AGGLOMERATION ECONOMIES SHAPING THE SPATIAL STRUCTURE IN GERMAN CITY REGIONS?

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Abstract

The emergence of polycentric spatial structures has been an area of research since the late 1970s. However, despite a large number of studies from economics, urban geography, and planning science many questions remain more or less unanswered. Researchers widely agree that agglomeration economies play a key role when monocentric urban systems have gradually transformed into polycentric or dispersed patterns of economic activities. But how other factors such as governmental policies or infrastructure systems interact with economic forces is highly unclear. In this paper, we try to shed some light on the urban spatial structure of four selected German city regions. By looking at employment and employment in higher-order service sectors we try to find evidence for different agglomeration economies at work. Our results suggest that both employment types show a concentrated spatial pattern but with quantitative and qualitative differences. These differences might be explained with agglomeration economies as well as influences from planning policies. Our findings for the German city regions are qualitatively similar to those for North America. However, there are fundamental differences with respect to magnitude and spatial manifestation. We conclude that agglomeration economies contribute to shaping the spatial structure but they are not solely responsible for this.

1.   Introduction

Inner city job losses often coin the urban and regional development. At the same time, however, job agglomerations arise in the respective cities' fringes and in the regional periphery (e.g. McMillen and McDonald, 1997; Siedentop *et al., 20*03; Bontje and Burdack, 2005). The term *edge cities* is frequently used in this context in the U.S. American literature (e.g. Garreau, 1992). It means that office and retail agglomerations containing high numbers of employment and floor space arise in rather remote areas while the core city loses in terms of employment. Some scholars believe that edge cities do not form a stable spatial equilibrium but serve as an intermediate spatial configuration towards a wide dispersion of jobs over a large metropolitan territory (e.g. Gordon and Richardson, 1996; Lang and LeFurgy, 2003). This, however, is heatedly disputed. Some experts pointed to signs of re-centralization of jobs rather than dispersion (e.g. Pfister *et al., 20*00; Scott *et al., 20*08*;* Geppert and Gornig, 2010). Another strand of discussions on this issue deals with the emergence of polycentric urban structures. These are not defined properly: neither as a technical term nor as a normative concept (e.g. Kloosterman and Musterd, 2001; Davoudi, 2003). However, most definition approaches agree on polycentricity being some sort of not centralized but at the same time neither dispersed distribution of economic activity in space.

Our interest is focused on the mechanisms that possibly lead to these different spatial structures. In doing so, we are interested in the question "Why and where do subcenters occur?". We follow amongst others Garcia-López and Muñiz (2013, pp. 515f) who believe that agglomeration economies play a driving role in shaping city regions. The motivation for our paper is that agglomeration econo-

mies are often empirically described and theoretically founded but their mechanisms and the channels through which they act and interplay with other factors of urban development are not fully understood yet (Melo and Graham, 2014, p. 31). There is a vast amount of literature dealing with aspects of agglomeration economies in spatial models. When it comes to polycentricity research, however, the agglomeration economies' role in the scientific discussion is less prominent. We combine economic aspects in the development of city regions with spatial planning policies based on our belief that there is some interaction and reverse influence between these. Thus, the one should not be considered without taking into account the other one.

The remainder of the paper is organized as follows: Section 2 provides an overview over the theoretical background of agglomeration economies in general and contributions with respect to polycentricity. Additionally, we discuss whether there are other aspects that might shape a city region such as spatial planning policies. This theoretically founded section is followed by empirical analyses which aim at shedding light on the outcomes of mechanisms at work in four selected German city regions (Section 3). The essentials gained from the previous sections are considered in section 4. Section 5 finally ties up loose ends and provides an outlook on further research needs.

2. Theoretical background

2.1 Agglomeration effects in spatial settings

The literature on agglomeration economies in spatial settings is wide-ranging and often intertwined since agglomeration economies are one of the main workhorses in spatial economics. However, no clear-cut definition of agglomeration economies seems to exist. A good synonym in combination with a spatial connotation describes them as "localized aggregate increasing returns" (Duranton and Puga, 2004, p. 2065). It should be noted, however, that agglomeration (and dispersion) do not appear from nowhere but "may arise as the unintended consequence of a myriad of decisions made by firms and workers pursuing their own interest" (Thisse, 2010, p. 282). Governmental policies try to stimulate these – hopefully positive – "unintended consequences" when fostering the location of e.g. an industrial cluster. In order to focus on our main research question, we narrow the discussion of agglomeration economies to contributions having an explicitly spatial aspect. Hence, effects based on amongst others mass production and increasing returns will not be considered.

A widely noted systematization of agglomeration economies stems from Duranton and Puga (2004) who roughly base their work on Marshallian agglomeration economies[1] and condense the *sharing – matching – learning* trinity as channels through which agglomeration economies act. Puga (2010) keeps up that classification but fails to empirically disentangle and prove it. Quite similar results gain Thisse (2000) and Rosenthal and Strange (2004). While the latter explicitly look for empirical evidence of agglomeration economies in the classification of Duranton and Puga (2004), the aforementioned elaborates on a number of (stylized) facts about city and regional development asking the question why agglomeration economies were that strong. (Thisse, 2000, pp. 63f). The topic of agglomeration economies is discussed in various contexts such as spatial economic development (e.g. Glaeser *et al., 19*92; Fujita and Thisse, 2004), labor-market pooling (e.g. Andini *et al., 20*13; Melo and Graham, 2014), trade (e.g. Ottaviano *et al., 20*02; Cavailhès *et al., 20*07) or transportation issues (e.g. McMillen and McDonald, 1998; Puga, 1999). Urban and regional structure in combination with agglomeration economies has been dealt with for a while as the work of Anas *et al.* (1998) shows. They rely on agglomeration forces and their meaning for different configurations in metropolitan development such as

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[1] These were defined from Marshall (1890) and comprise knowledge spillovers, input sharing, and labor market pooling.

the monocentric city model or polycentric configurations. Lee and Gordon (2007) additionally evaluate urban spatial structure with respect to economic efficiency, i.e. the relationship between urban form and growth. They find that a "metropolitan area with more clustered spatial form grows faster when it is small; whereas more dispersion leads to a higher growth rate as it grows large" (Lee and Gordon, 2007, p. 11).

Another field of agglomeration economies in spatial settings is that of knowledge economy and spillovers. Comprehensive contributions are those of Audretsch and Feldman (2004) or Kujath and Schmidt (2010). Both stress the importance of knowledge transmission as one main force of agglomeration. The necessity of face-to-face interaction – one form of knowledge spillovers – was theoretically and empirically described, tested, and proven, too (e.g. Coffey and Shearmur, 2002; Storper and Venables, 2004). However, knowledge spillovers are seen as forms of both economies of localization (e.g. Marshall, 1890) and economies of urbanization (e.g. Jacobs, 1961). In empirical analyses it is not clear though, whether or not these economies have a statistically significant effect as Illy *et al.* (2009) show.

2.2   *Polycentricity and agglomeration effects*

We have seen that agglomeration economies are often used to explain the location of economic activity. According to our question concerning the reason for subcenter occurrence and their respective locations, we now turn to agglomeration economies in the polycentricity debate, expecting that positive effects foster centralization whereas negative ones foster dispersion and thus, yield a concentrated but not centralized urban spatial structure which can be considered polycentric. Berliant and Wang (2007) and other scholars prove that a polycentric spatial pattern is stable if economies of scale are sufficiently strong. Nonetheless, different ideas about the polycentric pattern's origin exist. Thisse (2010) argues that individual decisions once aggregated influence economic conditions which in turn might yield a polycentric pattern (Thisse, 2010, pp. 288, 291). Anas *et al.* (1998) agree with him concerning agglomeration economies but rather focus on first and second-nature geography implying internal and external economies of scale.

In addition to these theoretical foundations there are contributions relating urban spatial structure and agglomeration economies in empirical research. Garcia-López and Muñiz (2013) consider intra-metropolitan development. A feature of their model is the ability to account for both economies of localization and economies of urbanization. A similar logic is adopted from Partridge *et al.* (2008), who prove that distance does not lose its importance. Meijers and Burger (2010) successfully demonstrate that a polycentric spatial pattern yields an increase in productivity as compared to a monocentric one since agglomeration diseconomies can be mitigated then. They also discuss economies of localization and urbanization which are effective and show that urbanization economies cannot be shared easily between cities within a metropolitan region. It should be noted, however, that there are studies demonstrating that polycentricity does not need to be the final outcome. Ahlfeldt and Wendland (2013) assume that initial advantages might have had so strong implications that despite deglomerating forces such as increased costs for land monocentricity can stay the prevalent urban form and probably mask small scale intra-city polycentricity.

Had there only been positive agglomeration effects, the explanation of subcenter emergence and polycentric urban spatial patterns would have been difficult. Negative agglomeration economies are e.g. congestion, high land prices, increased crime rates, or pollution. Several scholars discuss in theory and empirics that these diseconomies may lead to a dispersed spatial pattern ("urban sprawl") but may also give rise to polycentric spatial structures. The emergence of a polycentric urban systems is then thought to be the combined result of positive agglomeration economies originating from high activity densities and agglomeration diseconomies (e.g. McMillen, 2001; Berliant and Wang, 2007; Lee and

Gordon, 2007; Meijers and Burger, 2010). Taken together with the finding that "distance does not die" (e.g. Partridge *et al.,* 2008), subcenter formation is likely occur outside the core city but in close proximity. Subcenters at such locations still generate external savings to the firms without suffering from excessive land costs or other negative externalities.

2.3   Polycentricity and spatial planning policies

It would fall short to explain polycentric urban structures with agglomeration effects alone. Spatial planning plays a major role in shaping the land-use pattern in metropolitan areas. Planning regulates the location of businesses in both direct and indirect ways. Policies of "concentrated decentralization" have a long tradition in countries like Germany (Gatzweiler, 1994), South Korea (Cho 2002; Seo, 2009) or the United Kingdom (Hall, 1973). With planned "new towns" and subcenters policy-makers aim to direct urban growth to designated places in suburban or – in rare cases – rural areas. Such policies are frequently combined with growth management instruments such as zoning regulations, growth boundaries and greenbelts (Bengston, *et al.,* 2004). More recently, principles of transit-oriented development influences urban and regional planning worldwide (Dittmar and Ohland, 2004). The overall strategy behind such policies is to reduce the growth pressure in the dense core areas and to avoid urban sprawl at the suburban fringe. Indirect forms of fostering deconcentration and polycentricity refer to fiscal policies favoring suburban locations and investments into transport infrastructure (Wassmer, 2005; Debrezion *et al.,* 2007; Su and deSalvo, 2008). However, the contribution of spatial planning in promoting polycentric urban structures has not been empirically investigated in detail so far.

2.4   Interim conclusions

The previous paragraphs highlighted the discussion about agglomeration (dis-)economies' relevance concerning urban spatial structures. We find that it often focuses on the growth of cities or their performance. However, agglomeration economies have hardly been used to explain spatial structures. A rather surprising finding was that there seems to be almost no literature providing the link between spatial planning policies and agglomeration (dis-)economies. Additionally, very few studies explicitly address an international comparison. The literature on theoretical explanations and their empirical verification in national case studies, by contrast, is extensive. We believe that internationally comparative research could provide many new insights here.

3   Evidence for selected German city regions

The empirical part of this paper addresses the degree of polycentricity as well as its spatial manifestation in four selected German city regions. We then put our results in an international, especially North American, context in order to qualitatively discuss the convergence or divergence of subcenter formation in different countries and the potential – universal or regional – factors accounting for that. The empirical analysis is conducted on a very fine spatial scale of grid cells to reveal otherwise hidden intra-municipality differences in the distribution of economic activity. Recent developments in the availability of data below the municipality level in Germany allow for this (see also Fina *et al.,* 2014).

3.1   Regions and data basis

We consider four selected German city regions: Cologne, Frankfurt, Munich, and Stuttgart. These regions were roughly delineated on the basis of local labor markets defined by the Federal Institute for Research on Building, Urban Affairs and Spatial Development to ensure that agglomeration economies with respect to employment are not too arbitrarily cut off at the regions' fringes. We suspect

these regions to be representative for a polycentric-disperse urban spatial structure (region of Stuttgart), a monocentric configuration (region of Munich), polycentricity by definition (region of Frankfurt as it consists of four core cities and the respective hinterlands), and a region showing a rather bi-polar structure (region of Cologne). We analyze these regions with respect to their morphologic polycentricity taking into account both employment (number of jobs that are subject to social insurance) and floor space (volume of floor space). All analyses are conducted on the spatial level of grid cells having a side length of 1000m and being located in accordance with the European grid INSPIRE (Infrastructure for Spatial Information in the European Community). The choice of a spatial level below the administrative level of municipalities has two advantages: It mitigates the arbitrariness of administrative borders and allows for a more detailed picture of the regions revealing a heterogeneous intra-municipality structure.

The data we use originate from two sources: Floor space is computed for the above mentioned INSPIRE grid cells based on large-area 3D building models for the entire urban regions. These building models were generated by the information fusion of building footprints derived from topographic maps at a scale of 1:25,000 and building heights derived for these footprints from height measurements from stereoscopic satellite imagery (see Wurm *et al.,* 2014). Data on employment is taken from the georeferenced Integrated Employment Biographies (see Scholz *et al., 20*12) and subject to censoring due to Germany privacy policy. Grid cells containing less than three employees belonging to less than three firms or containing one firm that accounts for more than 50% or 75% of all employment were censored[2] and after that manually set to one, i.e. one employee. We are aware that this might induce a severe downward bias at times. However, the censored cells account for 0.5-1.0% of all employees subject to social insurance and 2.0-3.0% of employees in higher-order service sectors[3] subject to social insurance. Employees being not subject to social insurance or being marginally employed were excluded. In the remainder of this paper we will use the term "employees" implying that these are only employees subject to social insurance.

3.2   Concentration of activity

According to our definition of polycentricity, concentration measures seem to be adequate to roughly identify the degree of intra-regional concentration of jobs and floors space. We employed the traditional *Gini coefficient*: Values close to one indicate a very high concentration of (economic) activity while values close to zero imply low concentration. Unfortunately, the Gini coefficient does not have a spatial component. Hence, we cannot determine whether a given degree of concentration occurs because few non-neighboring grid cells contain high shares of employment or because these few grid cells are located in close proximity (Fig. 1).
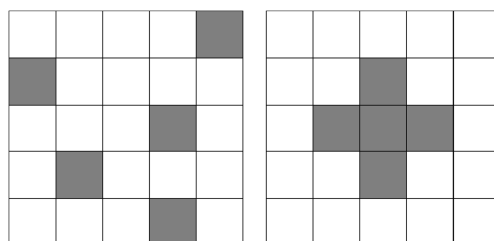

Figure 1: Spatial distributions of activity yielding identical Gini coefficients
(Source: Own depiction)

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[2] For details see Bundesagentur für Arbeit (2012).
[3] These are defined as all employees being registered in the sections J-N or S according to the Classification of Economic Activities, issue 2008.

Nonetheless, we believe that a concentration measure such as the Gini coefficient can be helpful at giving first insights into the overall distribution of activity. If we see high Gini coefficient values, we can infer that activity is concentrated in a few grid cells yielding either a polycentric (if not located together) or a monocentric structure (if located together). Table 1 provides an overview over the calculated Gini coefficients of our study regions.

Table 1: Gini-Coefficients concerning employees and floor space

	Region of Frankfurt	Region of Cologne	Region of Munich	Region of Stuttgart
	All employees			
All grid cells[a]	0,815	0,763	0,870	0,785
Only grid cells containing jobs[b]	0,674	0,685	0,809	0,673
	Employees in higher-order service sectors			
All grid cells[a]	0.840	0.798	0.892	0.814
Only grid cells containing jobs[b]	0.719	0.732	0.841	0.717
	Floor space[c]			
All grid cells[d]	0,793	0,696	0,787	0,763
Only grid cells containing floor space[e]	0,718	0,654	0,743	0,710

[a] Grid cells subject to censoring were considered by manually changing the number of employees in the respective cells to one employee per grid cell, grid cells without any employees by setting the number of employees to zero. [b] Dealing with censoring analogous to [a]. Grid cells without any employees were not considered. [c] The region of Cologne is not fully covered from the remote sensing because of clouds at the point in time of data generation. Thus, two gaps in the region's north-eastern and south-western fringe occurred accounting for about 8.7% of the region's total area. [d] Analogous to [a]. [e] Analogous to [b].

(Source: Own calculations based on the georeferenced Integrated Employment Biographies as of 30 June 2009 as well as remote sensing data from the German Aerospace Center in the German Remote Sensing Data Center)

All Gini coefficients indicate high levels of concentration both when looking at each region as a whole (rows 1, 3, and 5 in Tab. 1) and when excluding cells that have no employment (rows 2, 4, and 6 in Tab. 1). However, whether or not these relatively high levels of concentration result from a spatially clustered structure of employment cannot be said without further information[4].

Our ex-ante expectation concerning a lower concentration of all employees as compared to those in higher-order service sectors is proven for all study regions. Whether this is the case because of agglomeration economies or because of historical or other incidents cannot be derived from these figures. Nonetheless, there might be agglomeration economies present today which the employees take advantage of although these were not the actual cause for the employees' firms' location choice (see also Parr, 2002, pp. 725f).

We furthermore see floor space being less concentrated than employment. There are basically two reasons for this: First, floor space does not only contain commercial uses (mainly office and retail) but also space for residential use. Second, in contrast to employment, floor space is regulated by land use plans and respective zoning ordinances. Dependent on the kind of zone (residential, commercial, mixed use etc.) local land use plans limit the maximum amount of floor space. The combined analysis of concentration measures of employment and built forms in metropolitan areas gives first insights into the complex interplay of different shaping forces of urban spatial structures.

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[4] Density maps (not shown) indicate high density grid cells lying in close proximity to each other.

3.3   Spatial clusters of activity

Apart from the missing spatial component the Gini coefficient has another limitation: It only focuses on absolute numbers and cannot distinguish between high values with respect to the entire region and high values with respect to a specific subarea within that region. Why should this distinction be relevant? We are interested in identifying and explaining urban spatial structure. Starting from a classic monocentric city model it can be expected that the highest numbers of employees and floor spaces are located in the core cities. Taking into account that subcenters are located in fringe areas, it makes sense to define a decision rule for their identification based on a local spatial context (here neighbored grid cells).

Considering these issues we apply the so-called *local Moran's I*. This measure takes into account the neighborhood of a grid cell under consideration and classifies that grid cell based on its local context. Classification means that the method identifies clusters of high and low values as well as spatial outliers. High value clusters are grid cells containing high values and being located in a neighborhood that is coined from high values (high-high) and vice versa (low-low). Spatial outliers are grid cells that do not fit into their local context. Either a grid cell having a high value is surrounded by low-value grid cells or vice versa. The first is called hot spot (high-low) and the latter cold spot (low-high). The neighborhood definition applied here is a queen contiguity of second order implying that spillovers might affect the direct neighbors as well as the first neighbors' neighbors, i.e. each grid cell can be "influenced" from its surrounding 24 grid cells. Figure 2 visualizes this method's outcome in *LISA Cluster maps*. LISA stands for Local Indicators of Spatial Association and the local Moran's I is one of these (for details on the definition and calculation see Anselin, 1995). The grey circled municipalities within each region are the respective core cities. All analyses have been conducted on the spatial scale of grid cells and the core city boundaries are just shown for ease of interpretation.

At first glance all regions seem to be coined from strong local spatial association although distinct spatial clusters of both high and low values are visible. The high-high clusters and the hot spots are of main interest because we defined polycentricity as some sort of not centralized but at the same time neither dispersed distribution of economic activity in space. However, these clusters do not indicate high numbers of employees in absolute values but as compared to the local neighborhood. If the number is "conspicuous", it is considered statistically significant and thus gets assigned one of the classes defined above. The left column of Figure 2 is a depiction of the LISA Cluster maps for all employees. We see that there are clusters in the core cities in all study regions. Nonetheless, there are high-high clusters outside the regions' cores but in close proximity in all regions apart from Munich. Thus, some kind of polycentric spatial structure is visible in those regions. This is most obvious in the region of Stuttgart but also valid for the multi-core regions of Frankfurt and Cologne. The northern core city in the Cologne region, the city of Cologne, contains two spatially segregated high-high clusters which can be interpreted as a sign of intra-municipality polycentricity. These clusters as well as the other high-high clusters are located at or in close proximity to the river Rhine. In contrast to Frankfurt, Cologne and Stuttgart, Munich demonstrates a still highly monocentric pattern of employment.
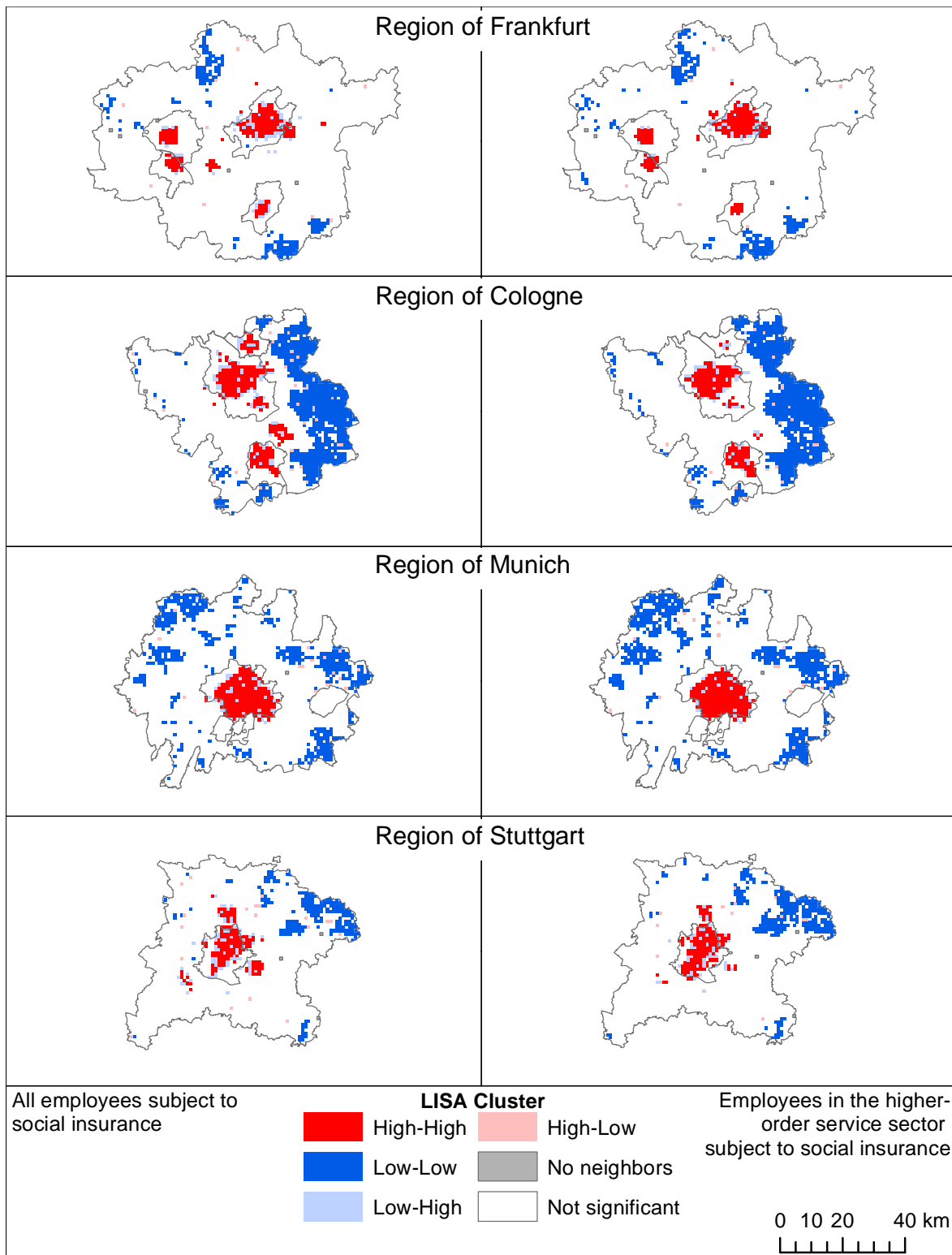
Region of Frankfurt

Region of Cologne

Region of Munich

Region of Stuttgart

All employees subject to social insurance

LISA Cluster

- High-High
- Low-Low
- Low-High
- High-Low
- No neighbors
- Not significant

Employees in the higher-order service sector subject to social insurance

0 10 20   40 km

Figure 2: LISA Cluster maps based on a false discovery rate with α = 0.05 and a pseudo-p-value derived from 9999 permutations (Source: Own calculations based on the georeferenced Integrated Employment Biographies as of 30 June 2009)

Things look slightly different when employment in higher-order service sectors is considered (right column of Fig. 2). In general, agglomeration forces seem to be stronger for this kind of employees (or the respective firms). However, due to privacy driven censorship it might be the case that we miss some high-high clusters or hot spots. The different "geography" of employment patterns (all employees and those in higher-order service sectors) becomes most visible in the region of Stuttgart. The spatial structure looks similar for both categories of jobs since subcenters outside the core city can be identified. However, their geographical size is obviously different. This seems reasonable since the regional economy is dominated by medium sized enterprises which are mostly related to manufacturing, both in production and in research. This can be in high-quality and technology sectors but our data does not allow for a finer distinction of higher-order service sectors.[5] Furthermore, in Stuttgart and Munich we observe a number of employment hot spots emerging when just the higher-order service sectors are considered. This is interesting as apart from all localization and urbanization economy discussions there seems to be a mechanism that motivates firms to locate in rather remote and isolated areas. Explanations could refer to planning policies and central place assignments. However, the hot spots do not necessarily mean that employment is high – they are high in their respective neighborhood. The region of Frankfurt loses one quite strong high-high cluster when looking at employees in higher-order service sectors. This "lost" cluster was located in the municipality of Russelsheim where the automotive sector dominates. A similar change can be seen in the region of Cologne where the high-high cluster in the North almost disappears. It is located in the municipality of Leverkusen which is coined from chemical industry.

4   Interpretation and comparison of the results

4.1   Urban spatial structure in selected German city regions

The previous paragraphs suggested that employment and employment in higher-order service sectors are strongly concentrated. Both measures we applied do not reveal anything about the shares of employment and the respective area they cover. Thus, we found it helpful to calculate these shares manually (Fig. 3).
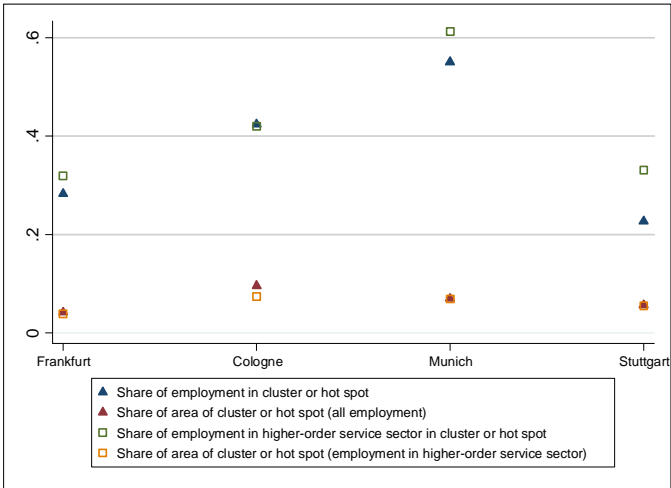

Figure 3: Shares of employment and area in high-high clusters and hot spots (Source: Own calculations based on the georeferenced Integrated Employment Biographies as of 30 June 2009)

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[5] The Classification of Economic Activities, issue 2008, does not reflect the present economic structure but is still based on an industrially coined economic structure.

Combining the results from Table 1 and Figures 2 and 3 reveals that both employment and employment in higher-order service sectors are highly concentrated in our study regions. The rather polycentric regions of Frankfurt and Stuttgart have just a bit more than 30% of their employees in higher-order service sectors located in high-high clusters or hot spots. These account for 3.9% (Frankfurt) and 5.5% (Stuttgart) of the regions' areas. This means in turn that almost 70% of those employees are located somewhere else in the region but those numbers are not statistically significant. The region of Munich is obviously monocentric since more than 50% (all employees) and 60% (employees in higher-order service sectors) respectively are located within the high-high cluster and the hot spots which account for 6.9% of the region's total area. The region of Cologne does not show a clear picture which might be the result of its bi-polar structure as well as intra-municipality polycentricity.

Our finding that all high-high clusters are located either in the core cities or in close proximity unifies the four study regions despite their respective peculiarities. If a street and rail network grid was laid over the LISA cluster maps, it could be seen that accessibility plays an important role since most clusters are located near transport nodes. There are some agglomeration effects behind this finding – positive as well as negative ones – but it is not possible to disentangle and quantify them without further information. Other scholars proved this for some metropolitan areas (e.g. McMillen and McDonald, 1998; Giuliano *et al., 20*12). Our results of high concentration of employment and even higher concentration of employment in higher-order service sectors are in line with arguments from agglomeration economies' theory. A possible explanation for the different patterns between all employees and employees in higher-order service sectors could be that "decreasing trade and communication costs lead to a pattern of activity in which headquarters remain in the core together with high-level business-to-business services, while plants move to the periphery" (Thisse, 2010, p. 292). Unfortunately, we do not have sufficient information in our data to test for this.

4.2   Urban spatial structure in an international context

After having analyzed four German city regions, it is interesting to evaluate these results against selected papers providing an international context on polycentricity research. Coffey and Shearmur (2002, p. 362) stress the importance of face-to-face interactions especially in the higher-order service sectors in the Montreal area which seems to be in line with our descriptive results. They further argue that this process could not have taken place without strong agglomeration economies at work facilitating the development and maturation of non-core centers. McMillen and McDonald (1998) conduct an analysis for the Chicago metropolitan area focusing on intra-regional agglomeration economies. They (and amongst others Giuliano *et al., 20*12) find accidental co-location because of good accessibility as well as agglomeration economies resulting from locating close to the core or subcenter to be significant. Thus, they infer that agglomeration economies of different kinds shape that metropolitan area's spatial structure. These findings could be similar with ours since the high-high clusters we identified are also located at transportation nodes. The location of firms close to or in a subcenter might be seen as avoiding agglomeration diseconomies in the core cities.

Giuliano *et al.* (2007, p. 2942) provide some information concerning the 10% of the study area containing most employment in the Los Angeles metropolitan area (i.e. reverse analysis of what we did in Fig. 3). Their findings suggest that the respective values are well above 50% of all employment which might be in accordance with our findings for the rather polycentric regions of Frankfurt and Stuttgart. Since these authors used, in contrast to us, time series data, they were able to show that dispersion and edgeless city formation are not excessively taking place in the L.A. region but that agglomeration economies are effective (which is in contrast to the study from Gordon and Richardson, 1996).

5   Conclusions

We started our analysis with a question concerning the urban spatial structure of four German city regions as well as possible mechanisms shaping this structure. For one point in time we could shed some light on this issue allowing an analysis on a spatial level much more detailed than the municipality level. We found relatively strong concentrations for employment, employment in higher-order services, and floor space.

The theoretical foundation against which we analyzed the employment distribution gave rise to the assumption that agglomeration economies positively influence the clustering of economic activity. Moreover, it seems to be the case that not only first-nature geography plays a role but also head starts and self-reinforcing effects. This rather speaks in favor of polycentricity being a successor of Christaller's Central Place Theory than that of land-use theories. Nonetheless, it can be argued that polycentricity can be identified with the help of bid-rent functions but this was not our analysis's focus. Of course, we cannot rule out that e.g. decentralization resulting from high land prices in the core city had an influence on the spatial pattern in our study regions. Accessibility and accidental co-location issues, too, but we cannot empirically test for them and have to postpone this to further research. However, we believe that economies of urbanization and localization are important as we saw a stronger concentration of employment in higher-order service sectors than of overall employment. In our hypothetical line of argument this results from positive agglomeration economies rather than land-use aspects. This seems to be in congruence with developments and their explanations in North American polycentric city regions. Some scholars had the chance to empirically test for agglomeration economies and could prove and explain their existence. It should be noted, however, that the magnitude, size, and spatial manifestation of U.S. American polycentric city regions are very different from those in Germany. Some mechanisms might work in a convergent manner but to what extent other factors could be responsible for these differences cannot be analyzed based on the information we have. This remaining question calls for a true internationally comparative analysis on the shape and spatial structures of metropolitan areas as well as their presumably different explanations.

Concerning the interpretation and understanding of our results, a closer look at particular agglomeration effects as well as planning policies would make much sense. We suspected agglomeration economies to be the driving forces but regression analyses might reveal that these are (not) statistically significant and/or whether there are other forces at work. Moreover, we did not quantitatively evaluate the reinforcing effects of economics and planning policy which would contribute to a better and more comprehensive understanding of the respective urban spatial structures.

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