Schumpeter School of Business and Economics

SCHUMPETER DISCUSSION PAPERS

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The Schumpeter Discussion Papers are a publication of the Schumpeter School of Business and Economics, University of Wuppertal, Germany
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SSBEEditor@wiwi.uni-wuppertal.de

SDP 2011-002
ISSN 1867-5352

Impressum
Bergische Universiät Wuppertal
Gaußstraße 20
42119 Wuppertal
www.uni-wuppertal.de

BERGISCHE UNIVERSITÄT WUPPERTAL

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A Proposal for an Alternative Spatial Weight Matrix under Consideration of the Distribution of Economic Activity

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Wuppertal, January 2011

JEL: R11, R15

Keywords: Russian Federation, Spillovers, Spatial Econometrics, Spatial Weights

Abstract

In economic geography all indicators and studies are based in one way or another on a measure of distances between two points of interest. The present study discusses the problems that arise in the course of calculating distances between regions. It is shown that measures presently in use are usually biased. A new measuring concept is therefore presented that takes into account the regional economic or demographic structures and constructs distances between regions accordingly.

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Acknowledegments

The author would like to thank Mr. Paul J.J. Welfens for helpful comments and technical support.

1 Introduction

> Everything is related to everything else, but near things are more related than distant things.
> *Waldo Tobler*

The first law or basic principle of geography states the importance of distance in geography and therefore economic geography as well. Especially in spatial econometrics distances play an important role. The establishment of cluster initiatives as well as the level of convergence across regions depends on the distances between them. Additionally, any measure of spatial interaction should not discriminate regions by their size or by any other characteristic. Rather it should give a feasible account of the geographic layout or the inner-regional distribution of economic activity or population as well as the distance of the region to its direct and indirect neighbors.

The traditional spatial weight matrices[1] generated by defining the neighborhood of a region A as the regions that neighbor region A (Type 1) discriminate small regions, as small regions usually border less regions.

Generating the spatial weight matrices by defining the neighborhood as the regions that lie within a circle of set radius around a reference point inside the region under consideration (Type 2) are biased by the choice of the reference point.

The neighborhood given with the capitals as reference points does not take into account the regional distribution of economic activity - especially if the regional capital is not situated in the center of the region but in a remote part of the region.

Even by using the geographic center as reference point, the measure will be biased against large regions.

Accounting for these problems of traditional spatial weight matrices, in this study a new approach is presented. It is additionally combined with a design scheme developed by Tiefelsdorf, M.; Griffith and Boots (1999), that ensures that the matrix is stable concerning its statistical properties.

The following second section gives an overview of the relevant literature while in the third section the new approach is presented. To show the dif-

[1]See Schulze (1993) and Döring (2004) for an introduction on spatial weight matrices.

ferences between the new approach and the traditional approaches, they are applied to the Russian regions in section 4.

2 The Spatial Weight Matrix - A Literature Review

The consideration of spatial aspects in the context of a comprehensive theoretic approach dates back to the works of von Thünen (1826). Even though, the theoretic approach by von Thünen (1826) does not use methods of spatial econometrics. The introduction of indicators for the impact of spatial effects is motivated by the works of Moran (1950), which in itself applies insights gained from Moran (1948) and the study of one dimensional serial autocorrelation to the two dimensional case.

The first approaches in designing the neighborhood were matrices of Type 1. Distance based measures were introduced together with the idea of a decay of the spatial effects[2]. Here a distinction can be made whether the distance decay is exponential, inverse quadratic or linear.

Linear distance decay functions cannot be found in any recent studies of spatial structures. On the contrary, exponential distance decay functions are implemented by Tondl (1997), Niebuhr and Schlitte (2004), Arbia (2004) or Kramar (2006). Approaches implementing an inverse squared distance decay function are, for example Baumont, C.; Ertur and Le Gallo (2002), Arbia and Piras (2005) or Fingleton (1999). Tiefelsdorf, M.; Griffith and Boots (1999) gives a comprehensive overview of possibilities to measure the distance between two regions, he also offers a modified version that takes account of the statistical problems when designing the spatial weights matrix.

3 An Alternative Approach

In the present study no different approach for measuring spatial autocorrelation is introduced. The focus is on the step before the calculation of autocorrelation statistics. All such statistics are based on an implemented neighborhood which in itself depends on distances from one region to another.

It is still an open question whether distance can be measured in an Euclidean way as the shortest distance between the centers of two regions or if actual distance as in miles of motorways or railways need to be considered - including additional travel impediments such as borders or construction sites.

[2]The rate by which spatial effects diminish over distance.

Additionally, if considering spillover activities or regional interactions in general, it might be prudent to consider the location and the infrastructure of the region under consideration as well as that of its neighbors. If a region reports an overall well-developed infrastructure of motorways or railways, it can be supposed that most of its interaction with other regions will be land-bound, while a large number of airports might suggest a bigger share of interaction via air. Finally a region that is land locked e.g. bordering no sea, large lake or considerable river will depend less on interaction via shipping. Therefore, the infrastructure and the geographical layout of the region - its location - could be included into modeling a spatial weight matrix as well.

Another question is about the right definition of the center of a region - the reference point for the calculation of distances. The most conclusive answer is given by the geographical center of the region. A second possibility - the most common one is defining the capital of the region or its major city as the center of the region, following the argument that most economic activity is situated in the capital.

The use of both approaches lacks in some ways. If the geographical center is considered, economical aspects, as well as infrastructure and population aspects are not considered. The example for this argument can be found in some large Russian regions like the Krasnoyarsk krai or the Republic of Sakha where the northern parts are only sparsely populated due to climatic reasons and most economic activity is situated in the southern part of the region.

If, instead, the regional capital is considered as the center, it is not necessarily the sole economic center in the region as can be seen for the region of North Rhein-Westphalia in Germany, where Düsseldorf is the capital but there is a broad range of other economic centers throughout the region.

Additionally, as is also true for North Rhein-Westphalia, the capital is not necessarily the major economic center. This gets even more pronounced when regions like the Russian Republic of Ingushetia, where the capital Magas is inhabited by less than 400 people and only hosts the regional government.

It is therefore necessary to implement a new way in defining the reference point of a region. This implementation needs to take into account the structure under consideration while discriminating regions as little as possible. For the calculation of an economically oriented reference point, the city GDP (GCP) is calculated for all cities in the region[3].

Defining every city as an object with its GCP as the weight and the

[3]Whether it is necessary to include settlements as well remains open to discussion. In the following it is assumed that settlements are considered as well as some settlements that reach population numbers larger than those of cities in the region.

geographic coordinates of the city as its center of gravity using the following physical equation can be used to calculate the overall center of gravity which is the true economic center of gravity. Here X gives the longitude and Y the latitude.

$$X = \frac{\sum_{i=1}^{N}(GCP_i \cdot X_i)}{\sum_{i=1}^{N} GCP_i} \tag{1}$$

$$Y = \frac{\sum_{i=1}^{N}(GCP_i \cdot Y_i)}{\sum_{i=1}^{N} GCP_i} \tag{2}$$

As the calculation of GCP is mostly impossible due to confidentiality issues of city statistics and the number of statistics necessary for a comprehensive analysis, the GCP is substituted by the population of the cities - even though this does implicitly assume that population and economic activity are proportional. The corresponding formulas are given as follows.

$$X = \frac{\sum_{i=1}^{N}(Pop_i \cdot X_i)}{\sum_{i=1}^{N} Pop_i} \tag{3}$$

$$Y = \frac{\sum_{i=1}^{N}(Pop_i \cdot Y_i)}{\sum_{i=1}^{N} Pop_i} \tag{4}$$

The weight matrix calculated this way needs to be further standardized using the method described in Tiefelsdorf, M.; Griffith and Boots (1999) and Tiefelsdorf (2002), so that it is consistent concerning its statistical properties.

Problems arise if the region under consideration is highly non-convex. If major economic centers are situated at opposite ends of a non-convex region, the overall economic center might be situated outside the region's borders. While this poses no problem mathematically, it nonetheless leaves room for discussion on the implications as well as on possible remedies.

4 Application of Alternative Designs to the Russian Regions

4.1 Changes in the Regional Centers

For the example of the Russian Federation and its regions figure 1 shows the difference between regional centers if the center is defined not by the capital of the region but by the economic center. For reasons of simplicity only the population of the ten largest settlements and cities has been considered. This reduction is feasible as in this way approximately 60% of the total population of Russia has been considered while the level of complexity is still manageable.

The position of the regional center is most important in connection with its distance to other regional centers. Figure 1 shows for which regions the average difference in the region's center in relation to all other regional centers has changed. The black regions are regions where the average distance of the center has changed by more than 100 km while in the gray regions, the distance to other regional centers has changed more than 50 km but less than 100 km.

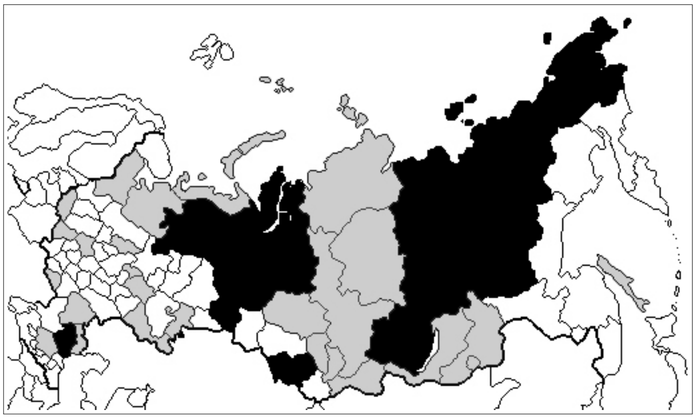

Figure 1: Divergence of traditional and new regional centers - 2008

It can be seen that most changes happen in the central Russian regions. Mostly those regions that are relatively large and that, like the oblast Tyumen, have a capital that is situated near a border away from the economic centers.

For some smaller regions like the Moscow oblast or especially the city of Moscow the change is a statistical artefact representing the changes in the other regions. With Moscow as the economic center of Russia and the initiator of most economic effects, an average shift of distances of 70 km is an indicator that using the new concept of economic centers instead of the traditional capital based approach will have important influences on the average structure of economic interaction or measures thereof respectively.

4.2 Application of Moran's I

To discuss in detail the effects that the choice of the weight matrix has on the structure of economic interaction, the local Moran's I statistic is calculated for two cases. As shown by Carroll, M.C.; Reid and Smith (2008), the Moran's I statistic is a reasonable tool for the detection of cluster activities. We calculated the statistic based on regional GDP per Capita levels, as has been argued by Breschi and Lissoni (2001) that local spillovers are not pure knowledge spillovers.

Of the two cases, in the first one the indicator is based on the capital city as the region's center, while in the second case the economic center is used.

The subjects are the Russian regions in the year 2008. For both approaches the weight matrix is calculated using the scheme by Niebuhr (2000) and the standardization method of Tiefelsdorf, M.; Griffith and Boots (1999) is used and the Moran's I statistic[4] as a measure of interregional but intranational spillovers[5], is calculated according to the formula given in Schulze (1993). The distance decay factor has been set to 0.5 as this value allows for a reasonable level of spatial interaction to be measured.

The regions that are colored in black are those regions that show a significantly positive influence while the regions in gray show a significantly negative influence on their neighbors. As significant we define regions that report a Moran's I statistic that is at least 10% of the maximum Moran's I statistic.

While we acknowledge that this approach is highly relativist but it allows to disregard those regions that only have marginal effects on their neighbors. A more mathematically consistent procedure is given by Tiefelsdorf (2002).

As shown in figures 2 and 3, in both cases the structure of regional interaction is well established. The results from the economically centered indicator are more widespread regionally, showing positive as well as negative indicator values in western as well as in eastern regions of Russia.

In comparison, the figures show that using the alternative indicator, more clustering activities can be detected across Russian regions. This is especially true concerning regions in the eastern parts of Russia or rather Siberia. In contrast to the traditional distances, the regions in the Chelyabinsk, Samara, Bashkortistan and Orenburg area do not show the levels of cluster activities as before. Only Samara reports significant regional autocorrelation. This is an interesting aspect insofar as Samara started a respective cluster initiative

[4]More advanced measures of spatial interaction can be found in Karlström and Ceccato (2002).

[5]A distinction in intra- and international interregional spillover effects is necessary as shown by Eckey, H.-F.; Kosfeld and Türck (2005).

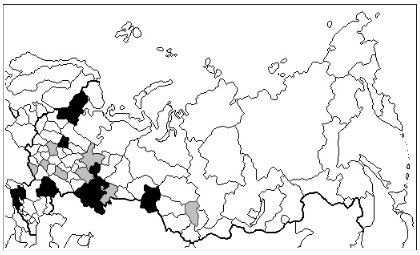

Figure 2: Moran's I for capital based distances - 2008

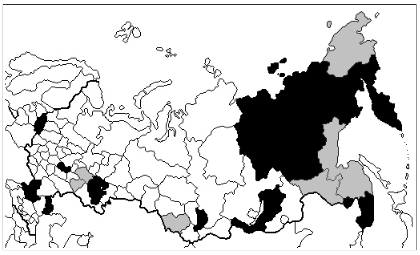

Figure 3: Moran's I for economic center based distances - 2008

while for the other regions no significant cluster initiative exists. The negative effects can be an artefact created by Samara enticing enterprises to settle in the region. Therefore it can be concluded that the cluster strategy of Samara has been successful insofar as the data points to the presence of new industry formation in the regions.

The same argument can also be stated in the opposite direction for the Republic of Sakha, which consistently lost its importance over the last decades shown by a significant positive effect on neighboring regions.

While these are only two examples, the results from using economic center oriented distances are more in sync with real world development trends than the traditional ones.

Especially, as the results do suggest that for explaining knowledge formation in Russia, a cumulative causation approach[6] or a related growth pole approach[7] seem more reasonable than a spillover oriented one.

Nonetheless, for a more in depth analysis of the clustering processes, additional factors like human capital stocks and formation need to be observed as well[8], thereby making a corresponding analysis a necessity.

5 Conclusions

The present study reevaluated the traditional ways of measuring distances between two geographic objects for which it is necessary to define some reference point that gives their center. The method presented has been applied to economic and population based aspects of regional analysis but can easily be transferred to any other aspect. In contrast to traditional approaches, the internal structures are therefore represented more correctly.

[6] See Kaldor (1957).
[7] See Perroux (1948) and Perroux (1988).
[8] See De La Fuente (2000).

To prove the feasibility of the method, it has been applied to the regions of the Russian Federation and for two examples it has been shown that the new approach has distinct advantages when measuring spillover effects than the traditional capital based one.

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