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Delineation of City Regions Based on Commuting Interrelations: The Example of Large Cities in Germany

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Abstract

The comparison of cities with regard to their economic or demographic development may yield misleading results, if solely the cities in their administrative borders are the object of consideration. Frequently, historical borders of cities neither conform to the contemporary settlement structures, nor do they consider the mutual dependencies between cities and parts of their hinterland. Therefore, it is often claimed to use city regions as objects of comparison or for the sake of urban planning. Commonly, the delineation of functional regions is based on commuting flows from the municipalities in the hinterland of the core cities directed to the cores. A municipality is regarded as belonging to a certain city region if the share of out-commuters from this municipality to the respective core in the total mass of those employees who reside in that municipality is the largest one, and if this share exceeds a certain threshold value. However, commuting flows in the opposite direction are not considered. The method presented here delineates city regions on the base of bidirectional commuting flows. Hereby, various modifications regarding the characteristics of the employment base, the possibility of overlaps of regions, the formation of polycentric city regions, and of the minimum threshold value of mutual connectivity are applied to the sample of 81 German cities with more than 100 000 inhabitants. Finally, the effects of different kinds of regionalisation on the coefficients of regional specialisation of these cities and city regions are demonstrated.

Keywords: city regions, functional urban regions, commuting, regional specialisation

JEL Classification: R12, R23, R58

Die Abgrenzung von Stadtregionen anhand von Pendlerverflechtungen am Beispiel der deutschen Großstädte

Zusammenfassung

Der Vergleich von Städten im Hinblick auf ihre ökonomische oder demographische Entwicklung kann zu Fehlinterpretationen führen, wenn die Städte ausschließlich in ihren administrativen Grenzen betrachtet werden. Diese Grenzen sind oft das Ergebnis weit zurückreichender historischer Prozesse und stimmen mit der heutigen Siedlungsstruktur in vielen Fällen nicht überein. Insbesondere wird die Zusammengehörigkeit von Städten mit Teilen des Umlandes aufgrund ökonomischer Verflechtungen nicht berücksichtigt. Daher wird immer wieder die Forderung erhoben, die Stadtregion als Gegenstand des räumlichen Vergleiches wie auch der Raumplanung heranzuziehen. Eine weitverbreitete Methode hierbei ist die Bildung funktionaler Regionen anhand von Pendlerverflechtungen. Zum Umland einer Kernstadt werden jene Gemeinden gezählt, deren jeweils stärkster Auspendlerstrom in diese Stadt führt und einen festgelegten Mindestschwellwert überschreitet. Hierbei bleiben allerdings die entgegengerichteten Pendlerströme unberücksichtigt. Im vorliegenden Beitrag wird ein Verfahren zur Bildung von Stadtregionen auf der Grundlage von bidirektionalen Verflechtungen vorgestellt. Dabei werden auch Modifikationen im Hinblick auf bestimmte Gruppen von Beschäftigten, auf die Möglichkeit von Überlappungen der Regionen, die Zusammenführung polyzentrischer Stadtregionen und die Anwendung unterschiedlicher Schwellwerte für die Pendlerintensität vorgenommen. Dies wird am Beispiel der Bildung von Stadtregionen für 81 deutsche Städte mit mehr als 100 000 Einwohnern demonstriert. Im Anschluss hieran wird die Wirkung unterschiedlicher Regionalisierungen auf die wirtschaftliche Spezialisierung der Städte bzw. Stadtregionen gezeigt.

Schlagwörter: Stadtregionen, funktionale Regionen, Pendlerverflechtungen, regionale Spezialisierung

JEL-Klassifikation: R12, R23, R58

Introduction

The delineation of cities and towns has a considerable impact on the results yielded by any kind of cross-sectional analysis of urban or regional socio-economic data. This holds true particularly for comparisons of cities (so called rankings).[1] If administrative borders cut the area that is relevant to the economic activities under consideration, the data from these units are more or less biased. In order to avoid this, one can combine sufficiently small adjacent areas (e.g. municipalities) around the core city into one region that more successfully captures the interrelations between the economic actors residing in the city itself and its hinterland – the city region. If the decision on which "building blocks" belong to the region (and which not) follows some (or at least one) criteria of socio-economic interrelations (e.g. commuting flows), such regions are called "functional urban regions[2]".

The notion of the city region can be traced as far back as Dickinson (1947). Its meaning stretches beyond the creation of statistically comparable units: certain kinds of services can be delivered more efficiently by associations of municipalities as city regions. And the city region may be regarded increasingly as a spatial agent whose constitution is defined rather by a network of relations than by territorial aspects; this point of view has emerged as so called "New Regionalism", a consequence of the rise of globalisation.[3] Functional urban regions were delineated "unofficially" after World War II in almost all industrialised countries, but "no national statistical institute has hitherto attempted *systematic* mapping of functional urban regions. It has been seen that researchers who have set themselves this aim have so far failed to achieve it".[4] One reason for this may be the impossibility of delineating city regions with regard to all purposes at once. The delineation of city regions remains, probably, an action that should be performed on demand, and adapted to the special requirements of particular purposes. In such cases, the disclosure of the methods and criteria that have been applied, and their rationale is of particular importance.

Regarding these methods, there are some similarities in the delineation of local labour markets using thresholds for commuting intensity. In contrast to most of these, city regions are delineated non-exhaustively. In many approaches, the centres are predefined according to other criteria. Secondly, labour market (or travel-to-work) areas should (for practical reasons) be disjoint. However, city regions targeted for the provision of statistically comparable units may overlap in cases where municipalities have strong functional ties with more than one core city. A further question is the choice of a measure of connectivity between cities. Traditionally, shares of out-commuting from peripheral municipalities to the core city have been computed and compared with certain threshold values. Since urban agglomerations are increasingly polycentric (Anas et al., 1998), in-commuters from the core to peripheral municipalities should also be considered. In so doing, this paper provides insights from methods that have not been applied to German commuting data before. Furthermore, the employees on whom the commuting matrix is based may be regarded as completely (as far as the statistical data that is available)[5] or partially constrained to certain groups (for e.g., white-collar only).[6]

[1] See e.g. Freeman (2004); for Germany: Teltemann (2008), particularly p. 37 ff.

[2] Other methods of delineation of urban agglomerations follow morphological (e.g. N.U.R.E.C., 1994) or socio-demographic (e.g. Benard, 1952) principles.

[3] See e.g. Parr (2005) p. 556; for Germany: Harrison/Growe (2012).

[4] Pumain et al. (1992) p. 31–32 and 61 (author's emphasis).

[5] In Germany, the Federal Employment Agency collects data for employees who are subject to social insurance. contributions.

[6] See e.g. Coombes et al. (1988, 2006) and Papanikolaou (2009) for the rationale of different commuting

Finally, if some core cities are strongly interrelated (or if their city regions overlap to a great extent), they may form a polycentric region.

In the Federal Republic of Germany, city regions have been delineated under the direction of the Academy for Spatial Research and Planning (Akademie für Raumforschung und Landesplanung, ARL) using commuting patterns from census data of 1950, 1961 and 1970. A new concept of delineating urban agglomerations developed by the ARL[7] was not realised in practice. A revival of the concept of the city region began to appear in academic research in Germany in the second half of the 1990s (but only in the case of cities within the territory of the "old" German states).[8] This method of delineation was based on Boustedt (1953) who referred to the delineation methods of the Standard Metropolitan Areas in the US. Since the commuting data for the "new" states of Germany were also available, the German Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) within the Federal Office for Building and Regional Planning (BBR) began to compute city regions for about 80 German cities, applying a method similar to Boustedt's (1953) to commuting data for different years from the Statistics of Federal Employment Agency.[9] In these publications first applications of this regionalisation perspective to the development of urbanisation patterns, general employment, population and migration were made. This process of finding a durable concept of delineation of city regions has not yet been completed by the BBSR.[10]

The aim of this contribution is to present a simple method to delineate city regions and to show the consequences of different variations with regard to labour force groups, separateness, relations between core cities and threshold values for commuting intensity, and their consequences for comparisons of city regions. The method is applied here to all 81 German cities which had at least 100 000 inhabitants at the end of 2007. This sample is comparable to the set of core cities of city regions described in Gatzweiler et al. (2006). Its spectrum of self containment and of labour mobility is broader than that of the set of core cities in BBSR (2012). However, in contrast to that work, the present paper discusses variations of the method, including their suitability for application to different sets of core cities.

The paper is structured as follows: based on the concept of the functional urban region, section 2 outlines the method applied to delineate the core and the hinterland regions. In section 3 the core cities are compared and grouped according to their size and their relationships of in- and out-commuting and other characteristics of labour mobility. In section 4, city regions resulting from variations of the method are compared. Section 5 reports results of a first application of overlapping city regions to the coefficients of regional specialisation. Section 6 concludes.

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behaviour of groups of employees with distinct levels of qualification.

[7] See ARL (1984).

[8] See Göddecke-Stellmann (1998a, b). However, a revisited concept of the Boustedt city region was applied to the data of the 1987 census (and, later, to employment data provided by the German Federal Employment Agency) by the private firm BIK aschpurwis + Behrens GmbH for commercial use after 1992. See AGRS (2005).

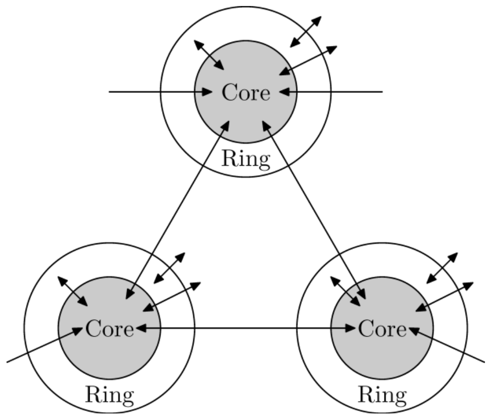
[9] See BBSR (2011) and Gatzweiler et al. (2006).

[10] See BBSR (2012) p. 72 ff. The BBSR approach is now refined insofar as only cities with at least 100 000 inhabitants are included in the sample of core cities if their relationship of in- to out-commuting exceeds 1, and if the main flow of in-commuters does not come from an adjacent centre.

2. Delineation of functional urban areas

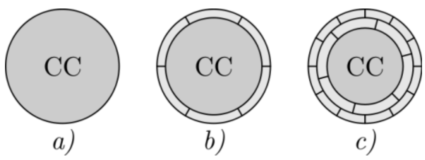
The concept of the functional urban area (FUA) emerged in the 1960s in the US, and was first known as "functional economic area".[11] In simple terms, a FUA consists of an urban core and its surrounding hinterland. Core and hinterland differ in population density (decreasing from centre to periphery),[12] as well as in composition and intensity of two essential categories of land use (residential and business).[13] These differences in functionality are strongly related to movements of goods, people (e.g. employees) and information between core and hinterland, but also between the cores of different regions (see fig. 1). The present approach to modelling FUAs considers only commuting relations. However, job-related commuters employ the same road or rail connections that are used in conjunction with other activities taking place in the same region. So, commuting relations may be regarded as an approximation of the strength of links between large cities and their surrounding municipalities, as far as their different socio-economic characteristics are concerned. If different core cities are closely (but not adjacently) located and strongly reciprocally dependent, together with their overlapping peripheries they may shape polycentric areas, sharing one common hinterland.

Fig. 1: Functional Urban Areas



Source: Based on Maier/Tödtling (2006) p. 160.

Fig.2: Administrative Boundaries of the Core City and their Effect on the Core Region (three Stylised Cases)



Source: Own research.

At least, the urban core of a single FUA in fig. 1 contains the core city, but it may contain (according to the core city's delineation) fewer or more (possibly some rings) of its surrounding municipalities. Three possible cases are sketched in fig. 2: the core city (cc) in fig. 2 b) is surrounded by one ring of adjacent municipalities which are very strongly connected to this core city. The magnitude of connectivity must exceed a

[11] See Parr (2005) p. 563 f.
[12] See Clark (1951).
[13] See e.g. Lucas/Rossi-Hansberg (2002) p. 1453.

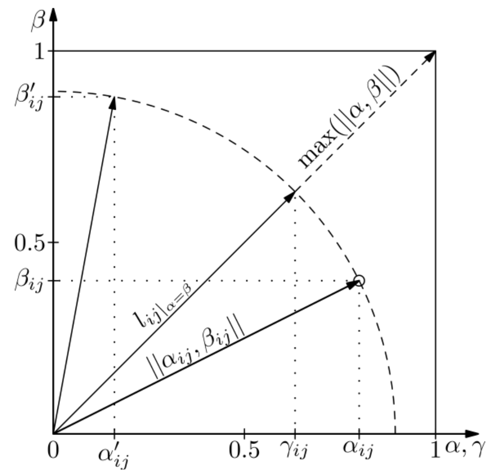
threshold value that is higher than the threshold value fixed for municipalities belonging to the urban hinterland. The core city in fig. 2 c) is even more tightly delineated and is surrounded by three rings of municipalities whose coefficients of connectivity with the core city exceed the threshold value. The core region in fig. 2 a) contains only the core city itself (that means, no adjacent municipality is so strongly linked with the core city that it becomes a part of the core region). In such a case, it may be that the core city already contains large parts of its hinterland within its boundaries; however, this cannot be investigated without additional data. The "ring" of urban hinterland in fig. 1 may consist of anything from a few (possibly even none) to many municipalities (possibly including some rings). The border of the urban hinterland distinguishes between the given FUA and its rural periphery, or it demarcates (or overlaps) the urban hinterland of other functional urban areas.

The process of delineation requires the matching of at least two data sets provided by official statistics: the first set contains data on employees who are liable to social insurance contributions (the eight-digit municipality keys of places of residence and of work, at least), the second is a GIS data set for the municipalities containing (at least) municipality keys ("Amtlicher Gemeindeschlüssel", AGS) and the polygons that delimit the areas of municipalities. Data on more than 27 million employees up to the reporting date of 30 June 2008 were provided by the Statistics of the German Federal Employment Agency. The reporting date of the GIS data set stemming from the Federal Agency for Cartography and Geodesy is 31 December 2008.[14] Because of the different reporting dates some adjustment procedures were required, leading to a reduction in the number of municipalities in the employment data from 12 241 to 12 226. Furthermore, data on employees with place of residence not stated (5 258) or in foreign states (109 742) were excluded. In order to calculate the commuting matrix, all pairs of places of residence/work and their (strictly positive) frequencies were saved in a hash table and thereafter transformed into a sparse matrix. Two commuting matrices $\mathbf{\Pi}$ were calculated this way: $\mathbf{\Pi^a}$ contains the commuting figures of *all* employees, and $\mathbf{\Pi^d}$ contains the figures only for employees holding a university *degree*. For each of these matrices, coefficients of connectivity for out-commuting α_{ij} and in-commuting β_{ij} were calculated as $\alpha_{ij} = \frac{\pi_{ij}}{\pi_{i.}}, \beta_{ij} = \frac{\pi_{ji}}{\pi_{.i}}$, where $\pi_{i.}$ and $\pi_{.i}$ are the row and column sums of $\mathbf{\Pi}$, respectively. The Euclidean norm of α_{ij} and β_{ij} combines both coefficients with the common coefficient of connectivity $\gamma_{ij} = \frac{1}{\sqrt{2}}\|\alpha_{ij}, \beta_{ij}\|$ that considers both in- and out-commuting. The normalisation with $\sqrt{2}$ allows an interpretation of γ_{ij} as a percent of the sum of employees residing and working in municipality i, whereby γ_{ij} = 100 % means that all employees residing in i work in firms located in municipality j, while the workplaces in i are all occupied by employees residing in j.

In fig. 3, the coefficient of connectivity γ_{ij} is derived geometrically: the axes of the diagram span the space of possible combinations of in- and out-commuting from (to) municipality i to (from) core city j, related to the number of employees residing (or working) in i. They are restricted by the maximum value of 1 that these relations may have. In the case of $\alpha = \beta = 1$, the resulting Euclidean norm is $\sqrt{2}$. For given α_{ij} and β_{ij}, there is an indefinite set of combinations (α, β) whose Euclidean norm $\|\alpha, \beta\|$ has the length $l_{ij} = \|\alpha_{ij}, \beta_{ij}\|$, for example ($\alpha'_{ij}$, β'_{ij}). One of these is characterised by the equality of α and β, lying on the diagonal of the 1x1 square. The perpendicular dropped to one of the axes (here the horizontal axis is chosen) crosses the respective axis at γ_{ij}. Thus, γ_{ij} is related only to the length of the vector (α_{ij}, β_{ij}), irrespective of its direction.

[14] See BKG (2009).

Fig. 3: Geometrical Derivation of the Coefficient of Connectivity γ_{ij}



Source: Own research.

In the present study, city regions are constructed for the sample **J** of German cities with at least 100 000 inhabitants (at reporting date 31 December 2007). The names and the population size of the n = 81 core cities are listed in Table A1 in the appendix, together with their abbreviations. As the next step, disjoint core regions according to fig. 2 have to be built. Every core region j contains the core city itself and the set of municipalities **I** (with the exception of other core cities) that are adjacent to the core city j or to at least one municipality that has already been identified as a direct or indirect neighbour of the core city j, *and* the coefficients of connectivity γ_{ij} $\forall\ i \in \mathbf{I}$ exceed the threshold value of $\frac{0.5}{\sqrt{2}} \approx 0.3635$. This value is attained if, for example, 50 % of the employees residing in i commute to j (and no one employee residing in j commutes to i) and vice versa; the same value results e.g. from α_{ij} = 40 % and β_{ij} = 30 %. Two municipalities are identified as neighbours if their polygons share at least one common point. The identification of "rings" of municipalities around a core "under construction" is implemented as a loop that ends if no further municipalities can be found with $\gamma_{ij} \geq \gamma_{\min}$ $\forall j$. Because the core regions have to be disjoint, after every single run the set of potential new municipalities must be controlled for duplicates between all cores $j \in \mathbf{J}$. After finishing the identification of potential members of the cores, the sets $\mathbf{I}_j$ must be controlled for "holes" (i.e. to ensure that there are no single municipalities $i \notin \mathbf{I}_j$ that are completely surrounded by neighbours $i \in \mathbf{I}_j$ or groups of contingent municipalities that are surrounded by members of $\mathbf{I}_j$). In the case of disjoint regions, the filling of the "holes" must be done, taking into consideration the constraint of separateness of the regions.

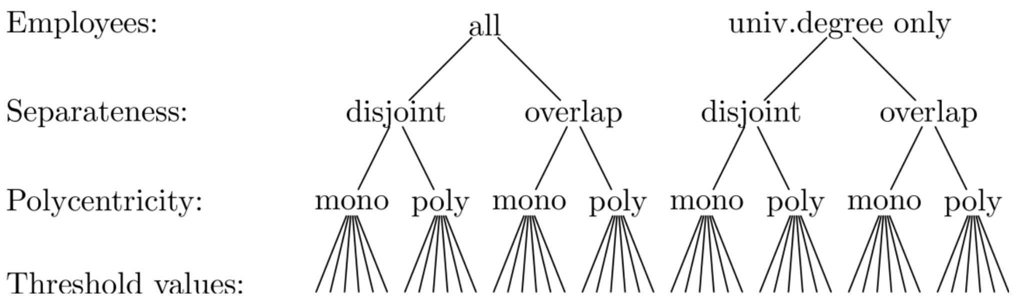
Having identified the core regions, the next step is the identification of core cities that are so strongly connected that they could be regarded as centres of polycentric regions. This is the case if $\gamma_{ij|\{i,j\}\in \mathrm{J}} \geq \gamma_{\min}$ where γ_{ij} stands for the coefficient of connectivity between a core city i and a core region j ($i \neq j$). $\gamma_{\min}$ represents the threshold value of connectivity between a municipality i and one of the core regions j that have so far been identified. In the present example, city regions for a vector $\boldsymbol{\gamma}$ of six minimum thresholds were constructed; $\boldsymbol{\gamma}$ = {0.28, 0.20, 0.16, 0.12, 0.09, 0.07}.[15] The construction of sets of peripheral municipalities $\mathbf{I}_j$ $\forall\ j \in \mathbf{J}$ $\forall\ \gamma_{\min} \in \boldsymbol{\gamma}$ follows the same algorithm as described for the core regions. In the case of disjoint regions, this must be checked for duplicate assignments of the same municipalities i to different cores j (in case of

[15] This corresponds to $\boldsymbol{\alpha}|_{\beta=0}$ = {0.4, 0.28, 0.22, 0.17, 0.13, 0.1}.

overlapping regions this is omitted). After finishing the loop for a specific $\gamma_{\min}$, a control for "holes" is conducted. In the case of disjoint regions, the filling of "holes" must be done carefully to avoid overlaps.

After identifying the hinterlands of all n monocentric city regions, those with strong connectivity between their core city and at least one core of another city region are merged to form polycentric regions. The number of polycentric regions (together with the remaining monocentric regions) depends on the value of $\gamma_{\min}$. All these steps have been taken for the two commuting matrices $\mathbf{\Pi^a}$ and $\mathbf{\Pi^d}$, in order to construct disjoint and overlapping city regions, monocentric and polycentric, for the six threshold values in $\boldsymbol{\gamma}$. Fig. 4 summarises the resulting 48 variants of delineation.

Fig. 4: Applied methods of building city regions



Source: Own compilation.

3. Characteristics of the core cities

The 81 core cities chosen by the single criterion of the number of their inhabitants display a great variety in their labour mobility characteristics, as well as in size and self containment. The following comparison and grouping focusses on the number of inhabitants, the relation of in- to out-commuting, the employment self containment ratio $ESC_i = \frac{\pi_{ii}}{\pi_{i.}}$ and the housing self containment ratio $HSC_i = \frac{\pi_{ii}}{\pi_{.i}}$.[16] The figures in table A1 and A2 in the appendix show a high degree of variation in all variables so that a grouping of them by means of cluster analysis seems to be more appropriate. The application of a "partitioning around medoids" cluster algorithm with euclidean distance function[17] yields nine clusters of core cities, displayed in fig. 5. Table 1 lists the correlation coefficients between the principal components (PC) and the original values of the four variables, together with the eigenvalues of the PCs and their share of the total variance.

The shares of the first two PCs are relatively large; so the interpretation of the clusters within the space spanned by PCs 1 and 2 should be fairly accurate. The first PC is correlated mainly with the number of inhabitants and with the ESC and HSC ratios, while the second PC correlates very strongly with the relation of in- to out-commuting but less strongly with the HSC ratio. Two clusters displayed in fig. 5 contain only one core city that represents the extremes of the single first two PCs: cluster 9 with Berlin (the federal capital with the largest number of inhabitants and the highest ratios of ESC and HSC of the 81 cities), and cluster 3 with Wolfsburg (the seat of the VW headquarters and main production lines), a rather small city in the sample that displays the highest ratio of in- to out-commuting. Cluster 2 contains the three biggest German

[16] The ESC and HSC ratios are discussed e.g. in Laan/Schalke (2001) p. 210 f.

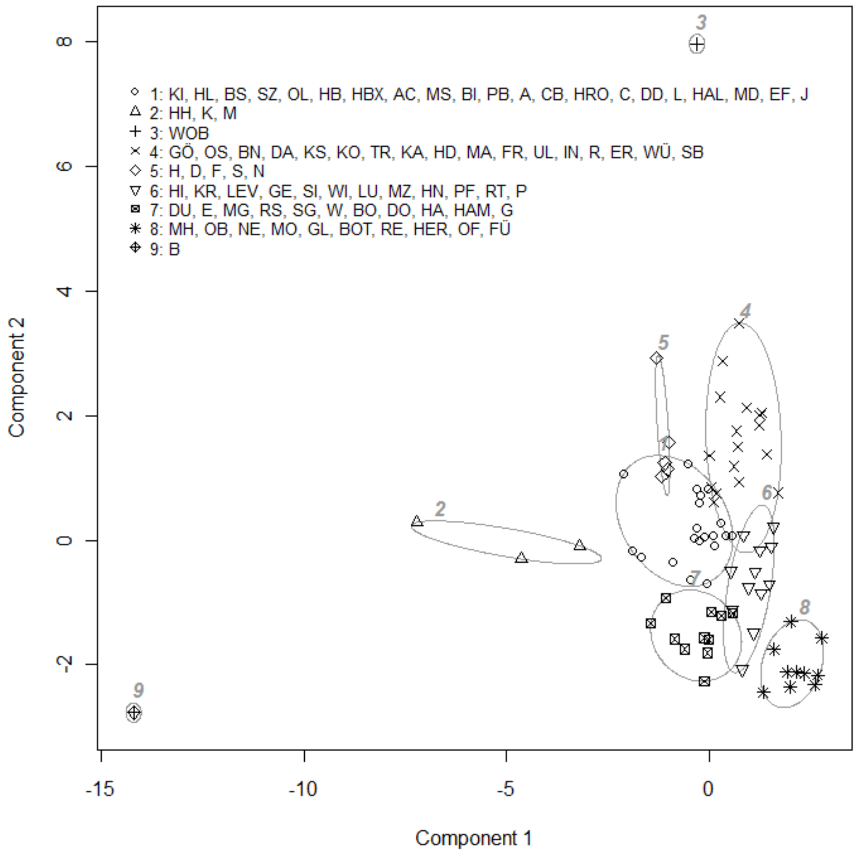
[17] See Pison et al. (1999), Struyf et al. (1996).

Table 1: Correlation Coefficients between Principal Components (PCs) and Original Values of Four Characteristics of 81 German Core Cities, Eigenvalues, and Shares of PCs of Total Variance

	Correlation Coefficients between PCs and ...				Eigenvalues of the PCs	Shares of PCs of Total Variance (Percent)
	Number of Inhabitants	Relation of In- to Out-Commuting	Employment Self Containment Ratio	Housing Self Containment Ratio		
PC 1	-0.75	-0.32	-0.87	-0.68	1.88	47.1
PC 2	0.27	-0.93	-0.39	0.63	1.49	37.3
PC 3	0.60	0.05	-0.27	-0.34	0.55	13.8
PC 4	0.01	-0.16	0.16	-0.14	0.07	1.8

Source: Own computations based on data from German Federal Office for Statistics (List of municipalities 31 December 2007) and Statistics of the Federal Employment Agency (employment data per 30 June 2008).

Fig.5: 81 German Core Cities, Grouped into Nine Clusters (Displayed in the Coordinate System of the Principal Components 1 and 2)



Note: The scales of component 1 and 2 correspond to the lengths of the eigenvectors of the correlation matrix of the four respective characteristics (see Table 1).

Source: Own computations based on data from German Federal Office for Statistics (List of municipalities 31th December 2007) and Statistics of the Federal Employment Agency (employment data per 30th June 2008).

cities after Berlin (Hamburg, Cologne and Munich) that show rather high ESC (but low HSC) ratios together with relatively low ratios of in- to out-commuting. Cluster 5 represents other large cities (Düsseldorf, Frankfurt, Hannover, Nuremberg and Stuttgart) with large relations of in- to out-commuting. The features of PC 1 and 2 in their lowest specification are combined most strongly in cluster 8 which encompasses the smaller cities, primarily of the Rhine-Ruhr area and the city of Fürth. All of these are very strongly linked to their adjacent cities (i.e. they show very low ratios of ESC and HSC, as well as low relations of in- to out-commuting). In addition, the cities in cluster 7 are almost all located in the Rhine-Ruhr area, but they are on average larger than those of cluster 8. One exception in cluster 7 is the smaller city of Gera. Its ESC ratio is relatively small compared to the other cities located in Thuringia, but high in relation to the ESC ratios of the other cities in cluster 7. Cluster 6 contains cities that are strongly linked to large adjacent cities (e.g. Potsdam–Berlin, Reutlingen–Stuttgart, Leverkusen-Cologne, etc.). Cluster 4 contains cities that display a larger relation of in- to out-commuters than the cities of cluster 6. Cluster 1 unifies the average features of the first two principal components and appears to be the centre of the scatter diagram.

4. Variations in delineation of city regions

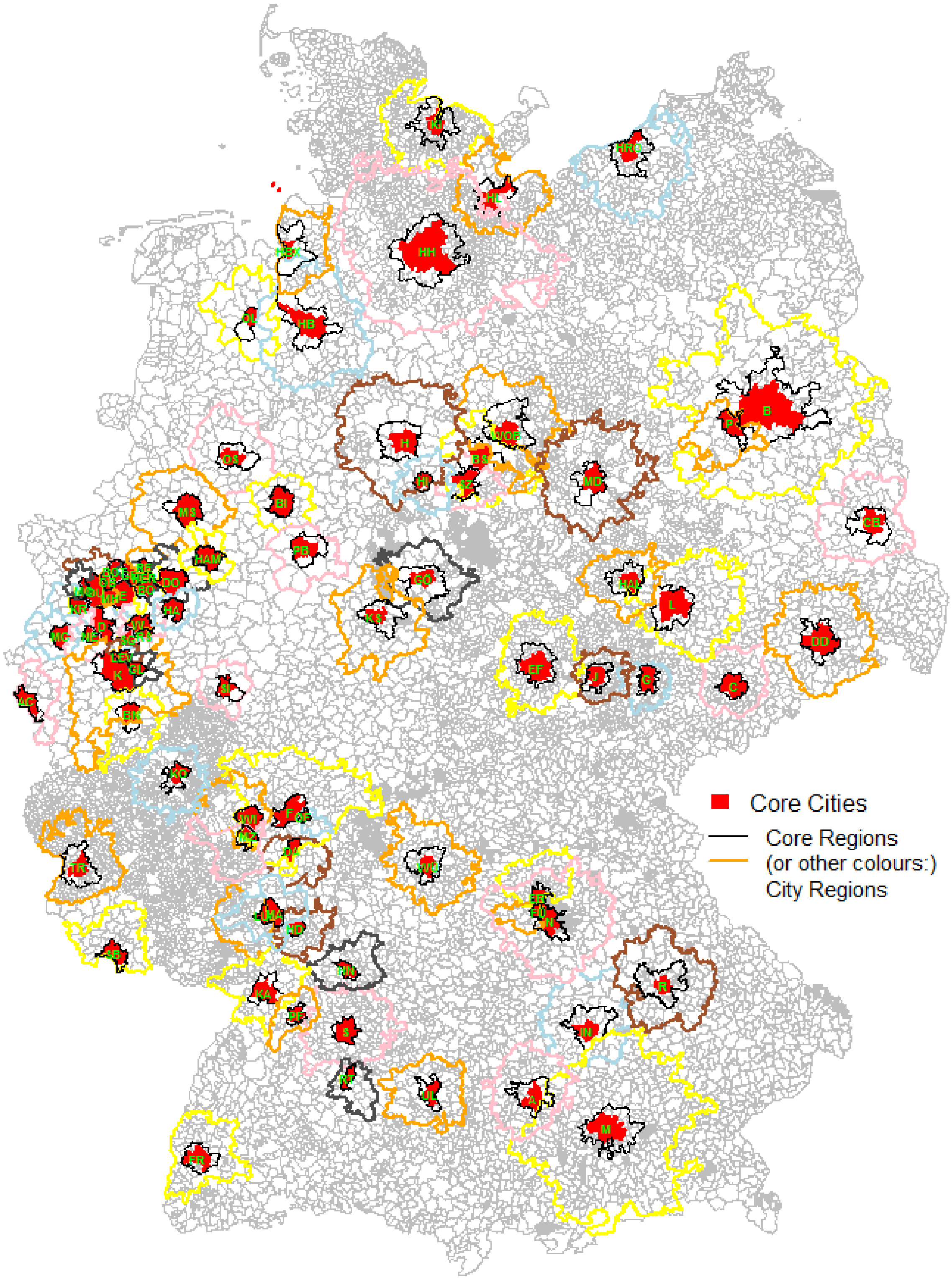
It is impossible to describe comprehensively the resulting characteristics of all 48 variants of delineation that were applied accordingly to fig. 4 above. However, the main distinctions between characteristics of the delineated city regions can be summarised. Firstly, the question of separateness will be considered. In the absence of any particular reasons for delimitating disjoint regions, they should be delineated without regard to this restriction, i.e. they may overlap. They do this increasingly, the lower the threshold values of connectivity between core regions and peripheral municipalities are set. However, if city regions are constructed mainly for the purpose of comparability of agglomerations, overlaps should be allowed. In other cases, the size and shape of city regions may be strongly influenced by the choice of the set of core cities. In order to avoid overlaps, one can merge strongly overlapping regions (whose core cities are strongly linked among themselves) to form polycentric regions. If overlaps are excluded, the optimal allocation of a municipality to exactly one specific core region (and, hence, its separation from other cores) depends on the purpose behind regionalisation. One purpose could be the delineation of borders of metropolitan regions. In a task such as this, perhaps, several criteria should be considered but this would go beyond the scope of the present paper.

Next, the question is from which subset of employees the commuting matrix should be computed. Fig. 6 shows monocentric city regions based on a commuting matrix computed for all employees who are liable to social insurance contributions. A hinterland municipality i is allocated to all core regions j whose coefficients of connectivity γ_{ij} exceed the relatively low threshold value of $\gamma_{\min} = 0.07$.[18] Fig.7 displays monocentric city regions whose hinterland is determined for the same $\gamma_{\min}$ on the basis of the commuting matrix of employees with an academic degree only. It is obvious that the size of the hinterland (the core regions are the same in all variations that have been calculated here) is larger in the case of commuting movements of employees who have a higher qualification than it is for the city regions displayed in fig. 6. Which employment base is the “better one” depends on the purpose of regionalisation. If it is aimed at determining areas in which the more highly educated live and work (which could be an approximation of areas where the functions of decision and control, as well as innovation activities and transport hubs – the so called metropolitan functions[19] – are concentrated), commut-

[18] This threshold value has been chosen because large city regions are more likely to show the effects of the choice of the respective units of the commuting base. Maps of city regions delineated using all 48 variants of the method are available from the author upon request.

[19] See e.g. Hornych/Franz (2010).

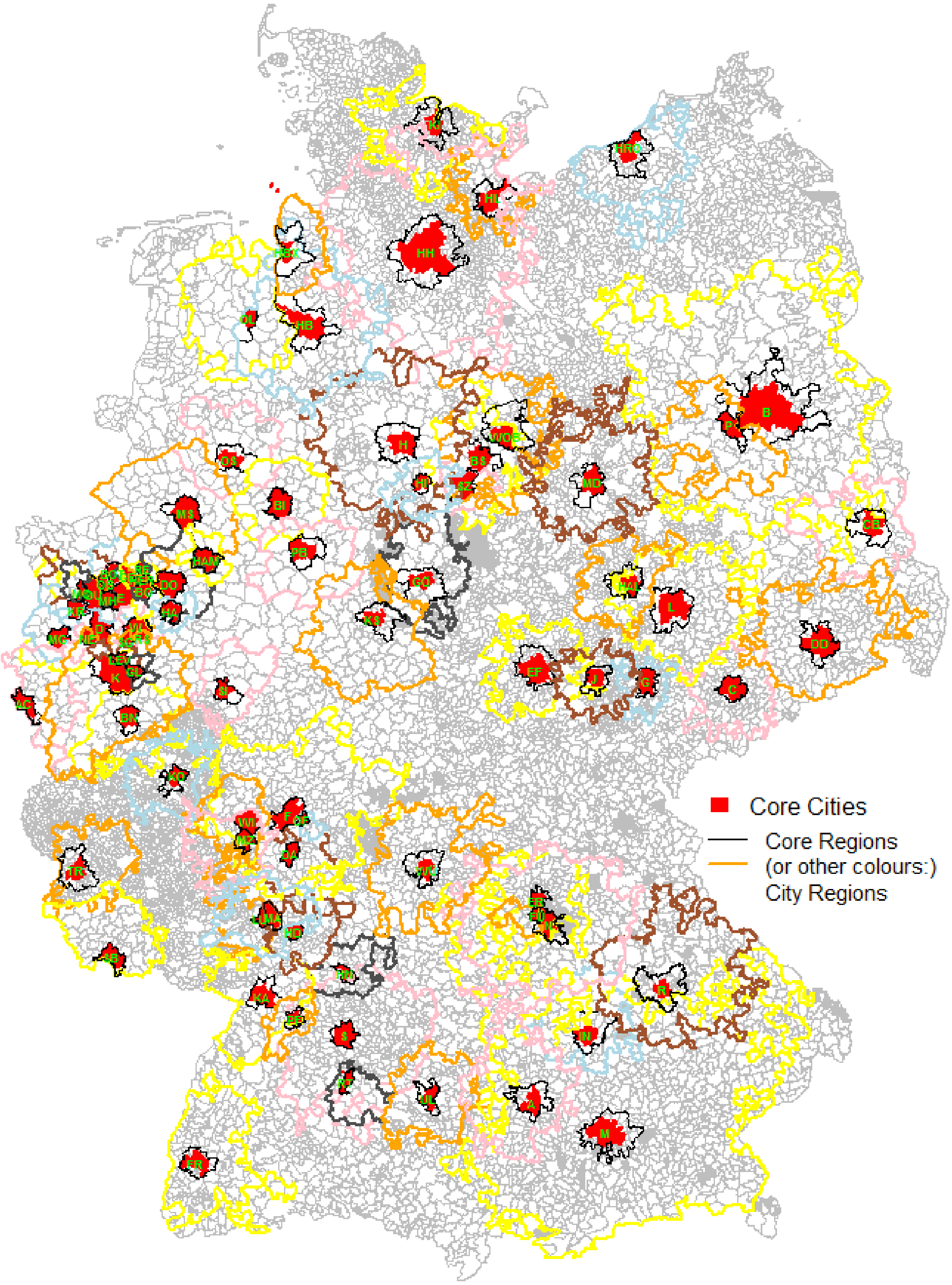
Fig. 6: Non-Disjoint Monocentric City Regions of 81 German Core Cities. Allocation of Hinterland Municipalities based on a Commuting Matrix for All Employees as per 30 June 2008 ($\gamma_{min} = 0.07$)



Source: Own computations based on figures from the German Federal Office of Statistics, Statistics of the Federal Employment Agency, and GIS data from the Office for Cartography and Geodesy.

ing matrices for white-collar employees should be used. For other purposes, commuting patterns of other groups of employees may be of greater relevance.

Fig. 7: Non-Disjoint Monocentric City Regions of 81 German Core Cities. Allocation of Hinterland Municipalities based on a Commuting Matrix for Employees with Academic Degree as per 30 June 2008 ($\gamma_{min} = 0.07$)



Source: Own computations based on figures from the German Federal Office of Statistics, Statistics of the Federal Employment Agency, and GIS data from the Office for Cartography and Geodesy.

One common aim of the delineation of city regions is the achievement of a high self containment. As table A2 in the appendix and the clusters in fig. 5 show, the variation of self containment between core cities (as well as clusters of these) is very high. The far columns of table A2 indicate that both employment and housing self containment improve for smaller threshold values of connectivity. Obviously, this depends heavily on the delineation of the core cities themselves, as well as of their surrounding municipalities. In principle, there are cities which can be compared only by shaping large city regions. These cities are extremely widely delineated (i.e. they contain a number of formerly autonomous small towns or villages that have been amalgamated). This applies, for example, to most municipalities of North Rhine-Westphalia. Comparisons between core cities that are more closely delineated should be possible in a framework of city regions that are more narrowly delineated as well (i.e. using higher thresholds of connectivity).

For all modes of delineation of city regions that are summarised in fig. 4 (p. 6), the relationships between threshold values γ and the resulting ESC and HSC ratios for core cities, core regions and city regions grouped according to the clusters in fig. 5 (p. 7) are displayed in fig. A1 in the appendix. The top half of fig. A1 displays the ESC ratios (on the left) and HSC ratios (on the right) of monocentric city regions, where the upper two charts indicate ESC and HSC ratios of disjoint city regions and the charts below show ESC and HSC ratios of the overlapping ones. The characters used in the charts stem from fig. 5. The horizontal axis label abbreviates the kind of delineation method (cc: core city itself, cr: core region, a1 ... a6: city regions based on commuting matrices for all employees who are subject to social insurance, d1 ... d6: city regions based on commuting patterns of employees with a degree). In particular, the self containment of cities in cluster 8 (that display the lowest self containment of the sample of 81 cities) increases only if the city regions are delineated as overlapping and only in cases of lower thresholds of connectivity.

Table 2: Number of poly- or monocentric city regions (delineation based on different subsets of employees and different minimum thresholds of connectivity)

Minimum Threshold of Connectivity	Subset of employees who are subject to social insurance:	
	all of them	with academic degree only
0.28	80	77
0.20	77	74
0.16	74	67
0.12	68	57
0.09	65	46
0.07	59	40

Source: Own computations based on figures from the German Federal Office of Statistics, Statistics of the Federal Employment Agency, and GIS data from the Office for Cartography and Geodesy.

The lower part of fig. A1 indicates the relationship between minimum connectivity thresholds used for the construction of monocentric city regions and the self containment ratios of the resulting polycentric regions. As already mentioned, polycentric city regions are constructed by merging monocentric regions in cases of pair wise strong links between core regions and other core cities. If the connectivity between them exceeds the minimum threshold, the two monocentric regions are merged. If the core region of the core city considered here is strongly linked to a further core city again, all three city regions are merged, and so on. In this way, chains of mergers can result in very large city regions. However, this occurs only in instances of very low minimum thresholds of connectivity. The resulting polycentric regions may display the features of metropolitan regions. Of course, the more core cities that are linked to larger centres, the more the number of resulting (poly- or monocentric) city regions decreases. Table 2 shows the resulting number of poly- or monocentric city regions for different values of γmin.

With regard to the lower half of fig. A1,[20] one must consider that the number of remaining core cities belonging to the clusters may shrink with the decreasing threshold value of γ_{min}. However, the tendencies deducible from these charts point to the same direction as was shown for monocentric city regions, with two distinctions: firstly, the self containment of polycentric city regions is higher than in case of monocentric delineation. Secondly, the differences between disjoint and overlapping city regions are smaller if polycentric city regions are determined. But, it should also be noticed that the method of delineating polycentric city regions practised here is ad hoc and may yield implausible results. However, these delineation methods may be helpful in determining polycentric city regions e.g. for the sake of evaluating the potential advantages of polycentricity.[21] This could be a question for further research.

The borders of disjoint city regions are determined by the application of two principles: firstly, a municipality should be allocated to the core region to which it is most strongly connected. Secondly, the regions should be contiguous. Four examples of disjoint mono- and polycentric delineations are displayed in figures A2–A5 in the appendix. In addition, the numbers of municipalities that belong to each region, the abbreviations of core cities that are merged into polycentric regions, and the ESC and HSC ratios are reported for disjoint and overlapping polycentric city regions which are based on commuting patterns of employees with an academic degree (for $\gamma_{min} = 0.07$).[22] The choice of colours filling the non-overlapping areas is only for the purpose of enhanced clarity.[23] According to Table A3 (which corresponds to fig. A2–A5), there are only small differences in self containment ratios between disjoint and overlapping polycentric city regions. Exceptions are the city regions in North-Rhine Westphalia. The delineation of strongly self contained disjunct city regions in the Rhine-Ruhr area probably requires the application of a minimum threshold of connectivity lower than 0.07, related to commuting employees with an academic degree.

Another peculiarity displayed in Table A3 is the relatively low self containment of the East German city regions. Those whose core city is the capital of a Land display, even for the very low $\gamma_{min} = 0.07$, very small HSC ratios (in particular the cities of Dresden, Erfurt and Magdeburg). Other East German cities display notably small ESC ratios (particularly, the cities of Chemnitz, Cottbus, Gera and Jena). This may be caused by different political and economic functions in these groups of cities, which may result in different commuting patterns: while a relatively large group of persons employed in services with higher centrality (and spatial coverage) resides in the old (western) states of Germany and commutes to the East, the cities with less central functionality are home to a larger group of less qualified employees who commute – particularly from East German cities with high unemployment – to the west. In order to investigate this question more carefully, the application of the concept of the city region may also be useful (as a matter for future research).

[20] In order to avoid redundancies, only the self containment ratios of the resulting city regions are displayed in these four charts.

[21] See e.g. Meijers (2007b) p. 117 f. and Limtanakool et al. (2007) p. 2129 f. For approaches to a measurement concept for polycentricity, see Meijers (2008). Regarding the concept of polycentric urban regions, see Parr (2004).

[22] Here too, the maps generated by application of the lowest γ_{min} have been chosen for a clearer demonstration of the effects of different (sub-)sets of commuters on the size of city regions.

[23] The maps of overlapping city regions (Fig. 6 and 7) display only the borders of the respective city regions (for the sake of separability). The allocation of colours to certain core cities remains constant in all maps.

5. Effects of regionalisation on local specialisation

One potential application of the concept of city regions is the measurement of local (or regional) specialisation. For example, as a precondition of successful cooperation within polycentric metropolitan regions, the largest cities as the main players in this game should display complementarities in industrial specialisation.[24] In this section, the patterns of specialisation in the 81 German cities of the sample are analysed for the core cities itself and for different kinds of functional regions. In comparing functional specialisation, the *coefficient of regional specialisation* (*CRS*) is used, which can be computed for each local unit (i.e. core city, core region or city region) *i* as

$$CRS_i = \frac{1}{2}\sum_{j=1}^{n}\left|s_{ij} - s_j\right| \quad , s_{ij} = \frac{E_{ij}}{\sum_j E_{ij}}, \qquad s_j = \frac{E_j}{E}.$$ [25]

Here, s_{ij} is the share of employment E_{ij} in industry j located in i, s_j the share of employment E_j in the respective industry of the total employment E in the country (here: total number of employees who are subject to social insurance in Germany), where the set of j covers all industries of a certain classification (here: the first two digits of WZ 2003 classification of industrial sectors, whose total number is n= 60). The *CRS* takes values between 0 (location i has the specialisation pattern of the country – no specialisation) and 1 (all employees in i occupy industries that are present in i only – full specialisation). One and the same *CRS* value can indicate specialisation in completely different industries, hence it should be interpreted carefully, and only in the sense that the employment in a location i is more or less specialised in one or several industrial sectors. The advantage of such a global measure is its simple comparability over locations by ranking. It should be noted that *CRS* are computed for all employees who are liable to social security contributions and who are part of the respective labour force E, E_i and E_{ij}, regardless of the set of employees whose commuting relations are the base of the delineation of the hinterland of the city region.

Tables A4 and A5 in the appendix display the rankings of *CRS* computed for the 81 core cities, core regions and monocentric overlapping city regions based on commuting matrices both for all employees and for employees with an academic degree only. The columns of table A4 show the abbreviations of core cities ordered by rank. This is useful for determining groups of cities occupying certain intervals of the vectors. The rows of table A5 show the ranks of the respective city region delineated by different methods. For each commuting matrix, all six minimum threshold values of $\boldsymbol{\gamma}$ are applied.

The changing order of cities (or city regions) regarding their specialisation reflects certain patterns, particularly in the upper and the lower tails of the column vectors of table A4 that appear more clearly in the city regions based on commuting relations of employees with an academic degree. Firstly, the *CRS* of core cities that are highly specialised diminishes if these cities are considered as single units together with increasing parts of their hinterland. Secondly, large FURs with a huge hinterland occupy the lowest positions of this ranking (e.g. Hannover, Munich, Dortmund and Cologne), if the minimum threshold of connectivity is small. Hence, the dispersion of the *CRS* decreases if the regions are more broadly delineated. Thirdly, the ranks of some city regions indicate increasing specialisation for decreasing minimum thresholds of connectivity (e.g. Bottrop, Herne). Bottrop as well as Herne remains alone for all kinds of monocentric delineation (see table A2). Therefore, their *CRS* is constant for all methods of delinea-

[24] See, for example, Meijers (2007a) and Franz/Hornych (2010). Both contributions investigate specialisation patterns of core cities. Meijers (2007b) discusses this shortcoming as "[d]ue to divergent delimitations of functional urban areas, or the absence thereof" (p. 893).

[25] See e.g. Robson (2009); Midelfart-Knarvik et al. (2000) use a similar measure.

tion applied here; the observed pattern has its roots solely in the patterns of changing specialisation of other cities (or city regions) that move downwards in this ranking. Fourthly, the regularity of decreasing relative specialisation of large metropolitan areas for decreasing minimum thresholds of connectivity does not hold in every case: one important exception is Berlin, the German capital. From the group of state capitals, only the city region of Rostock (the capital of Mecklenburg-Vorpommern) does not despecialise, related to the other city regions, if its hinterland is delineated more broadly. However, despite these exceptions one can conclude that relative specialisation of city regions decreases if their core city is a state capital and/or if other highly centralised functions are located there. One the other hand, cities with relatively strong specialisation may hold their rank position of *CRS* or even move up in the rankings if additional municipalities with similar specialisations are included in their hinterland (e.g. Cottbus, Pforzheim).

Table A6 presents the rank correlations of *CRS*, calculated for cities, core regions and overlapping city regions that were delineated for different groups of commuters, applying the set of six different threshold values of $\gamma_{\min}$. The increasingly different correlation coefficients point to strong effects on the perception of economic structure from different methods of delineation of city regions.

This analysis of specialisation patterns should be regarded as a limited exercise. Its main purpose was to confirm that the impression left by rankings of some characteristics (e.g. industrial specialisation) of a certain kind of location (e.g. cities in their administrative borders) depends very heavily on the choice of method of delineation of the spatial units of consideration. A more comprehensive investigation of this topic will be the subject of a more specific paper.[26]

6. Conclusions

The aim of this paper was to present a simple method of delineation of city regions that is applicable to and modifiable for different purposes.

The main findings are summarised as follows:

1. The consideration of commuting flows in both directions increases the size of the hinterland of those core cities that are functionally specialised as places of residence of employees. Comparisons with city regions that are delineated taking into account only out-commuting flows from hinterland municipalities to the core show that this phenomenon is peculiar to cities which have a high concentration of scientific institutions and which are surrounded by municipalities with many manufacturing industries. Increasing the weight of these cities relative to other city regions could be an advantage when compared to methods that consider thresholds of shares of commuters directed only to the core city, as opposed to the total mass of employees residing in the hinterland municipalities.
2. The variations in the commuting base may be useful to special purposes of regionalisation. In particular, the delineation of regions that could display the labour mobility of skilled (or managerial) professions requires such modification.
3. If city regions must be disjoint, the selection of core cities exerts a strong influence on the size and shape of the resulting city regions. If city regions have to be delineated, particularly for the purpose of comparison of some (e.g. demographic or economic) characteristics, overlapping regions could be an appropriate way out of this

[26] For exhaustive methods of regionalisation, some investigations of the effects of delineation on the perceived economic structure of regions exist (e.g. Menon, 2011; Briant et al., 2010). However, these effects of regionalisation have not as yet been analysed for city regions.

quandary. Alternately, the choice of higher threshold values could help, if the structure of the settlement is sufficiently fragmented. In addition, amalgamating overlapping monocentric city regions with disjoint polycentric regions diminishes the influence of the selection of the sample of core cities.

4. A general shortcoming of methods applying threshold values to single commuting flows between pairs of spatial units is their sensitivity to size heterogeneity of these spatial units. The application of one and the same threshold value of minimum connectivity between the core regions and surrounding municipalities for different settlement structures may yield unsatisfactory results: on the one hand, large basic spatial units may be strongly interconnected although the coefficients of connectivity between them are rather low. On the other, spatial units in highly fragmented regions indicate high coefficients of connectivity but these depend on the labour mobility of single individuals. The amalgamation of small spatial units applying particular criteria (e.g. members of associations of municipalities) seems rather arbitrary and does not really solve the problem. In order to overcome the dilemma, the application of other methods should be considered: for example, a transformed commuting matrix could be used as input for a hierarchical aggregation procedure that indicates city regions taking into consideration the total mass of commuting flows.[27]
5. Besides the shortcomings of the method presented here, there are several potential fields of research that could profit by their use. Some examples have been addressed above: the discovery of (non)complementarities between city regions which are potential candidates in shaping a polycentric urban region, the East-West divide of commuting relations within Germany, the different patterns of specialisation of city regions in different tiers of the urban hierarchy. A further application could be the investigation of commuting (and other) flows between city regions.[28]

An unsolved question at this point is the determination of the "right" threshold values for coefficients of connectivity as a criterion for "merging" municipalities into city regions. In order to prevent the concept of city region falling prey to arbitrariness, it should be made clear that answers to this question must be based on theory. This – or the application of alternative methods – could be the subject of future research.

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[27] The "intramax method" presented by Masser/Scheurwater (1980) could be appropriate for the delineation of city regions. For an overview of hierarchical aggregation procedures, see Fischer (1982).

[28] An application to this topic has been made by the author who investigated the commuting relations between the city regions of the core cities that form the metropolitan area of "Central Germany" (Kauffmann, 2011 and 2012).

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Appendix: Tables and Figures

Table A1: Cities in Germany with more than 100 000 Inhabitants: Inhabitants and Density of Population per 31 December 2007

Name of the city	Ab-bre-via-tion	Inhab-itants	Dens. of Pop.	Name of the city	Ab-bre-via-tion	Inhab-itants	Dens. of Pop.
Aachen	AC	259030	1611	Koblenz	KO	106087	1010
Augsburg	A	262992	1791	Köln	K	995397	2457
Bergisch Gladbach	GL	105840	1273	Krefeld	KR	236516	1717
Berlin	B	3416255	3834	Leipzig	L	510512	1717
Bielefeld	BI	324912	1260	Leverkusen	LEV	161345	2046
Bochum	BO	381542	2623	Ludwigshafen am Rhein	LU	163777	2112
Bonn	BN	316416	2241	Lübeck	HL	211541	988
Bottrop	BOT	118597	1179	Magdeburg	MD	230140	1145
Braunschweig	BS	245810	1281	Mainz	MZ	198118	2027
Bremen	HB	547769	1683	Mannheim	MA	309795	2137
Bremerhaven	HBX	115313	1462	Moers	MO	107111	1582
Chemnitz	C	244951	1109	Mönchengladbach	MG	260018	1525
Cottbus	CB	102811	626	Mülheim an der Ruhr	MH	168925	1850
Darmstadt	DA	142191	1165	München	M	1311573	4225
Dortmund	DO	586909	2093	Münster	MS	272951	901
Dresden	DD	507513	1546	Neuss	NE	151449	1522
Düsseldorf	D	581122	2678	Nürnberg	N	503110	2699
Duisburg	DU	496665	2133	Oberhausen	OB	217108	2816
Erfurt	EF	202929	754	Offenbach am Main	OF	118245	2634
Erlangen	ER	104650	1362	Oldenburg (Oldenburg)	OL	159563	1550
Essen	E	582140	2768	Osnabrück	OS	162870	1360
Frankfurt am Main	F	659021	2654	Paderborn	PB	144181	804
Freiburg/Breisgau	FR	219430	1434	Pforzheim	PF	119423	1218
Fürth	FÜ	114130	1802	Potsdam	P	150833	805
Gelsenkirchen	GE	264765	2525	Recklinghausen	RE	120536	1814
Gera	G	101618	669	Regensburg	R	132495	1642
Göttingen	GÖ	121513	1036	Remscheid	RS	113935	1527
Hagen	HA	193748	1208	Reutlingen	RT	112458	1292
Halle (Saale)	HAL	234295	1735	Rostock	HRO	200413	1105
Hamburg	HH	1770629	2344	Saarbrücken	SB	176452	1056
Hamm	HAM	183065	809	Salzgitter	SZ	105320	470
Hannover	H	518069	2538	Siegen	SI	105049	916
Heidelberg	HD	145311	1335	Solingen	SG	162575	1817
Heilbronn	HN	121627	1218	Stuttgart	S	597176	2880
Herne	HER	168454	3277	Trier	TR	103888	887
Hildesheim	HI	103593	1124	Ulm	UL	121434	1023
Ingolstadt	IN	123055	923	Wiesbaden	WI	275849	1353
Jena	J	102752	898	Wolfsburg	WOB	120009	588
Karlsruhe	KA	288917	1666	Würzburg	WÜ	135212	1543
Kassel	KS	193803	1815	Wuppertal	W	356420	2117
Kiel	KI	236902	1997				

Source: German Federal Office for Statistics: List of municipalities 31 December 2007

Table A2: FURs of German Cities with over 100 000 inhabitants:[a] Number of Municipalities Belonging to the Corresponding Ring of the FUR (Num. of Mun.), In-/Out-commuting Relations (I/O), Employment Self Containment (ESC), Housing Self Containment (HSC)

Core City (Abbr.)	Core Cities			Core Region				City Region							
								Disjoint				Overlapping			
	I/O	ESC	HSC	Num. of Mun.	I/O	ESC	HSC	Num. of Mun.	I/O	ESC	HSC	Num. of Mun.	I/O	ESC	HSC
AC	2.8	0.73	0.49	1	2.5	0.72	0.50	23	1.0	0.84	0.84	31	0.9	0.83	0.88
A	2.1	0.65	0.47	10	1.4	0.77	0.65	87	1.0	0.81	0.80	158	0.9	0.79	0.85
GL	0.9	0.36	0.39	0	0.9	0.36	0.39	0	0.9	0.36	0.39	4	0.6	0.40	0.55
B	1.7	0.86	0.79	29	1.2	0.88	0.84	259	0.9	0.89	0.91	273	0.9	0.91	0.93
BI	1.9	0.73	0.59	0	1.9	0.73	0.59	29	1.1	0.88	0.81	32	1.1	0.88	0.82
BO	1.2	0.56	0.52	0	1.2	0.56	0.52	2	1.0	0.59	0.59	8	0.9	0.64	0.68
BN	2.7	0.65	0.41	2	2.0	0.66	0.47	88	1.0	0.69	0.70	118	0.9	0.70	0.76
BOT	0.8	0.38	0.44	0	0.8	0.38	0.44	0	0.8	0.38	0.44	0	0.8	0.38	0.44
BS	2.2	0.69	0.5	7	1.4	0.69	0.59	41	0.9	0.68	0.72	97	1.1	0.86	0.81
HB	3.2	0.81	0.57	7	1.8	0.84	0.66	91	1.1	0.86	0.84	137	1.1	0.88	0.85
HBX	2.7	0.75	0.53	7	1.1	0.79	0.74	27	0.9	0.82	0.84	38	0.9	0.80	0.86
C	2.1	0.71	0.54	1	2.0	0.72	0.55	95	0.9	0.79	0.82	98	0.9	0.78	0.82
CB	2.1	0.67	0.49	6	1.4	0.69	0.58	46	1.0	0.76	0.78	49	0.9	0.76	0.78
DA	2.8	0.55	0.30	0	2.8	0.55	0.30	39	0.9	0.66	0.71	53	0.9	0.66	0.73
DO	1.4	0.64	0.57	0	1.4	0.64	0.57	19	0.9	0.71	0.75	28	0.9	0.76	0.78
DD	2.1	0.77	0.61	5	1.8	0.8	0.66	149	1.0	0.86	0.86	152	1.0	0.86	0.86
D	3.6	0.69	0.38	0	3.6	0.69	0.38	23	1.4	0.69	0.57	51	1.2	0.85	0.79
DU	1.1	0.56	0.53	0	1.1	0.56	0.53	11	0.9	0.57	0.62	18	0.9	0.66	0.72
EF	2.6	0.74	0.51	23	1.9	0.75	0.57	149	1.1	0.81	0.76	161	1.1	0.81	0.77
ER	3.8	0.64	0.32	6	2.7	0.65	0.37	55	1.0	0.69	0.67	106	1.2	0.87	0.77
E	1.7	0.62	0.50	0	1.7	0.62	0.50	7	1.2	0.61	0.57	20	1.0	0.78	0.78
F	4.9	0.71	0.34	3	4.1	0.72	0.36	228	1.2	0.82	0.74	322	1.1	0.89	0.82
FR	3.2	0.72	0.45	17	1.8	0.76	0.57	129	1.0	0.87	0.84	129	1.0	0.87	0.84
FÜ	0.9	0.32	0.34	0	0.9	0.32	0.34	0	0.9	0.32	0.34	17	0.6	0.38	0.54
GE	0.9	0.47	0.49	0	0.9	0.47	0.49	0	0.9	0.47	0.49	2	0.8	0.49	0.56
G	1.3	0.61	0.56	9	1.2	0.63	0.57	63	0.9	0.65	0.71	72	0.9	0.66	0.71
GÖ	3.9	0.75	0.44	9	1.6	0.8	0.62	67	1.0	0.81	0.82	68	1.0	0.81	0.82
HA	1.3	0.64	0.57	0	1.3	0.64	0.57	4	1.1	0.63	0.60	6	1.0	0.66	0.65
HAL	1.6	0.66	0.54	17	1.2	0.68	0.62	116	0.9	0.70	0.74	132	1.0	0.74	0.75
HH	3.3	0.84	0.62	42	1.9	0.89	0.71	536	1.1	0.90	0.86	669	1.1	0.91	0.87
HAM	0.9	0.61	0.63	0	0.9	0.61	0.63	1	0.8	0.59	0.65	6	0.8	0.60	0.68
H	3.3	0.72	0.44	8	1.8	0.83	0.60	152	1.0	0.86	0.84	180	1.0	0.87	0.87
HD	3.3	0.59	0.31	1	2.7	0.61	0.34	50	1.1	0.70	0.67	65	1.3	0.78	0.67
HN	2.1	0.55	0.37	1	1.9	0.56	0.39	40	1.0	0.75	0.74	52	1.0	0.77	0.77
HER	0.9	0.39	0.41	0	0.9	0.39	0.41	0	0.9	0.39	0.41	0	0.9	0.39	0.41
HI	2.1	0.64	0.45	1	1.9	0.65	0.48	12	1.0	0.67	0.67	33	0.8	0.65	0.76
IN	3.3	0.69	0.40	18	1.5	0.79	0.62	34	1.1	0.81	0.78	54	0.9	0.78	0.82
J	2.1	0.72	0.55	18	1.6	0.73	0.60	105	1.0	0.71	0.73	139	0.9	0.73	0.75
KA	2.8	0.68	0.43	4	1.8	0.72	0.53	131	1.1	0.83	0.81	149	1.0	0.85	0.83
KS	3.1	0.66	0.39	12	1.5	0.76	0.60	67	0.9	0.82	0.86	73	0.9	0.83	0.87
KI	2.6	0.72	0.50	46	1.3	0.81	0.69	188	1.1	0.84	0.81	207	1.1	0.84	0.81
KO	3.7	0.65	0.33	13	2.3	0.65	0.40	221	1.0	0.80	0.78	237	1.0	0.81	0.79
K	2.4	0.72	0.51	1	2.2	0.73	0.53	67	1.0	0.74	0.73	111	1.0	0.84	0.82
KR	1.4	0.57	0.48	0	1.4	0.57	0.48	6	1.0	0.61	0.59	7	1.0	0.61	0.61
L	2.0	0.74	0.58	8	1.6	0.80	0.67	133	1.0	0.79	0.8	161	1.1	0.83	0.81

[a] Municipalities belonging to the hinterland (e.g. the outer ring of municipalities of a specific city region) are determined using a commuting matrix of employees with academic degree for a connectivity coefficient of $\gamma_{min} = 0.07$.

Table continues on next page.

Table A2 (continuation).

Core City (Abbr.)	Core Cities			Core Region				City Region							
								Disjoint				Overlapping			
	I/O	ESC	HSC	Num. of Mun.	I/O	ESC	HSC	Num. of Mun.	I/O	ESC	HSC	Num. of Mun.	I/O	ESC	HSC
LEV	1.2	0.52	0.48	0	1.2	0.52	0.48	0	1.2	0.52	0.48	6	0.8	0.50	0.56
LU	2.4	0.54	0.33	0	2.4	0.54	0.33	71	1.0	0.67	0.69	85	1.3	0.78	0.68
HL	2.1	0.71	0.54	13	1.3	0.75	0.66	59	1.0	0.75	0.75	88	1.0	0.74	0.75
MD	2.2	0.72	0.53	7	1.8	0.76	0.59	190	1.0	0.80	0.81	199	1.0	0.79	0.81
MZ	2.1	0.55	0.37	5	1.8	0.55	0.40	163	1.0	0.66	0.68	194	1.1	0.74	0.71
MA	2.8	0.65	0.40	1	2.6	0.65	0.41	57	1.1	0.65	0.63	135	1.0	0.77	0.79
MO	0.8	0.32	0.37	0	0.8	0.32	0.37	0	0.8	0.32	0.37	5	0.7	0.46	0.57
MG	1.1	0.59	0.57	0	1.1	0.59	0.57	2	0.9	0.57	0.60	10	0.7	0.61	0.73
MH	1.1	0.44	0.43	0	1.1	0.44	0.43	0	1.1	0.44	0.43	0	1.1	0.44	0.43
M	2.5	0.75	0.54	33	1.9	0.87	0.64	719	1.0	0.89	0.87	891	1.0	0.90	0.89
MS	3.1	0.75	0.5	1	2.8	0.75	0.51	46	1.0	0.81	0.82	54	0.9	0.81	0.84
NE	1.4	0.43	0.36	0	1.4	0.43	0.36	0	1.4	0.43	0.36	3	1.0	0.47	0.49
N	3.1	0.73	0.47	5	2.3	0.74	0.51	155	1.1	0.81	0.77	245	1.0	0.89	0.88
OB	0.8	0.41	0.48	0	0.8	0.41	0.48	0	0.8	0.41	0.48	0	0.8	0.41	0.48
OF	1.2	0.34	0.29	0	1.2	0.34	0.29	0	1.2	0.34	0.29	6	0.8	0.43	0.50
OL	2.1	0.67	0.48	1	1.8	0.68	0.52	44	0.9	0.78	0.81	53	0.9	0.76	0.82
OS	2.8	0.66	0.40	5	1.5	0.72	0.57	42	1.0	0.80	0.80	47	1.0	0.81	0.82
PB	2.3	0.69	0.50	3	1.5	0.72	0.60	20	0.8	0.73	0.8	23	0.8	0.73	0.81
PF	1.6	0.59	0.47	2	1.4	0.59	0.50	18	0.9	0.69	0.72	31	0.9	0.73	0.79
P	1.7	0.52	0.39	1	1.5	0.52	0.41	0	1.5	0.52	0.41	38	0.9	0.63	0.67
RE	0.9	0.38	0.41	0	0.9	0.38	0.41	2	0.7	0.43	0.53	6	0.7	0.55	0.67
R	5.1	0.71	0.33	23	1.6	0.75	0.56	135	1.0	0.81	0.82	154	0.9	0.80	0.84
RS	1.2	0.64	0.59	0	1.2	0.64	0.59	2	1.1	0.67	0.65	3	1.0	0.69	0.71
RT	1.5	0.55	0.44	0	1.5	0.55	0.44	22	0.8	0.62	0.72	28	0.8	0.68	0.77
HRO	1.6	0.71	0.61	24	1.2	0.78	0.72	101	0.9	0.82	0.86	101	0.9	0.82	0.86
SB	3.5	0.68	0.37	1	3.1	0.69	0.40	71	1.0	0.91	0.91	76	1.0	0.91	0.91
SZ	2.1	0.67	0.49	5	1.7	0.67	0.52	4	1.5	0.66	0.54	21	0.8	0.58	0.67
SI	1.7	0.58	0.45	2	1.4	0.64	0.54	52	1.0	0.81	0.83	52	1.0	0.81	0.83
SG	0.7	0.60	0.68	0	0.7	0.60	0.68	0	0.7	0.60	0.68	1	0.8	0.58	0.64
S	3.3	0.68	0.39	1	3.1	0.68	0.40	271	1.1	0.89	0.86	319	1.0	0.89	0.88
TR	4.5	0.76	0.42	37	1.6	0.82	0.63	185	1.1	0.86	0.82	188	1.1	0.85	0.81
UL	3.6	0.64	0.33	4	2.4	0.65	0.39	94	1.0	0.81	0.81	100	1.0	0.81	0.81
WI	1.8	0.58	0.43	0	1.8	0.58	0.43	50	1.1	0.63	0.59	118	1.0	0.67	0.68
WOB	9.6	0.85	0.37	24	2.3	0.83	0.53	96	1.1	0.78	0.75	139	1.1	0.87	0.83
WÜ	3.8	0.67	0.35	25	1.5	0.77	0.60	132	1.1	0.85	0.80	138	1.1	0.85	0.81
W	1.1	0.65	0.63	0	1.1	0.65	0.63	5	1.0	0.67	0.67	10	1.0	0.74	0.75

Source: Own computations based on figures from the German Federal Office of Statistics, Statistics of the Federal Employment Agency, and GIS data from the Office for Cartography and Geodesy.

Table A3: 40 Poly- and Monocentric City Regions:[a] Number of Municipalities Linked to the Core City, Other Core Cities within the City Region (Abbreviations), Employment Self Containment (ESC), Housing Self Containment (HSC)

	Disjoint Poly- and Monocentric City Regions				Overlapping Poly- and Monocentric City Regions			
Core City (Abbr.)	Num. of Mun.	Other Core Cities	ESC	HSC	Num. of Mun.	Other core Cities	ESC	HSC
AC	24		0.84	0.84	32		0.83	0.88
B	289	P	0.91	0.93	303	P	0.91	0.93
BI	29		0.88	0.81	32		0.88	0.82
BS	179	SZ WOB	0.86	0.85	195	SZ WOB	0.85	0.86
HB	179	OL HBX	0.88	0.88	199	OL HBX	0.89	0.89
C	96		0.79	0.82	99		0.78	0.82
CB	52		0.76	0.78	55		0.76	0.78
DO	24	HA	0.74	0.77	31	BO HA	0.76	0.78
DD	154		0.86	0.86	157		0.86	0.86
D	71	DU E KR MG MH OB W MO BOT GE RE BO HER	0.87	0.83	83	DU E KR MG MH OB RS SG W NE MO BOT GE RE BO HER	0.89	0.87
EF	172		0.81	0.76	184		0.81	0.77
F	492	DA OF WI MZ	0.91	0.85	504	DA OF WI MZ	0.90	0.85
FR	146		0.87	0.84	146		0.87	0.84
G	72		0.65	0.71	81		0.66	0.71
GÖ	76		0.81	0.82	77		0.81	0.82
HH	651	HL	0.91	0.87	730	HL	0.91	0.88
H	174	HI	0.87	0.86	196	HI	0.86	0.87
HN	41		0.75	0.74	53		0.77	0.77
J	123		0.71	0.73	157		0.73	0.75
KA	156	PF	0.85	0.83	167	PF	0.85	0.85
KS	79		0.82	0.86	85		0.83	0.87
KI	234		0.84	0.81	253		0.84	0.81
KO	234		0.80	0.78	250		0.81	0.79
K	166	RS SG NE BN LEV GL	0.84	0.83	195	RS SG NE BN LEV GL	0.84	0.83
L	275	HAL	0.83	0.85	276	HAL	0.83	0.85
MD	197		0.80	0.81	206		0.79	0.81
MA	182	LU HD	0.85	0.83	196	LU HD	0.84	0.84
M	903	IN A	0.92	0.90	988	IN A	0.90	0.90
MS	49	HAM	0.81	0.82	58	HAM	0.80	0.83
N	223	ER FÜ	0.89	0.86	253	ER FÜ	0.89	0.88
OS	47		0.80	0.80	52		0.81	0.82
PB	23		0.73	0.80	26		0.73	0.81
R	158		0.81	0.82	177		0.80	0.84
HRO	125		0.82	0.86	125		0.82	0.86
SB	72		0.91	0.91	77		0.91	0.91
SI	54		0.81	0.83	54		0.81	0.83
S	295	RT	0.91	0.88	325	RT	0.89	0.88
TR	222		0.86	0.82	225		0.85	0.81
UL	98		0.81	0.81	104		0.81	0.81
WÜ	157		0.85	0.80	163		0.85	0.81

[a] Municipalities belonging to the hinterland (e.g. the outer ring of municipalities of a specific city region) are determined using a commuting matrix of employees with academic degree for a connectivity coefficient of $\gamma_{min} = 0.07$ related to the particular core region of 81 monocentric city regions. Pairs of monocentric city regions are merged if γ_{min} between one of these core cities and the core region of the other exceeds 0.07.

Source: Own computations based on figures from the German Federal Office of Statistics, Statistics of the Federal Employment Agency, and GIS data from the Office for Cartography and Geodesy.

Table A4: Coefficients of Regional Specialisation, Computed for 81 German Core Cities, Core Regions, and Overlapping Monocentric City Regions Delineated by Different Methods (Abbreviations of Core Cities in Rank Order)

	Core City	Core Region	City Regions Based on Commuting Relations of All Employees, γ_{min} = …						City Regions Based on Commuting Relations of Employees with Academic Degree, γ_{min} = …					
			0.28	0.20	0.16	0.12	0.09	0.07	0.28	0.20	0.16	0.12	0.09	0.07
1	WOB	WOB	WOB	WOB	WOB	WOB	WOB	WOB	WOB	WOB	SZ	SZ	LEV	HER
2	ER	LU	ER	LU	ER	ER	ER	ER	LU	SZ	WOB	LEV	SZ	SZ
3	LU	ER	LU	ER	SZ	SZ	LEV	HER	SZ	LU	LEV	RS	HER	NE
4	IN	SZ	SZ	SZ	LEV	LEV	HER	PF	ER	ER	NE	NE	WOB	PF
5	SZ	IN	LEV	LEV	LU	LU	IN	IN	IN	LEV	BS	WOB	NE	RS
6	F	F	IN	IN	PF	IN	LU	RS	LEV	NE	IN	PF	IN	IN
7	P	LEV	F	F	P	HER	SZ	LEV	F	IN	HER	HER	RS	BOT
8	LEV	P	P	P	IN	P	P	SZ	P	P	RS	IN	PF	MH
9	BN	BN	BN	NE	HER	CB	RS	BOT	NE	HER	P	P	BOT	WOB
10	CB	DA	DA	PF	CB	PF	PF	MO	HER	CB	ER	CB	MH	CB
11	DA	CB	NE	HER	J	NE	CB	CB	CB	PF	LU	ER	BS	SI
12	J	J	HER	CB	NE	HD	MH	P	J	OF	OF	BS	MO	MO
13	HAL	NE	D	J	F	RS	BOT	HBX	D	RS	PF	BOT	CB	HBX
14	GÖ	D	CB	OF	RS	J	J	J	OF	J	CB	MH	SI	LEV
15	S	MZ	J	RS	BOT	BOT	MO	HD	RS	BOT	BOT	SI	SG	BS
16	NE	HER	PF	BOT	MH	MH	HD	RE	HD	MH	MH	SG	OF	SG
17	HD	S	OF	MH	EF	MO	NE	NE	EF	F	J	HBX	HBX	RE
18	HRO	HAL	RS	EF	BN	SG	OF	SI	PF	SG	SG	OF	RE	HRO
19	MZ	HD	EF	D	SG	F	HBX	LU	BOT	HBX	SI	MO	LU	OF
20	D	EF	BOT	BN	SI	OF	SI	HA	DA	MO	HBX	LU	J	J
21	EF	GÖ	HD	SG	GÖ	HBX	F	RT	MH	DU	MO	J	HRO	TR
22	HER	OF	MH	GÖ	MZ	SI	SG	SG	MZ	MZ	HD	RT	P	OB
23	M	RS	MZ	HD	HBX	RE	HA	HRO	BN	RE	F	HRO	GÖ	HN
24	MD	M	GÖ	DA	OF	BN	RT	TR	SG	HD	HN	RE	HD	RT
25	DD	BOT	S	MZ	DA	RT	D	MH	WI	HAL	RT	HD	TR	P
26	OF	MH	SG	HN	HAL	MZ	RE	OB	MO	BN	D	HAM	OB	HA
27	RS	MS	WI	MO	HD	D	HAL	D	GÖ	SI	HRO	GÖ	GE	GÖ
28	G	HI	HBX	DU	D	EF	HRO	GÖ	DU	D	GÖ	HA	HAM	GE
29	TR	WI	HAL	HBX	HN	HAL	MZ	OF	HAL	EF	RE	HI	RT	W
30	KO	G	MO	HAL	MO	HRO	TR	W	HBX	DA	HAM	TR	W	HL
31	PB	PF	DU	RE	RT	S	OB	HAL	HI	GÖ	HAL	OB	HA	HAM
32	FR	KO	K	SI	RE	GÖ	GÖ	F	RE	HAM	HA	HN	HL	HI
33	MS	SG	MD	HRO	HAM	TR	DA	HN	HRO	HRO	HI	GE	HN	KR
34	HH	K	KA	WI	HRO	HA	HN	HAM	MD	HI	OB	HAL	HAL	B
35	R	AC	SB	MD	HI	OB	GE	GE	KR	HA	DU	DA	ER	PB
36	BOT	DD	RE	S	OB	HN	B	HL	HAM	HL	MA	GL	B	HAL
37	MH	MD	M	HAM	WI	DA	S	B	HA	WI	GE	EF	PB	FÜ
38	OL	HBX	G	HI	DU	HAM	EF	DA	B	OB	KR	F	KR	WI
39	HBX	PB	HRO	TR	GE	B	W	S	OB	GE	EF	HL	FÜ	GL
40	HI	OL	TR	HA	B	KI	HAM	WI	SI	KR	HL	B	GL	UL
41	L	SB	AC	B	TR	MA	KI	BN	RT	RT	WI	G	F	ER
42	WI	KA	HI	OB	KI	GE	G	MZ	HL	B	DA	FÜ	HI	KI

Table continues on next page.

Table A4 (continuation)

	Core City	Core Region	City Regions Based on Commuting Relations of All Employees, γ_{min} = …						City Regions Based on Commuting Relations of Employees with Academic Degree, γ_{min} = …					
			0.28	0.20	0.16	0.12	0.09	0.07	0.28	0.20	0.16	0.12	0.09	0.07
43	PF	MO	KS	M	MD	WI	BN	MD	GE	TR	TR	DU	MZ	G
44	K	HH	HAM	GE	HA	HL	BS	PB	KA	E	GL	WI	MD	BI
45	KA	DU	PB	KR	S	MD	HL	GL	L	GL	B	MZ	WI	F
46	AC	FR	L	KA	M	HI	FÜ	EF	S	G	MZ	KR	KI	R
47	SB	HRO	HH	RT	E	G	KR	HI	HN	MD	G	PB	G	S
48	SG	L	MS	KI	HL	FÜ	PB	FÜ	KI	BO	MD	UL	UL	DU
49	KI	TR	HA	HH	G	M	MD	KR	E	KI	FÜ	S	S	MD
50	H	RE	BS	HL	HH	DU	GL	G	GL	S	PB	MD	DA	EF
51	N	SI	OB	E	KA	BS	MA	KI	G	FÜ	S	BI	BI	MZ
52	MO	N	GE	G	KR	KA	HI	BI	MA	BS	BN	W	DU	LU
53	B	R	KR	PB	FÜ	HH	HH	HH	TR	HN	HH	HH	EF	C
54	DU	B	KO	L	L	KR	WI	DU	HH	MG	KA	MG	L	OS
55	SI	RT	B	BO	W	PB	M	L	BO	PB	L	MA	R	L
56	KS	KR	KI	K	KS	GL	L	UL	PB	HH	W	KI	DD	DA
57	BS	HAM	RT	FÜ	PB	K	BI	BS	FÜ	MA	MG	L	C	WÜ
58	RE	KI	OL	KS	GL	L	KO	KA	KO	W	E	FR	HH	OL
59	WÜ	HL	HL	W	R	W	DU	MA	K	L	UL	D	OL	KS
60	HB	HA	E	BS	BS	OL	K	DD	MG	KA	KI	DD	OS	HH
61	HL	BS	GL	R	BO	MS	KA	FR	M	KS	BO	BN	MG	KO
62	RT	OB	SI	OL	K	BO	DD	OL	KS	K	FR	R	MA	DD
63	KR	GE	BO	GL	DD	DD	R	M	BS	DD	DD	OL	AC	MG
64	HAM	C	FR	MA	MA	R	FR	KO	W	BI	OS	KA	KS	FR
65	HA	HN	FÜ	SB	MS	E	OL	R	OL	OL	BI	E	FR	HD
66	OS	UL	MG	DD	OL	BI	UL	OS	MS	FR	K	WÜ	D	BN
67	A	E	R	MG	MG	N	OS	E	DD	UL	KS	C	WÜ	AC
68	UL	HB	C	MS	FR	OS	E	KS	FR	DO	R	OS	KO	SB
69	OB	GL	MA	AC	UL	KS	KS	WÜ	WÜ	R	OL	KO	BO	BO
70	C	MA	DD	FR	BI	FR	N	C	DO	OS	KO	AC	BN	A
71	GE	BO	HN	KO	AC	MG	MG	K	UL	KO	C	BO	SB	MA
72	HN	FÜ	N	C	KO	AC	BO	N	AC	HB	WÜ	K	A	E
73	E	WÜ	W	BI	C	HB	AC	SB	C	MS	SB	KS	E	N
74	GL	MG	WÜ	UL	DO	KO	C	MS	R	WÜ	AC	N	HB	KA
75	MA	H	UL	WÜ	SB	C	SB	AC	BI	C	HB	SB	DO	D
76	BO	KS	DO	DO	HB	UL	WÜ	BO	HB	AC	DO	A	N	HB
77	FÜ	BI	HB	HB	OS	WÜ	MS	MG	SB	M	N	HB	KA	MS
78	MG	W	BI	N	WÜ	DO	HB	HB	OS	SB	MS	MS	K	K
79	BI	OS	OS	OS	N	SB	DO	DO	N	N	M	DO	MS	DO
80	W	DO	H	H	H	H	H	A	H	A	A	M	M	M
81	DO	A	A	A	A	A	A	H	A	H	H	H	H	H

Source: Own computations based on figures from the German Federal Office of Statistics, Statistics of the Federal Employment Agency, and GIS data from the Office for Cartography and Geodesy.

Table A5: Coefficients of Regional Specialisation, Computed for 81 German Core Cities, Core Regions, and Overlapping Monocentric City Regions Delineated by Different Methods (Rank Order)

	Core City	Core Region	City Regions Based on Commuting Relations of All Employees, γ_{min} = …						City Regions Based on Commuting Relations of Employees with Academic Degree, γ_{min} = …					
			0.28	0.20	0.16	0.12	0.09	0.07	0.28	0.20	0.16	0.12	0.09	0.07
AC	46	35	41	69	71	72	73	75	72	76	74	70	63	67
A	67	81	81	81	81	81	81	80	81	80	80	76	72	70
GL	74	69	61	63	58	56	50	45	50	45	44	36	40	39
B	53	54	55	41	40	39	36	37	38	42	45	40	36	34
BI	79	77	78	73	70	66	57	52	75	64	65	51	51	44
BO	76	71	63	55	61	62	72	76	55	48	61	71	69	69
BN	9	9	9	20	18	24	43	41	23	26	52	61	70	66
BOT	36	25	20	16	15	15	13	9	19	15	15	13	9	7
BS	57	61	50	60	60	51	44	57	63	52	5	12	11	15
HB	60	68	77	77	76	73	78	78	76	72	75	77	74	76
HBX	39	38	28	29	23	21	19	13	30	19	20	17	17	13
C	70	64	68	72	73	75	74	70	73	75	71	67	57	53
CB	10	11	14	12	10	9	11	11	11	10	14	10	13	10
DA	11	10	10	24	25	37	33	38	20	30	42	35	50	56
DO	81	80	76	76	74	78	79	79	70	68	76	79	75	79
DD	25	36	70	66	63	63	62	60	67	63	63	60	56	62
D	20	14	13	19	28	27	25	27	13	28	26	59	66	75
DU	54	45	31	28	38	50	59	54	28	21	35	43	52	48
EF	21	20	19	18	17	28	38	46	17	29	39	37	53	50
ER	2	3	2	3	2	2	2	2	4	4	10	11	35	41
E	73	67	60	51	47	65	68	67	49	44	58	65	73	72
F	6	6	7	7	13	19	21	32	7	17	23	38	41	45
FR	32	46	64	70	68	70	64	61	68	66	62	58	65	64
FÜ	77	72	65	57	53	48	46	48	57	51	49	42	39	37
GE	71	63	52	44	39	42	35	35	43	39	37	33	27	28
G	28	30	38	52	49	47	42	50	51	46	47	41	47	43
GÖ	14	21	24	22	21	32	32	28	27	31	28	27	23	27
HA	65	60	49	40	44	34	23	20	37	35	32	28	31	26
HAL	13	18	29	30	26	29	27	31	29	25	31	34	34	36
HH	34	44	47	49	50	53	53	53	54	56	53	53	58	60
HAM	64	57	44	37	33	38	40	34	36	32	30	26	28	31
H	50	75	80	80	80	80	80	81	80	81	81	81	81	81
HD	17	19	21	23	27	12	16	15	16	24	22	25	24	65
HN	72	65	71	26	29	36	34	33	47	53	24	32	33	23
HER	22	16	12	11	9	7	4	3	10	9	7	7	3	1
HI	40	28	42	38	35	46	52	47	31	34	33	29	42	32
IN	4	5	6	6	8	6	5	5	5	7	6	8	6	6
J	12	12	15	13	11	14	14	14	12	14	17	21	20	20
KA	45	42	34	46	51	52	61	58	44	60	54	64	77	74
KS	56	76	43	58	56	69	69	68	62	61	67	73	64	59
KI	49	58	56	48	42	40	41	51	48	49	60	56	46	42

Table continues on next page.

Table A5 (continuation).

	Core City	Core Region	City Regions Based on Commuting Relations of All Employees, γ_{min} = …						City Regions Based on Commuting Relations of Employees with Academic Degree, γ_{min} = …					
			0.28	0.20	0.16	0.12	0.09	0.07	0.28	0.20	0.16	0.12	0.09	0.07
KO	30	32	54	71	72	74	58	64	58	71	70	69	68	61
K	44	34	32	56	62	57	60	71	59	62	66	72	78	78
KR	63	56	53	45	52	54	47	49	35	40	38	46	38	33
L	41	48	46	54	54	58	56	55	45	59	55	57	54	55
LEV	8	7	5	5	4	4	3	7	6	5	3	2	1	14
LU	3	2	3	2	5	5	6	19	2	3	11	20	19	52
HL	61	59	59	50	48	44	45	36	42	36	40	39	32	30
MD	24	37	33	35	43	45	49	43	34	47	48	50	44	49
MZ	19	15	23	25	22	26	29	42	22	22	46	45	43	51
MA	75	70	69	64	64	41	51	59	52	57	36	55	62	71
MO	52	43	30	27	30	17	15	10	26	20	21	19	12	12
MG	78	74	66	67	67	71	71	77	60	54	57	54	61	63
MH	37	26	22	17	16	16	12	25	21	16	16	14	10	8
M	23	24	37	43	46	49	55	63	61	77	79	80	80	80
MS	33	27	48	68	65	61	77	74	66	73	78	78	79	77
NE	16	13	11	9	12	11	17	17	9	6	4	4	5	3
N	51	52	72	78	79	67	70	72	79	79	77	74	76	73
OB	69	62	51	42	36	35	31	26	39	38	34	31	26	22
OF	26	22	17	14	24	20	18	29	14	12	12	18	16	19
OL	38	40	58	62	66	60	65	62	65	65	69	63	59	58
OS	66	79	79	79	77	68	67	66	78	70	64	68	60	54
PB	31	39	45	53	57	55	48	44	56	55	50	47	37	35
PF	43	31	16	10	6	10	10	4	18	11	13	6	8	4
P	7	8	8	8	7	8	8	12	8	8	9	9	22	25
RE	58	50	36	31	32	23	26	16	32	23	29	24	18	17
R	35	53	67	61	59	64	63	65	74	69	68	62	55	46
RS	27	23	18	15	14	13	9	6	15	13	8	3	7	5
RT	62	55	57	47	31	25	24	21	41	41	25	22	29	24
HRO	18	47	39	33	34	30	28	23	33	33	27	23	21	18
SB	47	41	35	65	75	79	75	73	77	78	73	75	71	68
SZ	5	4	4	4	3	3	7	8	3	2	1	1	2	2
SI	55	51	62	32	20	22	20	18	40	27	19	15	14	11
SG	48	33	26	21	19	18	22	22	24	18	18	16	15	16
S	15	17	25	36	45	31	37	39	46	50	51	49	49	47
TR	29	49	40	39	41	33	30	24	53	43	43	30	25	21
UL	68	66	75	74	69	76	66	56	71	67	59	48	48	40
WI	42	29	27	34	37	43	54	40	25	37	41	44	45	38
WOB	1	1	1	1	1	1	1	1	1	1	2	5	4	9
WÜ	59	73	74	75	78	77	76	69	69	74	72	66	67	57
W	80	78	73	59	55	59	39	30	64	58	56	52	30	29

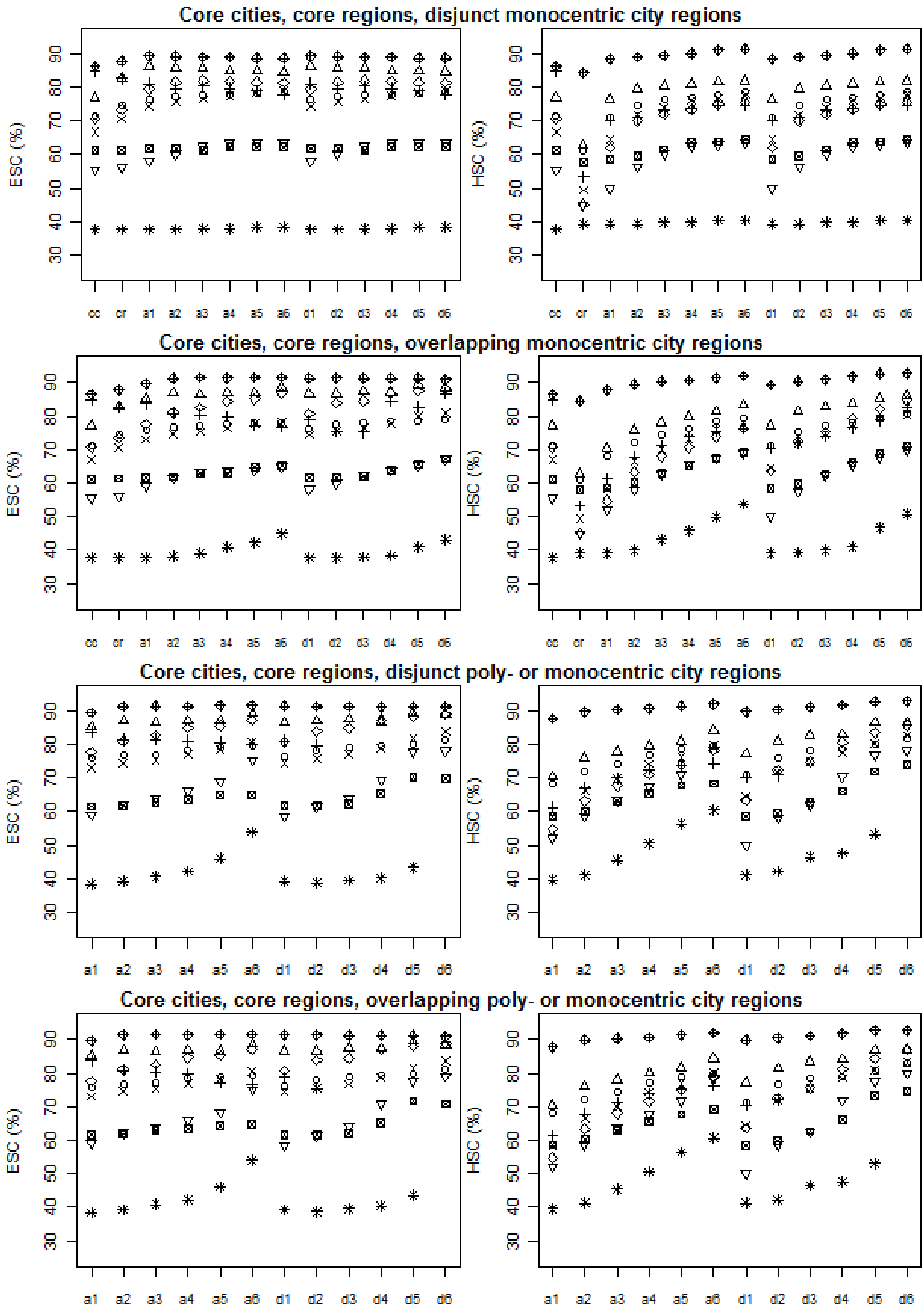
Source: Own computations based on figures from the German Federal Office of Statistics, Statistics of the Federal Employment Agency, and GIS data from the Office for Cartography and Geodesy.

Table A6: Rank Correlation of *CRS*, Computed for 81 German Core Cities, Core Regions, and Overlapping Monocentric City Regions Delineated by Different Methods

		Core Cities	Core Reg.	City Regions (all employees)						City Regions (employees with degree only)					
				a1	a2	a3	a4	a5	a6	d1	d2	d3	d4	d5	d6
Core Cities		1.00	0.93	0.81	0.68	0.64	0.62	0.57	0.50	0.65	0.55	0.45	0.41	0.33	0.21
Core Reg.			1.00	0.91	0.79	0.75	0.73	0.66	0.59	0.77	0.68	0.57	0.52	0.41	0.30
City Regions (all employees)	a1			1.00	0.90	0.85	0.82	0.76	0.71	0.88	0.82	0.71	0.64	0.54	0.43
	a2				1.00	0.98	0.95	0.9	0.87	0.97	0.94	0.87	0.81	0.73	0.63
	a3					1.00	0.96	0.93	0.90	0.95	0.95	0.88	0.85	0.77	0.68
	a4						1.00	0.97	0.93	0.93	0.94	0.91	0.87	0.81	0.71
	a5							1.00	0.97	0.89	0.91	0.92	0.91	0.88	0.78
	a6								1.00	0.85	0.89	0.90	0.92	0.89	0.83
City Regions (employees with degree only)	d1									1.00	0.96	0.88	0.80	0.71	0.60
	d2										1.00	0.92	0.88	0.81	0.72
	d3											1.00	0.96	0.90	0.81
	d4												1.00	0.96	0.90
	d5													1.00	0.95
	d6														1.00

Source: Own computations based on figures from the German Federal Office of Statistics, Statistics of the Federal Employment Agency, and GIS data from the Office for Cartography and Geodesy.

Fig. A1: Employment and Housing Self Containment (ESC and HSC): Mean Values for 9 Clusters of Core Cities,[a] delineated as Core Cities (cc), Core Regions (cr) and City Regions Using Different Commuting Matrices (a: all, d: degree) and Thresholds of Connectivity[b]

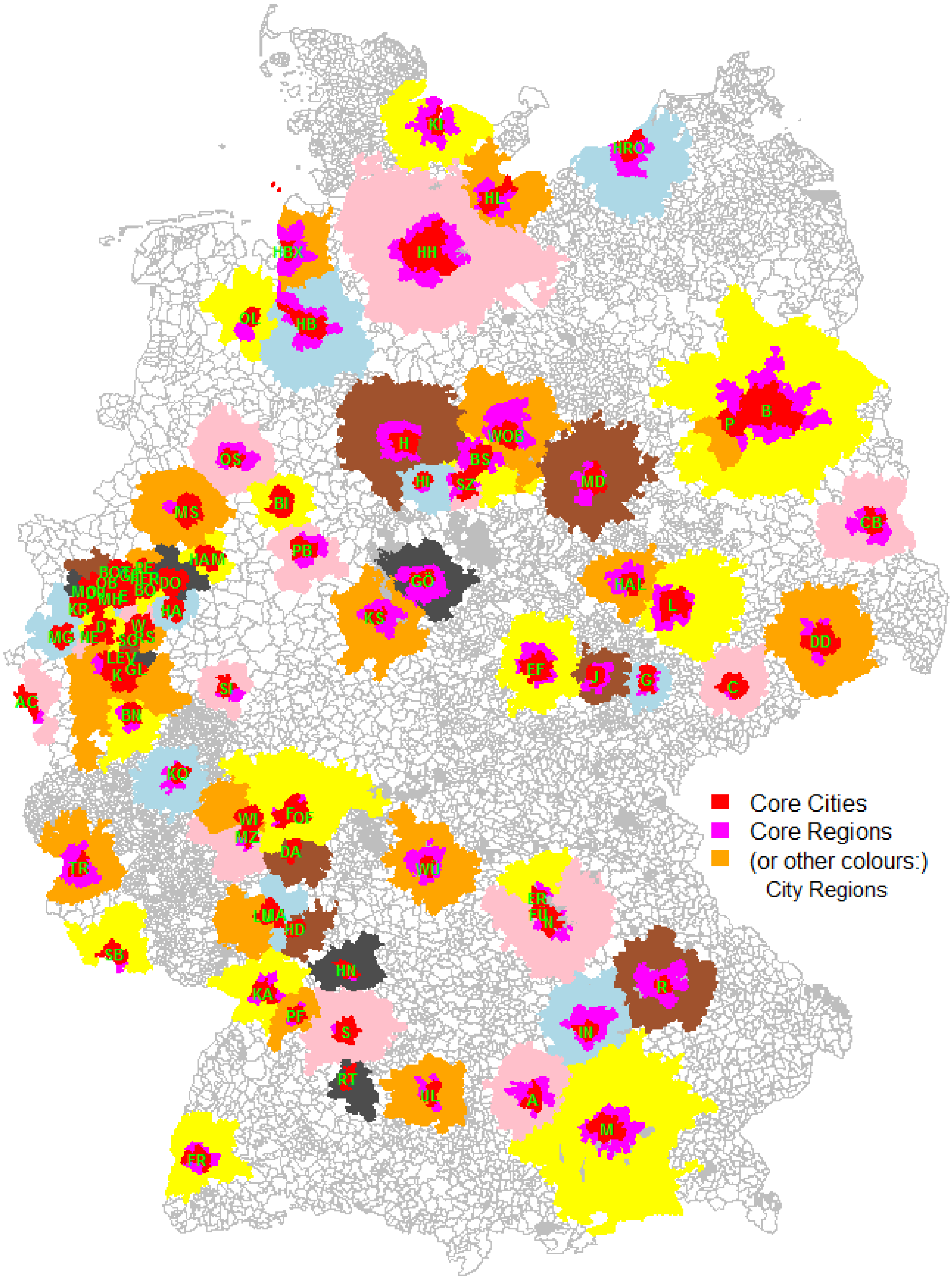


[a] See fig. 5 p. 7.

[b] γ_{min} (1...6) = {0.28, 0.20, 0.16, 0.12, 0.09, 0.07}.

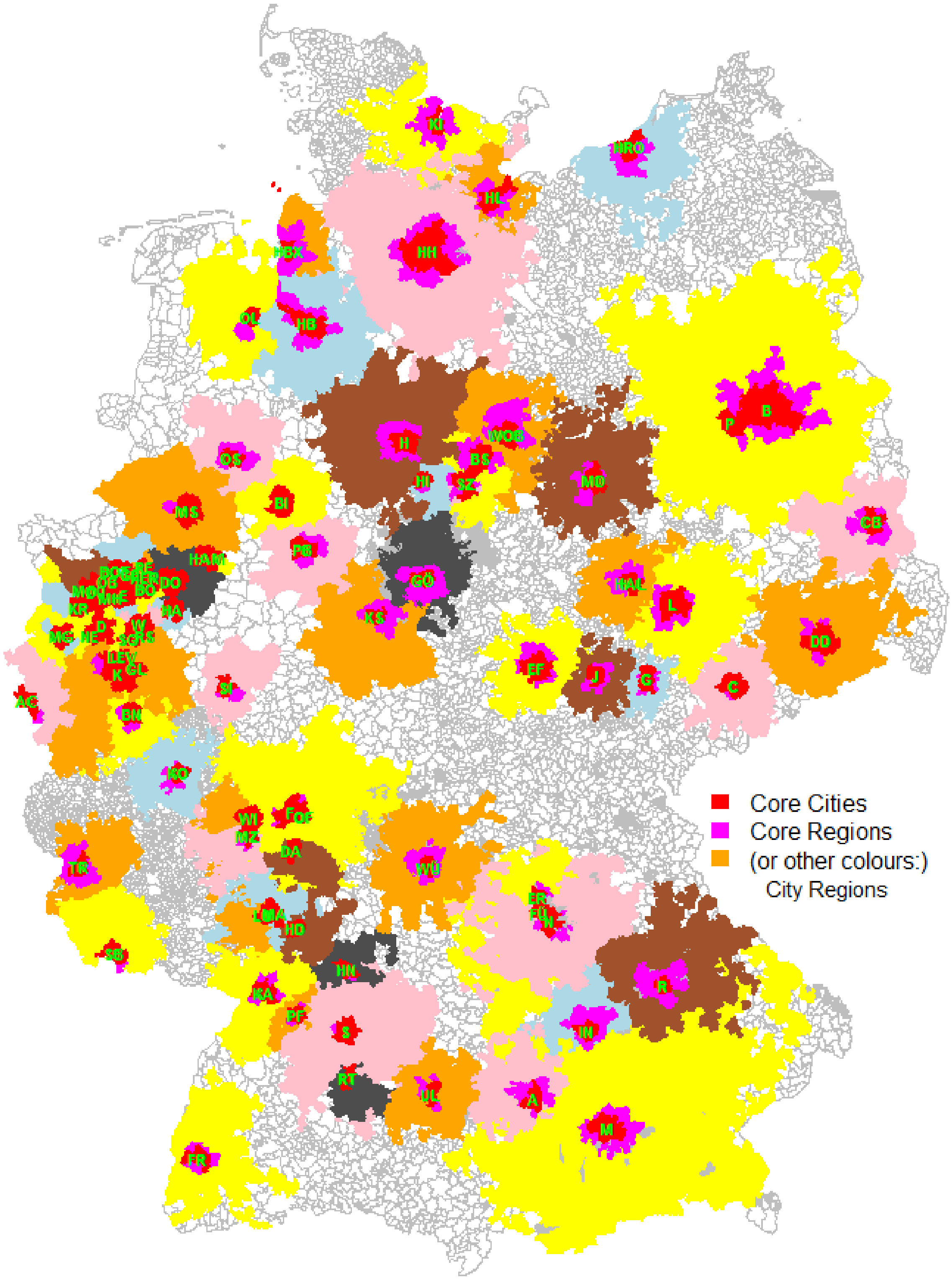
Source: Own computations based on figures from the German Federal Office of Statistics, Statistics of the Federal Employment Agency, and GIS data from the Office for Cartography and Geodesy.

Fig. A2: Disjoint Monocentric City Regions of 81 German Core Cities. Allocation of Hinterland Municipalities Based on a Commuting Matrix for All Employees as per 30 June 2008 ($\gamma_{min} = 0.07$)



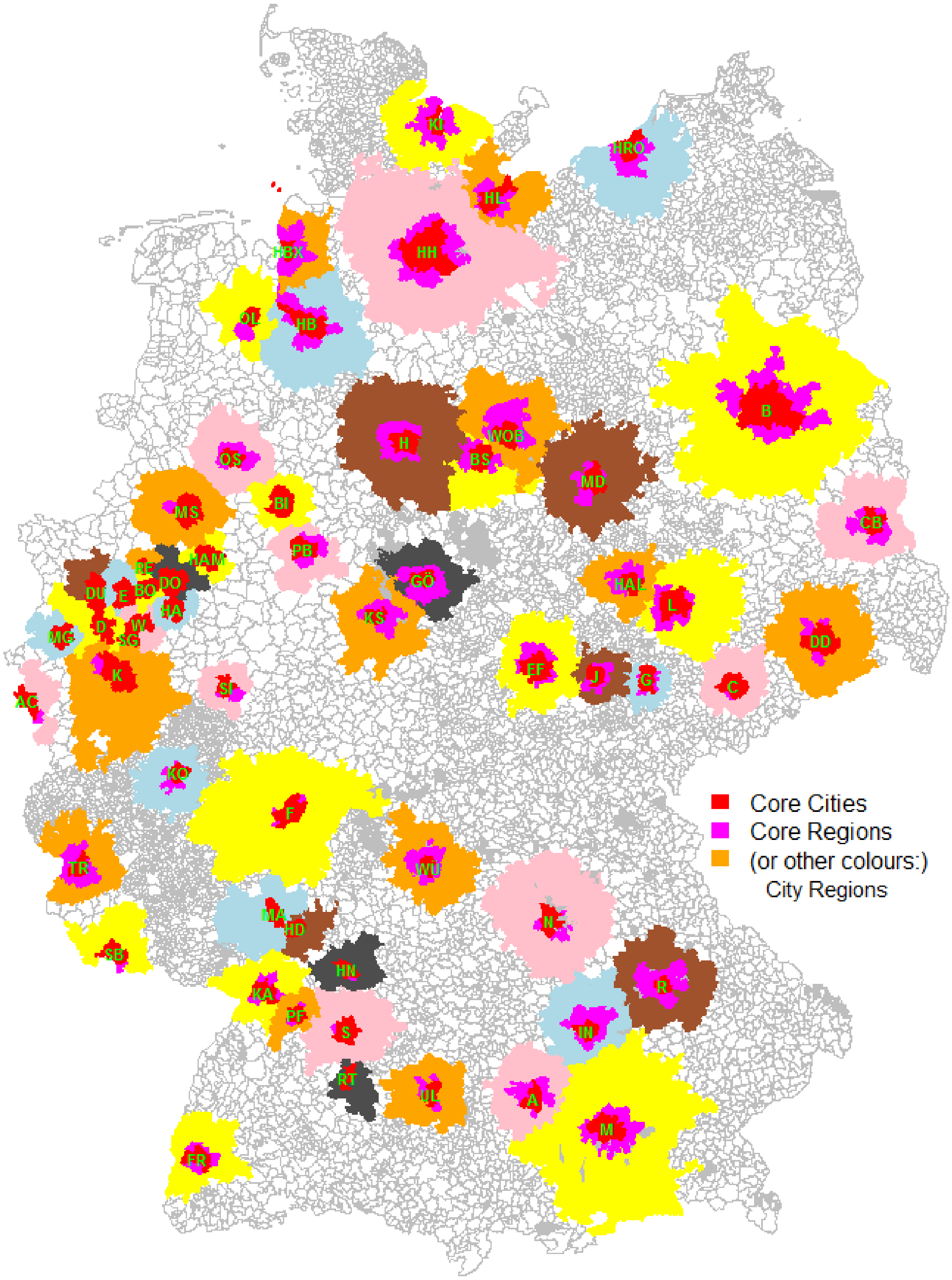
Source: Own computations based on figures from the German Federal Office of Statistics, Statistics of the Federal Employment Agency, and GIS data from the Office for Cartography and Geodesy.

Fig. A3: Disjoint Monocentric City Regions of 81 German Core Cities. Allocation of Hinterland Municipalities Based on a Commuting Matrix for Employees with Academic Degree as per 30 June 2008 ($\gamma_{min} = 0.07$)



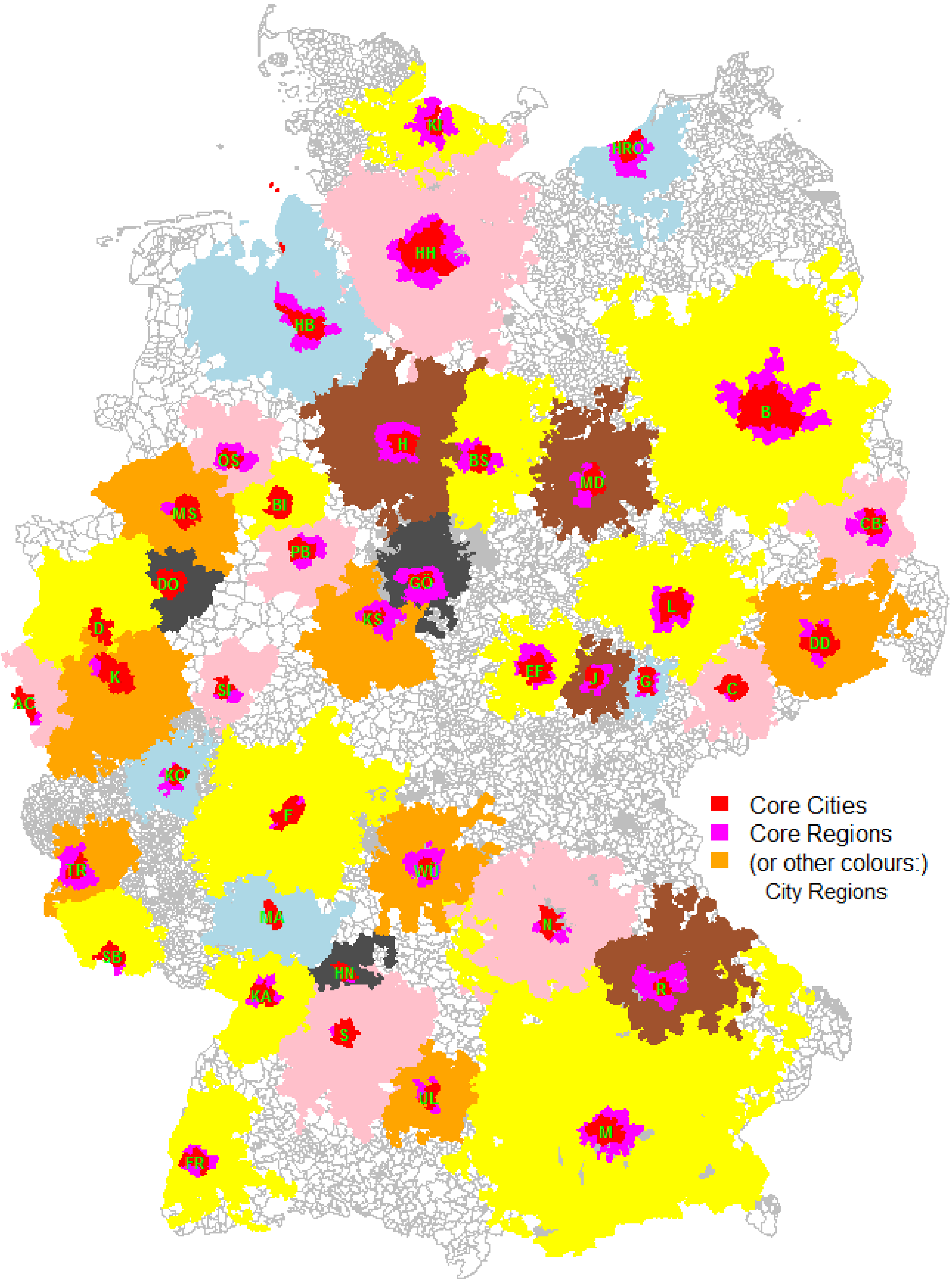
Source: Own computations based on figures from the German Federal Office of Statistics, Statistics of the Federal Employment Agency, and GIS data from the Office for Cartography and Geodesy.

Fig. A4: 59 Disjoint Polycentric City Regions of 81 German Core Cities. Allocation of Hinterland Municipalities Based on a Commuting Matrix for All Employees as per 30 June 2008 ($\gamma_{min} = 0.07$)



Source: Own computations based on figures from the German Federal Office of Statistics, Statistics of the Federal Employment Agency, and GIS data from the Office for Cartography and Geodesy.

Fig. A5: 40 Disjoint Polycentric City Regions of 81 German Core Cities. Allocation of Hinterland Municipalities Based on a Commuting Matrix for Employees with Academic Degree as per 30 June 2008 ($\gamma_{\min} = 0.07$)



Source: Own computations based on figures from the German Federal Office of Statistics, Statistics of the Federal Employment Agency, and GIS data from the Office for Cartography and Geodesy.