Extended Abstract

Analyzing Polycentricity by Counterfactuals: Applying a 'Donut Model'.

Angelika Krehl
ILS – Research Institute for Regional and Urban Development, Brüderweg 22-24, 44135 Dortmund, Germany
(Landline: +49 231 9051 248; email: angelika.krehl@ils-forschung.de)

1 Motivation

It has been under scientific debate for some decades that the urban spatial structure of metro areas in the so-called Global North has been changing. These changes manifest in restructuring processes both regarding large urban areas gaining regional importance and regarding regional dispersion processes diluting the core city's traditional primacy. Therefore, a multi-centric and at times almost dispersed urban spatial structure has emerged especially in North American metro areas (e.g., McMillen and McDonald, 1998; Coffey and Shearmur, 2001; Shearmur and Coffey, 2002; Lang and LeFurgy, 2003). Those spatial patterns are in some contrast with findings for European and German city regions as amongst others, Bontje and Burdack (2005), Adolphson (2009) or Krehl (2016) show. All of these investigations reveal a comparatively dense urban fabric meaning that European city regions are on average more densely populated than American city regions, but show weaker spatial disparities. Nevertheless, spatial densifications can be observed outside the core cities, too (e.g., Riguelle et al., 2007; Adolphson, 2009; Münter and Volgmann, 2014; Krehl, 2016). It has, however, been unresolved yet to what extent such urban areas can be considered polycentric.

A city region's urban spatial structure is considered polycentric if two or more equally relevant spatial densifications exist (e.g., Meijers and Burger, 2010; Parr, 2014). However, a region is multi-centric if these densifications are not equally relevant, but if one dominates the others. Based on this definition, the following thought experiment is made referring to a kind of counterfactual: What happens if a city region's core is eliminated, that is, if there had been a lake instead of a densely populated urban area causing a donut-like shape? The expectation is that the more polycentric a city region is the fewer changes regarding the number, size and location of non-core city densifications will appear if the administrative core is cut off. Contrastingly, core city omission should have strong effects in pronounced multi- or even monocentric regions.

2 Objective and expected contribution

This paper's theoretical background is based on the alleged existence of agglomeration shadows. These shadows' spatial outcome in urban areas is that comparatively few and 'weak' densifications exist in close proximity to the core. It has been under debate that cities, especially core cities, might not emerge or grow too close to each other due to spatial price competition. The rationale is that denser places are subject to higher land prices and thus proximity advantages are offset by congestion costs. Whereas distance to the CBD would predict higher densities, fierce price competition works as a centrifugal force pushing development away from the core (see Partridge et al., 2009 for details).

However, this agglomeration shadow can be countered by the concept of borrowed size, introduced by Alonso (1973) and revisited by Meijers and Burger (2017) in the context of polycentricity. Borrowed size means that small and medium sized cities located in a metro area are economically more successful than they would be if they had been located in isolation (Meijers and Burger, 2017: 271). Referring

to European policies oriented towards territorial cohesion and balanced growth, for example, the concept of borrowed size is appealing: it offers a justification of striving for polycentric developments. If borrowing size from neighboring cities worked, it would mean that striving for a polycentric urban spatial structure was economically reasonable.

Thus, the idea is to test an exploratory means to visualize agglomeration shadows and to analyze if the shadows are especially cast on medium sized centers as defined by urban and regional planning. Accordingly, the expected contributions are to find exploratory (visual) evidence of agglomeration shadows and to investigate if the expected changes due to core city omission may be related to spatial planning policies. I exemplarily study this in four selected German city regions.

These regions are Cologne, Frankfurt, Munich and Stuttgart (for an overview, see e.g., Krehl et al., 2016). They are characterized by core city dominance as previous analyses have shown (Krehl, 2015, 2016). However, it has not been studied yet to what extent this core city dominance actually masks suburban spatial densifications. Thus, this contributions aims to shed light on potentially masked urban subcenters in the vicinity of core cities. This is done by an experiment described in the Motivation section: What happens to the urban spatial structure if the region's core is eliminated?

3 Data, empirical procedure and first results

All analyses are conducted on the spatial level of 1 km² grid cells located in accordance with the European grid INSPIRE (Infrastructure for Spatial Information in the European Community). The data – employees subject to social insurance – are taken from the georeferenced Integrated Employment Biographies as of June 30, 2009, which have been provided by the Research Data Centre (FDZ) of the German Federal Employment Agency (BA) at the Institute for Employment Research (IAB).

The empirical analysis is organized as follows: first, the local Moran's I is calculated for each region to identify statistically significant spatial clusters of both high and low values as well as spatial outliers (see Krehl, 2015). Second, the analysis is repeated omitting the administrative area of the core city and the emerging patterns are described and analyzed. The issue is to study if the regions are truly polycentric or if there are potential agglomeration shadows that mask relevant densification close to the core city.

As the omission of the whole core city's administrative area might be too general, a modification is tried as well: instead of omitting the core city in step 2, only the largest high-high cluster located within the core city is cut off. The idea is to gain a better understanding whether intra-core city densifications exist that might be masked by a central business district. Another set of analyses is done in those study regions that have more than one core city: the predefined core cities are stepwise reinserted after step 2. Then the local Moran's I is calculated to investigate if all core cities are equally relevant for the city region's urban spatial structure. Table 1 provides an overview of the empirical procedure.

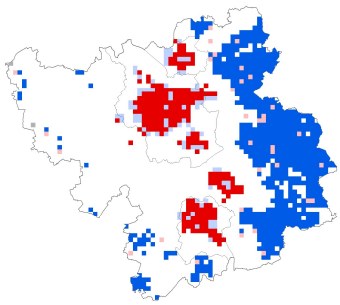
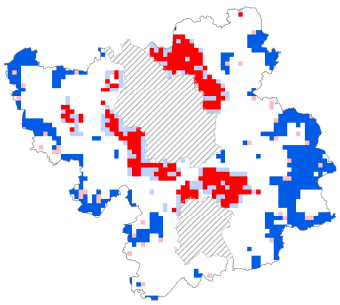
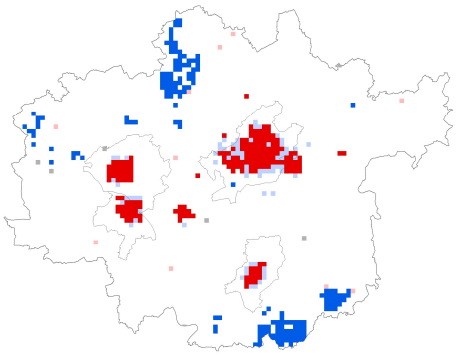
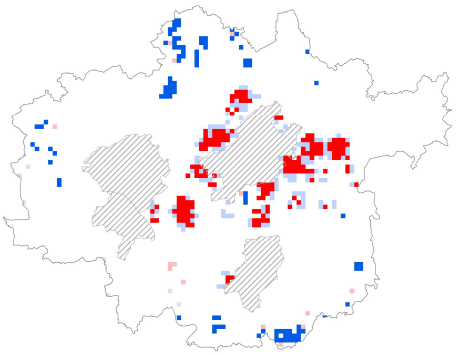
Table 1: Empirical design

Step	All regions	Regions with more than one core city
1	Local Moran's I	
2	Local Moran's I without core city's/cities' administrative area	
3	Local Moran's I without core city's/cities' largest high-high cluster	
4	-	Local Moran's I without all but n-1 core cities' administrative area[a]
5	-	Local Moran's I without all but n-1 core cities' largest high-high cluster[a]

[a] n = number of core cities

The results of steps 2 and 3 are expected to not differ substantially from those of step 1 if the region under consideration is polycentric, whereas marked differences are expected for both core city dominated and monocentric regions. Furthermore, only slight differences should occur between step 2 and 3's results on the one hand and step 4 and 5's results on the other hand for regions with several core cities and if these regions are truly polycentric. Similarly, if one core dominates the other(s), substantial changes in the spatial patterns are expected.

The empirical results of steps 1 and 2 are shown in Figure 1. They reveal that omitting the predefined core(s) causes spatial clusters of high densities (i.e., red areas representing high values of employees per km² in high-density areas) to appear in several medium sized centers. Thus, all study regions are core city dominated which is in line with earlier results. Likewise, agglomeration shadows seem to exist because core city omission reveals several new statistically significant clusters of high values.

	LISA Cluster map including the core city	LISA cluster map excluding the core city ('donut model')
Cologne region		
Frankfurt region		

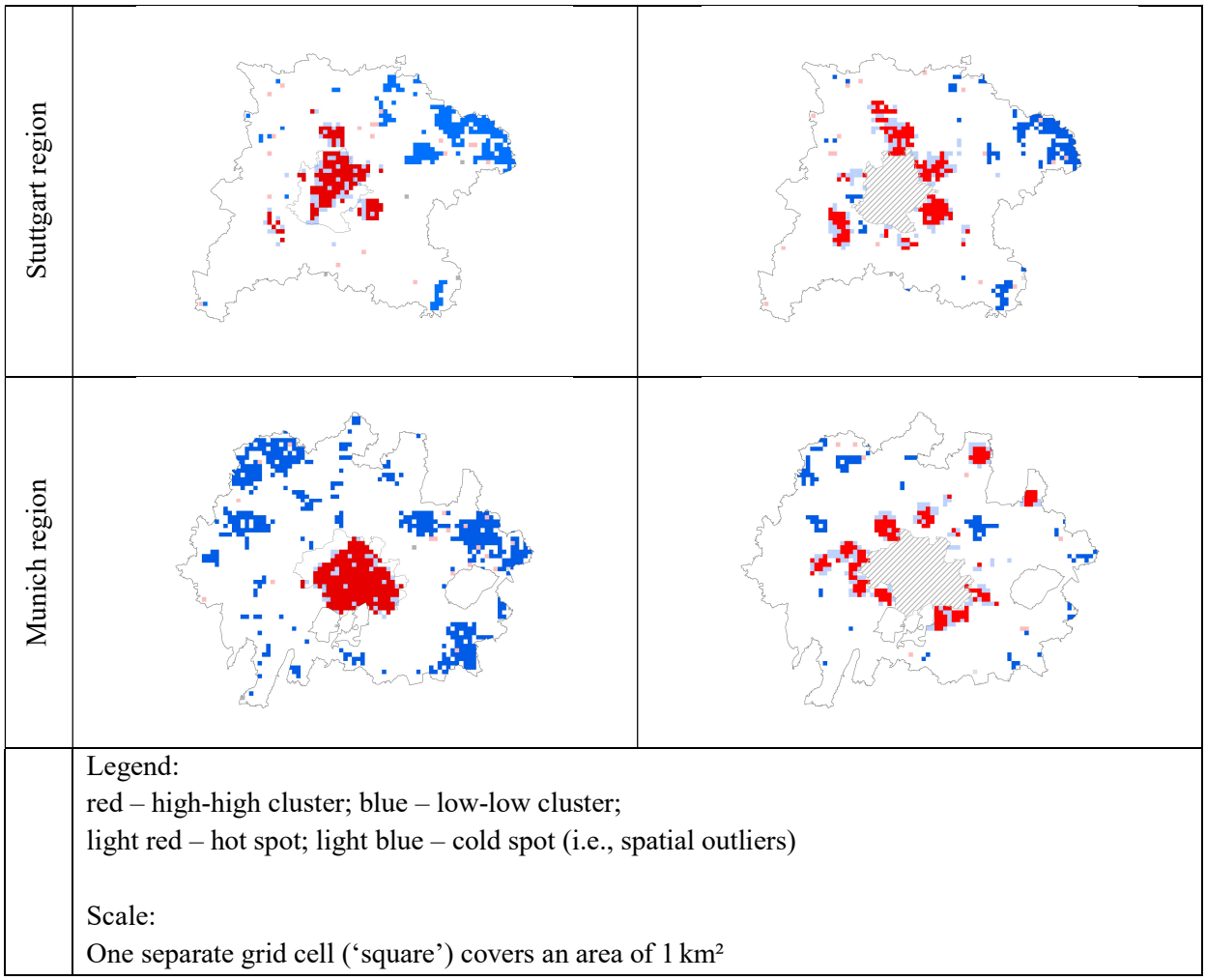


Figure 1: LISA Cluster map with and without (all) core city/cities

Some preliminary insights from step 4 (not shown) furthermore suggest that the largest core cities substantially dominate the others in the case of several core cities. The corona-like results shown in Figure 1 can be almost identically replicated if only the largest core city is omitted. Thus, the smaller core cities' status rather is that of a subcenter.

4 Tentative Conclusions

From a methodological point of view, a means has been shown to distinguish polycentric spatial structures from multicentric/core city dominated structures using exploratory methods and counterfactuals ('donut-models'). Similarly, these analyses suggest a way to visualize alleged agglomeration shadows. From a content-wise perspective, the analyses have cast more light on the urban spatial structure of selected German city regions. Not only core city dominance could be confirmed, but also invisible 'masked' suburban densifications in the vicinity of the (largest) core city in each study regions could be discovered. Due to these revealed high-high clusters, it seems reasonable to suspect agglomeration shadows being effective in the study regions. However, the analyses have been solely exploratory. Thus, further research is necessary to disentangle cause and consequences as well as the precise mechanisms at work in more detail.

Similarly, more in-depth analyses of these results are needed: they should be checked regarding their robustness and sensitivity to parameter settings. They should also be analyzed regarding the clusters'

main characteristics. Do the spatial clusters' characteristics with and without core omission, for example, differ from each other and what does this imply regarding polycentricity? Finally, investigations could be made to analyze if the results are methodology driven or if the suggested procedure is truly feasible to visualize agglomeration shadows.

References

Adolphson M (2009) Estimating a Polycentric Urban Structure. Case Study: Urban Changes in the Stockholm Region 1991–2004. *Journal of Urban Planning and Development* 135(1): 19–30.

Alonso W (1973) Urban zero population growth. *Daedalus* 102(4): 191–206.

Bontje M and Burdack J (2005) Edge Cities, European-style: Examples from Paris and the Randstad. *Cities* 22(4): 317–330.

Coffey WJ and Shearmur RG (2001) INTRAMETROPOLITAN EMPLOYMENT DISTRIBUTION IN MONTREAL, 1981-1996. *Urban Geography* 22(2): 106–129.

Krehl A (2015) Urban Spatial Structure: An Interaction between Employment and Built-up Volumes. *Regional Studies, Regional Science* 2(1): 290–308.

Krehl A (2016) Urban subcentres in German city regions: identification, understanding, comparison. *Papers in Regional Science*: n/a.

Krehl A, Siedentop S, Taubenböck H and Wurm M (2016) A Comprehensive View on Urban Spatial Structure: Urban Density Patterns of German City Regions. *ISPRS International Journal of Geo-Information* 5(6): n° 76.

Lang RE and LeFurgy JB (2003) Edgeless cities: Examining the Noncentered metropolis. *Housing Policy Debate* 14(3): 427–460.

McMillen DP and McDonald JF (1998) Suburban Subcenters and employment density in metropolitan Chicago. *Journal of Urban Economics* 43(2): 157–180.

Meijers EJ and Burger MJ (2010) Spatial structure and productivity in US metropolitan areas. *Environment and Planning A* 42(6): 1383–1402.

Meijers EJ and Burger MJ (2017) Stretching the concept of 'borrowed size'. *Urban Studies* 54(1): 269–291.

Münter A and Volgmann K (2014) The Metropolization and Regionalization of the Knowledge Economy in the Multi-Core Rhine-Ruhr Metropolitan Region. *European Planning Studies* 22(12): 2542–2560.

Parr JB (2014) The Regional Economy, Spatial Structure and Regional Urban Systems. *Regional Studies* 48(12): 1926–1938.

Partridge MD, Rickman DS, Ali K and Olfert MR (2009) Do New Economic Geography agglomeration shadows underlie current population dynamics across the urban hierarchy? *Papers in Regional Science* 88(2): 445–466.

Riguelle F, Thomas I and Verhetsel A (2007) Measuring urban polycentrism: a European case study and its implications. *Journal of Economic Geography* 7(2): 193–215.

Shearmur RG and Coffey WJ (2002) A Tale of Four Cities: Intrametropolitan Employment Distribution in Toronto, Montreal, Vancouver, and Ottawa – Hull, 1981 – 1996. *Environment and Planning A* 34(4): 575–598.