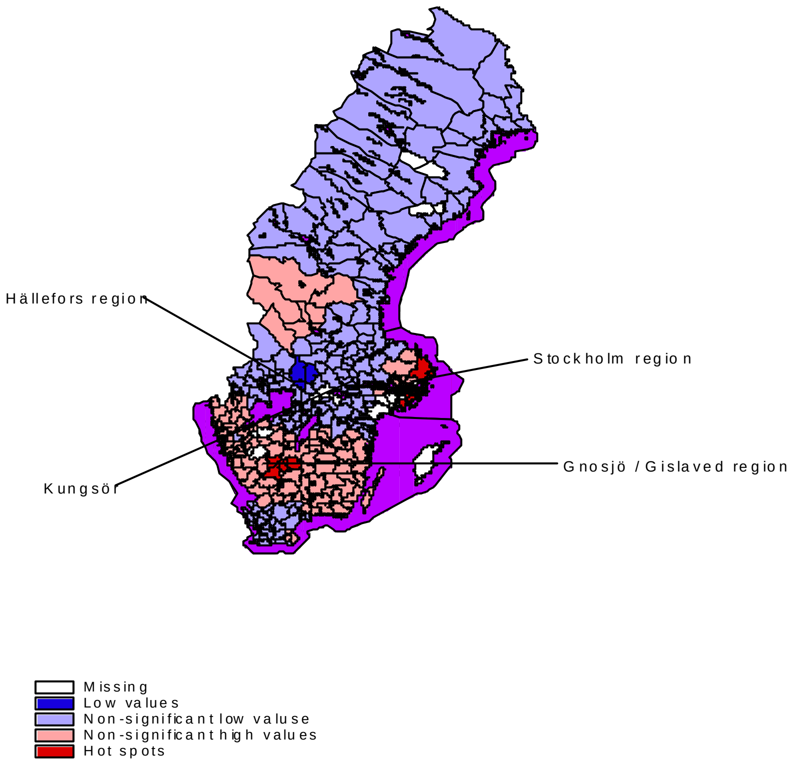

Figure 2: Regional disparities in new G*-statistic using weights matrix **W10**.

any significant clusters of municipalities with low average income growth rates.

Expanding the definition of neighbors to include the two and five nearest municipalities makes little difference. We still find a cluster of high average income growth rates in the Stockholm region. Therefore, and in order to save some space, these two maps are excluded. When the definition of neighbors are expanded to include the 10 nearest municipalities, our results suggest regional Hot Spots in the regions of Stockholm and Gnosjö/Gislaved (which also include the municipalities Tranemo and Vaggeryd), a region with a net migration rate close to zero. Compared to Figure 1, the cluster of municipalities with high average income growth rates in the Stockholm region has now expended to include 14 municipalities. In addition, Figure 2 also displays two clusters of municipalities with low average income growth rates, the Hällefors region (also including Filipstad and Storfors) and Kungsör. These municipalities have during the same period faced a decline in population due to net migration only ranging from 10 to 14-percent.

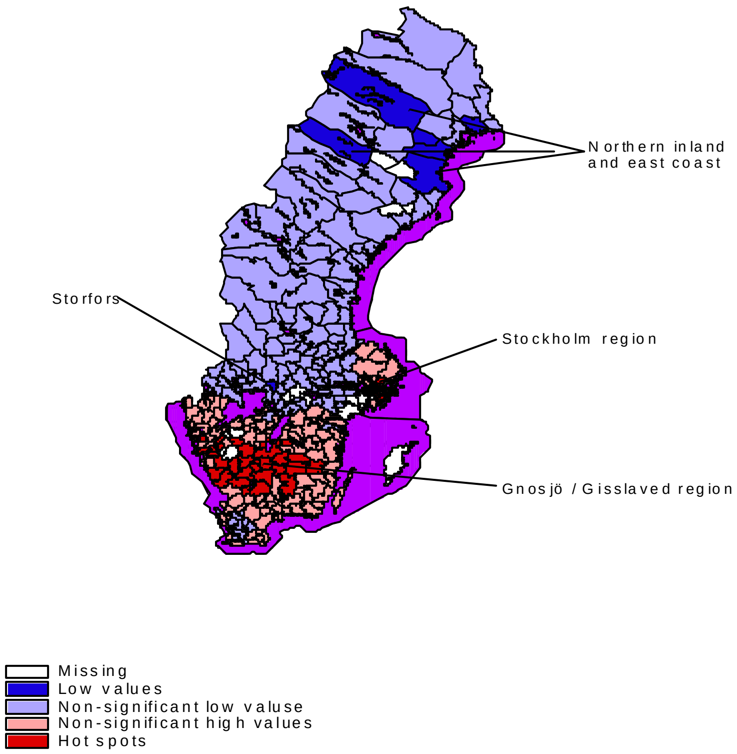

Figure 3: Regional disparities in new G*-statistic using weights matrix **WInv**.

The number of municipalities included in the cluster of high average income growth rates in the Gnosjö/Gislaved region expand quite dramatically when using weights matrix **WInv** where the elements w_{ij} are defined as $w_{ij} = 1/d_{ij}$, where d_{ij} is the traveling time by car between municipalities i and j. The Hot Spot detected in the Stockholm region in Figure 2 has now decreased to include 12 municipalities. At the same time, the significant pattern of a cluster with low average income growth rates in the Hällefors region has now declined to only include the municipality of Storfors. Now we also find a significant cluster of low average income growth rates in the northern inland and along the northern east coast.

The results presented in Figure 1, 2 and 3 are based on weights matrices where each municipality is assigned the same number of neighbors. Let us now turn to results where the number of neighbors assigned may differ between municipalities. The results presented in Figure 4 are based on the weights matrix **WB**, e.g. neighbors are defined as those municipalities who share a common border. Again,

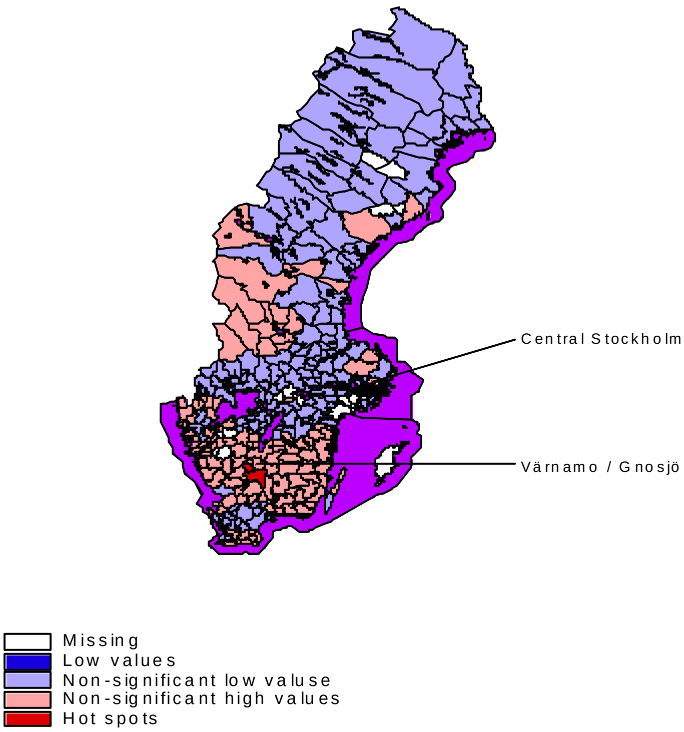

Figure 4: Regional disparities in new G*-statistic using weights matrix **WB**.

there is a cluster of municipalities with high average income growth rates in the Stockholm and Gnosjö regions, while we find no significant cluster of municipalities with low average income growth rates.

The results using the weight matrices **WInv30** and **WInv75** are shown in Figure 5 and 6. As these results were very similar to those using **WBin30** and **WBin75**, those figures are left out in order to save space. In addition, the results from using the matrices **WBin45**, **WBin60**, **WInv45** and **WInv60** lies somewhere in between **WInv30** and **WInv75** and are therefore, for the same reason, left out from this presentation.

Municipalities that are not assigned a neighbor in Figure 5 and 6 are marked in light green. Here, pretty much the same pattern emerge as in Figure 1 and 4. Figure 5 display clusters of high average income growth rates in the Stockholm region and for Gnosjö. When the definition of neighbors are extended to include those municipalities located within a traveling time of 75 minutes, shown in Figure 6, the number of municipalities that fall in the group of Hot Spots in the Stockholm and Gnosjö regions

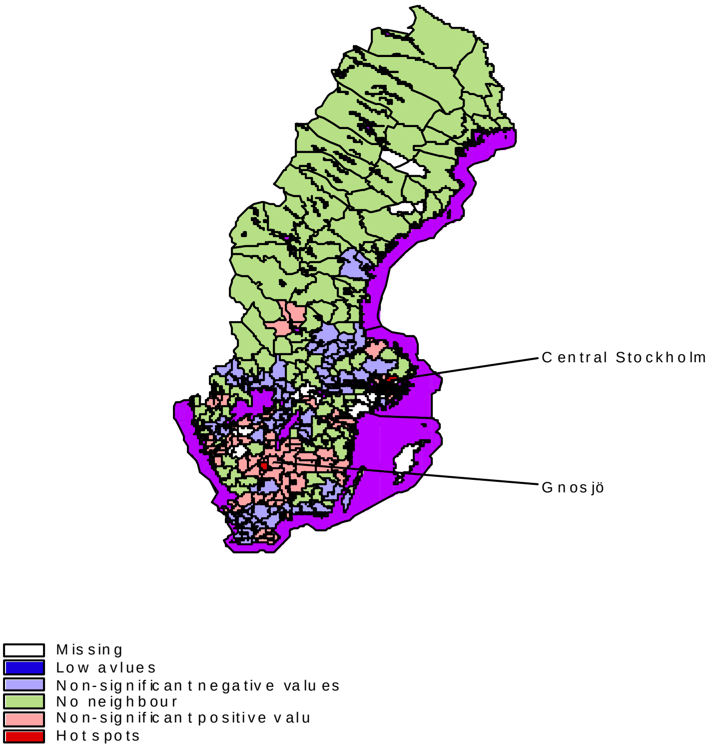

Figure 5: Regional disparities in new G*-statistic using weights matrix **WInv30**.

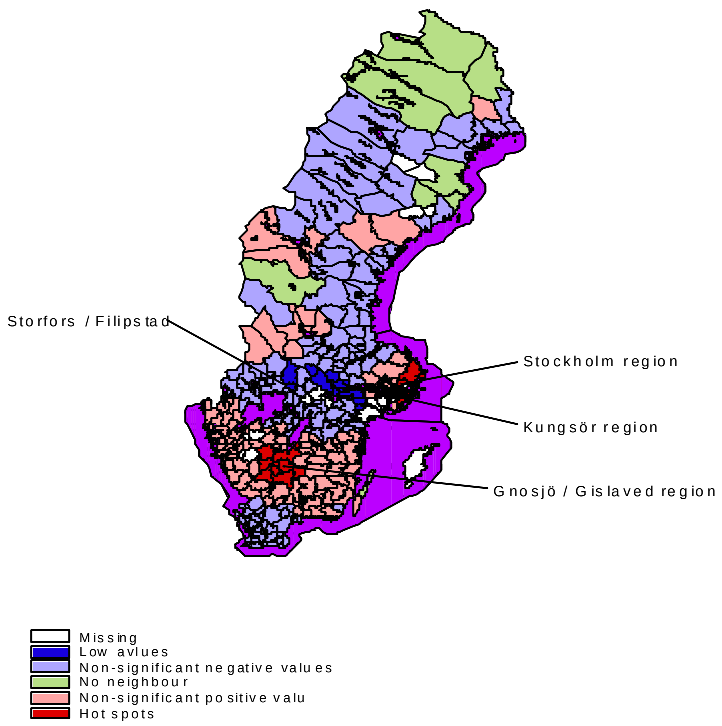

Figure 6: Regional disparities in new G*-statistic using weights matrix **WInv75**.

increase.

Our results differ somewhat depending on the definition of neighbors used (e.g. which weights matrix used). As the number of neighbors assigned to each municipality increases, the number of municipalities being part of a cluster of high or low average income growth rates increase. This result could be driven by the fact that there are a small number of municipalities with extreme values. As these municipalities become part of larger set of neighbors, they also affect the new $G_i^*(d)$-statistic for a larger set of municipalities. This reasoning suggests that some of the significant values might be caused by a few extreme values. In order to evaluate this possible explanation, let us take a closer look at the growth values for the Gnosjö/Gislaved region.

When assigned only one neighbor (**W1**), Gislaved and Gnosjö are considered as neighbors to each other. The growth rates for these two municipalities fall within the top 25 for the whole country. When the number of neighbors are extended to ten (**W10**), significant high new $G_i^*(d)$-statistic are also calculated for Tranemo and Vaggeryd. Vaggeryd have experienced a high average income growth rate during this period (53-percent, which is top 18 in the country). However, Tranemo's growth rate has only been 43-percent, which is above average (42-percent, see Table 1) but only the 97th highest out of 269 municipalities. This indicate that the high significant new $G_i^*(d)$-statistic for Tranemo is driven by the fact that Tranemo is surrounded by municipalities with high average income growth rates, not unnecessarily that the average income growth rate in Tranemo is relatively high. When the definition of neighbors are extended to include municipalities within a radius of 75 minutes travel time by car (**WInv75**), even Jönköping (average income growth rate of 41-percent, 124th in country) is considered as part of a cluster of municipalities with high average income growth rates, and hence referred to as being a Hot Spot.

This rises the question of to what extent could a positive and significant value of the new $G_i^*(d)$-statistic be due to high values of its neighbors only? Consider the following situation. Assume a municipality, let it be denoted k, with a high average income growth rate during this period, a weights matrix that only assigns one neighbor to each municipality and that municipality k and l are defined as neighbors to each other. Then, how low average income growth rate could k's neighbor l have experienced during this period and still being considered as part of a cluster (together with its neighbor municipality k) with high average income growth rates. Let us give an arithmetic example using the data on Danderyd and Täby. Danderyd have experienced the highest average income growth rate during this period, 106-percent. All other growth rates constant, the average income growth rate for Täby could decrease from its actual value of 57-percent to only 7-percent and the new $G_{Täby}^*(d)$-statistic will still be significant at the 99-percent level making Täby part of a cluster of municipalities with high average income growth rates. Using the conventional 95-percent level of significance, the average income growth in Täby could actually be negative (-1-percent) and the new $G_{Täby}^*(d)$-statistic will still be positive and significant, making Täby a Hot Spot. Based on these calculations, we make the general recommendation that significant values of the new $G_i^*(d)$-statistic is complemented by an analysis of the actual values of those individuals (in our case municipalities) that are considered as neighbors.

5. Concluding remarks

The main purpose in this paper has been to test the hypothesis that municipalities with high average income growth rates are more spatially clustered than could be expected from pure chance and to what extent these results are sensitive to the definition of the spatial weights matrix. In order to accomplish this task, we make use of two commonly used test statistics for spatial correlation, the Moran's I and the new $G_i^*(d)$-statistic and a large set of plausible definitions of neighbors, that is, weights matrices. The analysis is based on a data set covering 269 Swedish municipalities and their average income growth rates during the period 1981-1999.

Based on the Moran's I, we conclude that municipalities with similar average income growth rates are more spatially clustered than could be caused by pure chance. The level of significance of the Moran's I tend to increase as the number of neighbors assigned to each municipality increases. However, the Moran's I give no guidance regarding the nature of this or these clusters, it only suggests that municipalities with either high or low average income growth rates are more spatially clustered than could be caused by pure chance. The results from the Moran's I is complemented by the new $G_i^*(d)$-statistic. Independent of the definition of neighbors, the results from the new $G_i^*(d)$-statistic suggest a spatial cluster of high average growth rates, so-called Hot Spots, in the Stockholm region. However, the results from the new $G_i^*(d)$-statistic differ some what depending on the definition of neighbors. As the number of neighbors assigned to each municipality increases, the new $G_i^*(d)$-statistic indicate an additional cluster of municipalities with high average income growth rates in the Gnosjö/Gislaved region. Moreover, when the definition is extended, the results from the new $G_i^*(d)$-statistic also suggest clusters of low average income growth rates in the Storfors region, Kungsör and the northern inland and north eastern coast.

The results presented in this paper highlight an important issue in spatial econometrics, the design of the weights matrix (or the definition of neighbors). Even thought we have used different definitions that are, at least we think so, reasonable from a theoretical perspective, the results differ quite much depending on the weights matrix used. For instance, if we in this paper had used only the weights matrix where neighbors are defined as the nearest one, the cluster of municipalities with high average income growth rates in the Gnosjö/Gislaved region has never been observed, neither had the cluster of municipalities with low average income growth rates in the regions of Hällefors, Kungsör and in the northern part of the country. Therefore, if the design of the weights matrix is not based on strong theoretical arguments, we make the general recommendation to use not only one but several different definitions of neighbors (or weights matrices) in order to test to what extent the results are sensitive to different weights matrices. This is of importance as the elements in the weights matrix in most cases are not possible to estimate together with the other parameters in the model.

Finally, our calculations suggest that a significant new $G_i^*(d)$-statistic could be driven by extreme values of individual i's neighbors. Considering the situation where the highest average income growth rate is found in municipality k, and that k is assigned only one neighbor, i. Even though the average growth rate for municipality i is the lowest in the sample, the new $G_i^*(d)$-statistic could still be significant making municipality i part of a cluster of municipalities with high average income growth rates. Therefore, in order to avoid misinterpretations of the results, we recommend significant values of the new $G_i^*(d)$-statistic to be complemented by an analysis of the actual values of individual i (in our case the municipality i) and its neighbors.

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