Gravitation and dispersion -

a disaggregate view on urban agglomeration and sprawl in Germany

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"Zipf´s Law"

- For a wide range of countries, the population of cities in relation to that of the largest city is inversely proportional to their within-country rank in size (e.g. the city at rank 2 is 1/2 the size of the largest city)
- In the regression

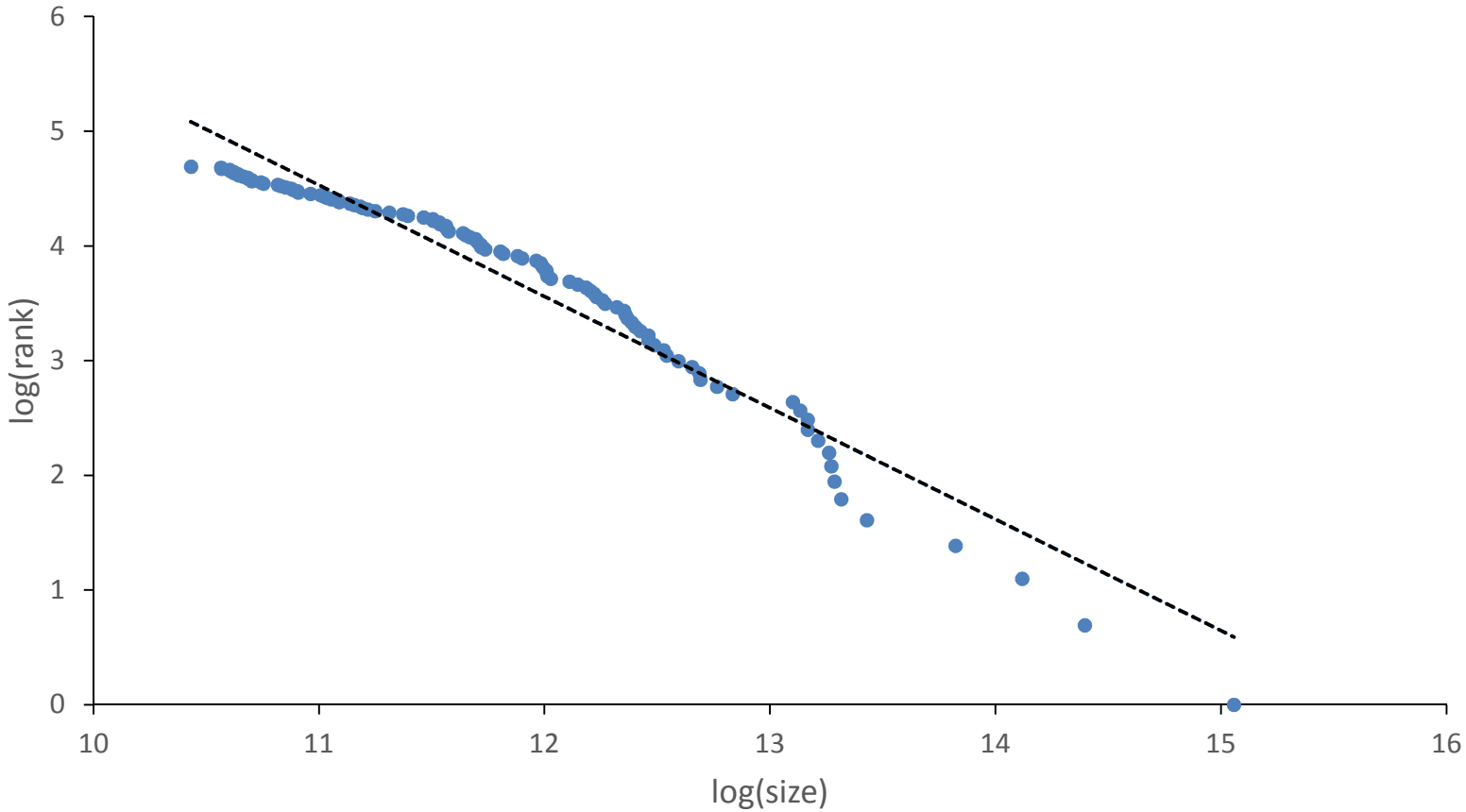
$$\log(R_i) = \alpha - \beta \log(P_i) + \varepsilon_i,$$

- in which R_i is the within-country rank of city i in size and P_i represents the total population of city i,
- the slope β of the regression line is (close to) -1.

- Giesen and Südekum (2011, JOEG): in Germany city size distribution follows a linear size-rank relationship according to Zipf´s law, even within Länder
- "*We are unused to seeing regularities this exact in economics – it is so exact that I find it spooky*". Krugman, P. (1996), The self-organizing economy. Oxford:

Size ranking of cities (administrative territories, kreisfreie Städte) in Germany

2010



Authors´ calculation. Data source: Federal Statistical Office and the statistical offices of the Länder (Regional Database Germany).

1. Issues/Literature

- Gabaix (1999, QJE): If rate and variance of city growth proceed independently of size ("Gibrat´s law"): log-normal rank-size distribution; among large cities virtually indistinguishable from ranking that obeys Zipf´s law
- Fujita/Krugman/Venables (1999): if a city´s growth rate were independent of size, **constant returns** to city size would be assumed
- but **new economic geography** literature finds agglomeration economies, e.g. Redding/Venables (2004, JIE): average regional income relates to "market access" by consumers and suppliers
- Duranton (2007, AER): if **agglomeration economies** dominate disadvantages of crowding among **large cities**, innovation (and growth) may increase more than proportionally with size and Zipf coefficient be reduced
- Bosker et al. (2008, RSUE): city growth in Germany 1925-1999 suggests **increasing returns** to scale

- Regional analysis in Germany commonly refers to territorial entities representing **administrative districts** (e.g. Gemeinden, kreisfreie Städte)
- It is also common to draw on statistics compiled at the level of labour market regions (commuter zones, Klemmer 1971) or planning regions (Boustedt 1953, ARL 1984), i.e. combinations of municipal areas
- **Difficulties**: municipal territories may not represent settlement patterns accurately, they are not consistent over time, difficult to compare across countries

„Modern urban centers are surrounded by very large, diffuse zonal boundaries, … Thus, population does not constitute a conventional countable set, where people are unequivocally members or not. … **A number as a measure of population is thus gross oversimplification**" (emphasis added).

Alonso, W. (1971), The economics of urban size. *Papers in Regional Science* 26(1): 67-83

Research Questions

i. What is the **rank-size distribution** among cities in Germany, if they are defined unambiguously and **independently of administrative boundaries**, using information about population density among small areas (spatial grids)?

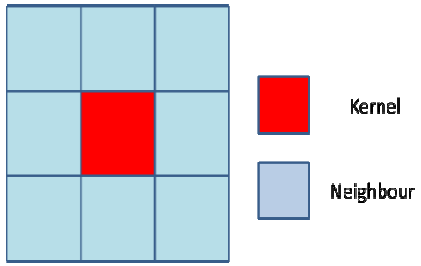
ii. Is the size ranking affected by variation in the size of **surrounding zones**, which are attributed to urban cores?

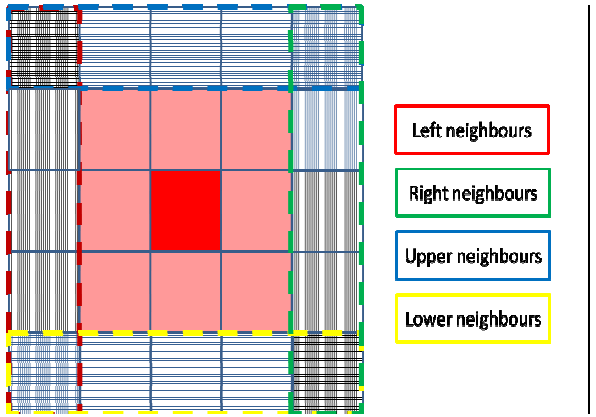
iii. Are there **deviations** from Zipf´s law (only) among large cities suggesting scale economies, as expected in part of the literature?

- Data Source: Mikromarketing-System und Consult GmbH (microm); estimation of **population in 1 km-grids**; from basic information on 40 million households

Stepwise definition of agglomerations

- Cells with highest population density: kernels/centres of agglomeration
- Definition of “high population density”: CLARA (Clustering for Large Applications)
- Agglomeration 1: cell with highest population density; neighbours added as long as av. population density is above a **critical value**, e.g. 300 inhabitants per grid cell
- Agglomeration 2: kernel with highest population density outside Agglomeration 1; neighbours added….. If Agglomeration 2 borders on Agglomeration 1, it will be incorporated into Agglomeration 1
- ……



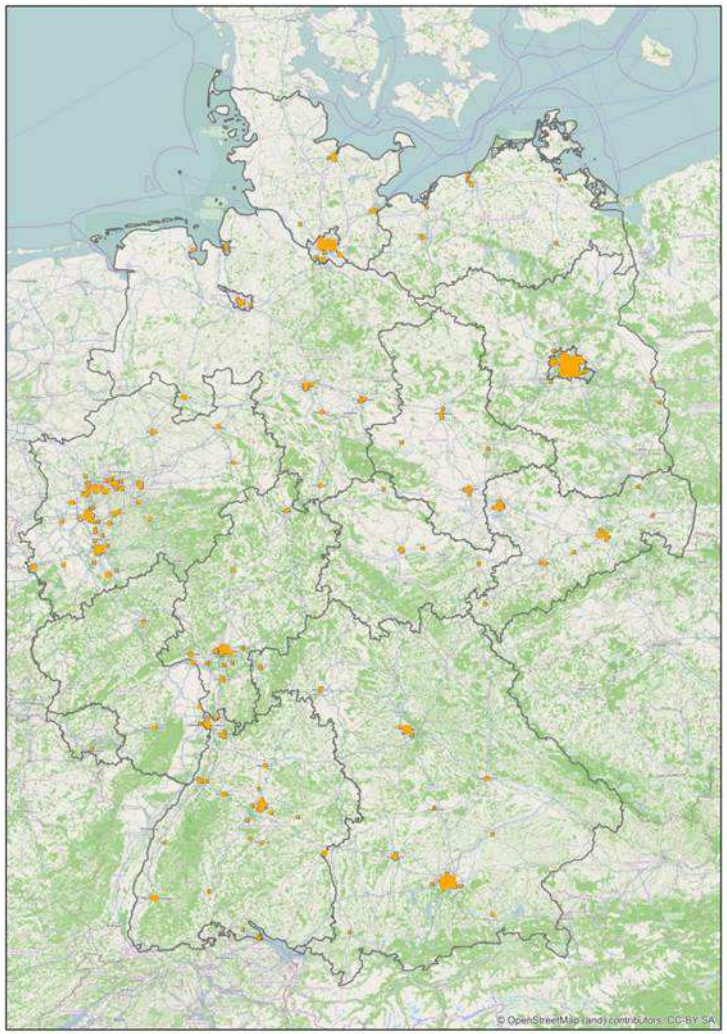


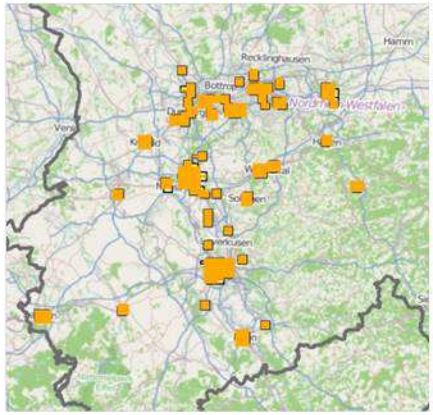
772 Agglomeration Centres
(12-Cluster-Solution, median pop. 9,228)

Authors´ calculation. Data source: microm

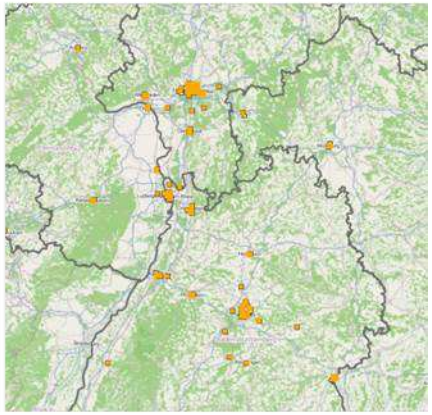
Administrative cities (kreisfreie Städte) with ≥ 10 agglomeration centres			
City	cores	pop. in cores	share of territory in cores (in %)
Berlin	168	2,008,957	18,8
Hamburg	61	642,571	8,3
München	58	654,251	18,6
Köln	41	413,487	10,1
Frankfurt/M.	28	286,615	11,3
Düsseldorf	22	246,738	10,1
Nürnberg	22	239,295	11,7
Reg. Hannover	16	166,170	0,7
Stuttgart	16	168,870	7,6
Bremen	14	131,431	3,7
Leipzig	14	142,860	4,7
Dresden	13	121,044	4,0
Essen	11	101,529	5,2
Wuppertal	11	106,774	6,5
Duisburg	10	91,338	4,3
Karlsruhe	10	101,458	5,7
Mannheim	10	104,083	6,9

Characteristics of urban agglomerations defined by different levels of population density
Threshold value 4000

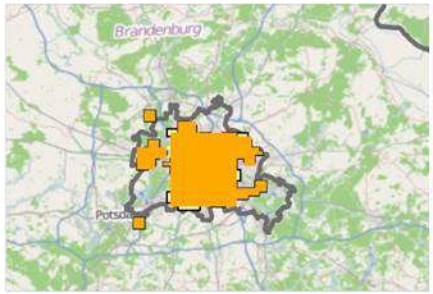




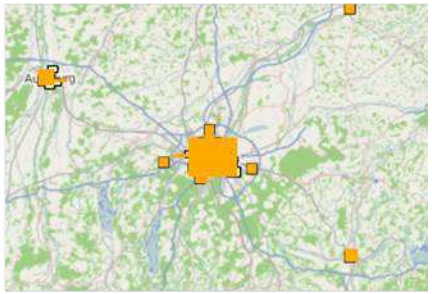
Rhein-Ruhr



Rhein-Main



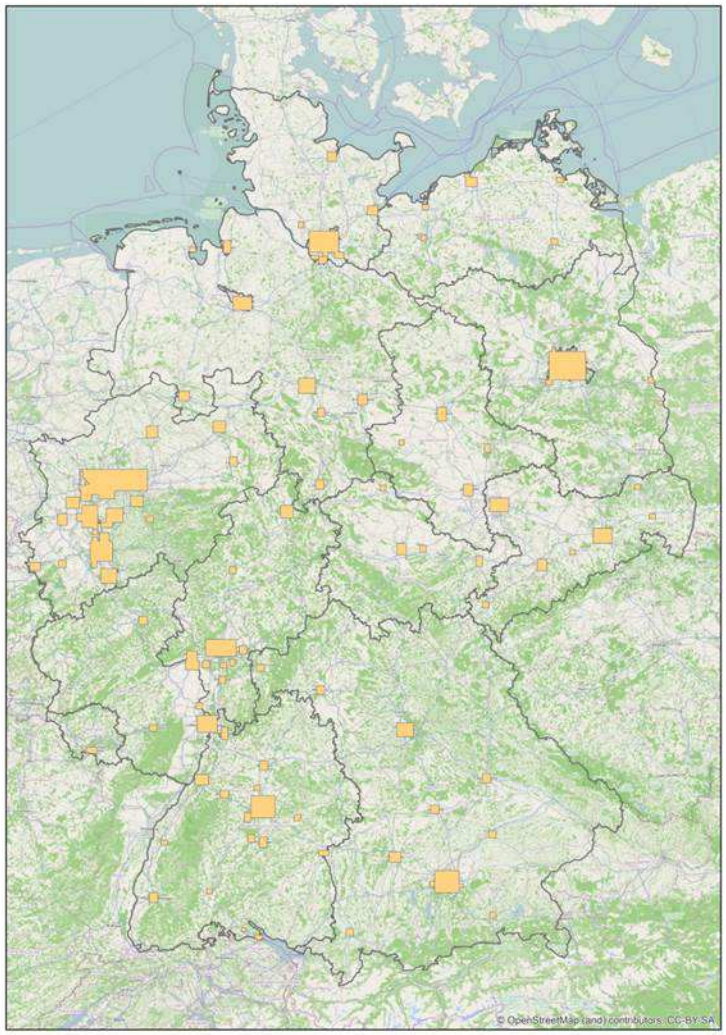
Berlin

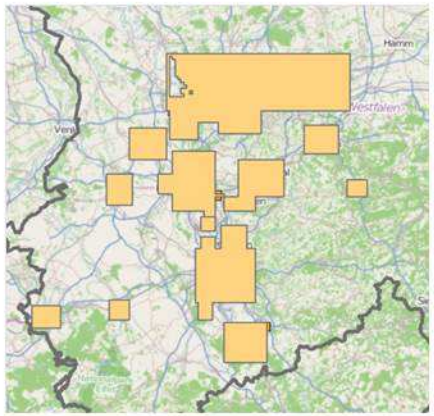


München

Authors´ calculation. Data source: microm

Characteristics of urban agglomerations defined by different levels of population density
Threshold value 1000





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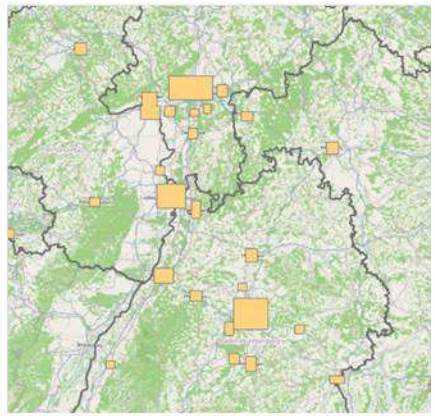

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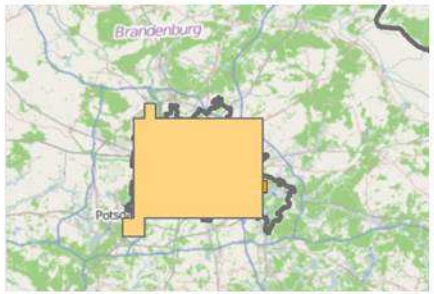
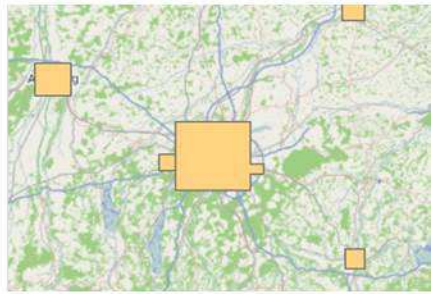


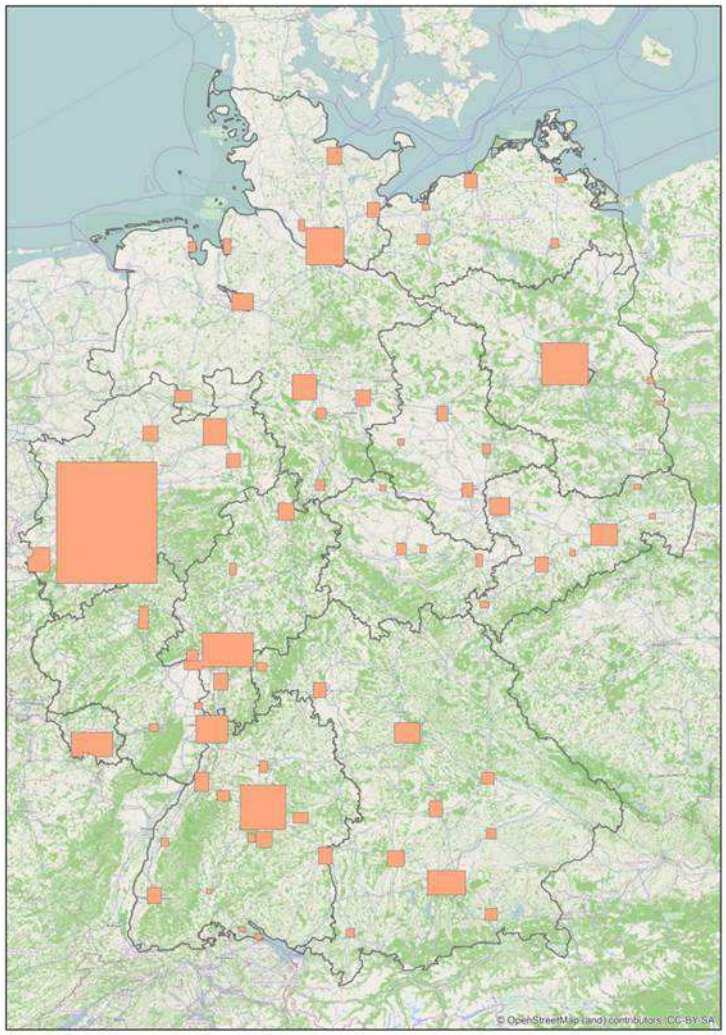
Berlin

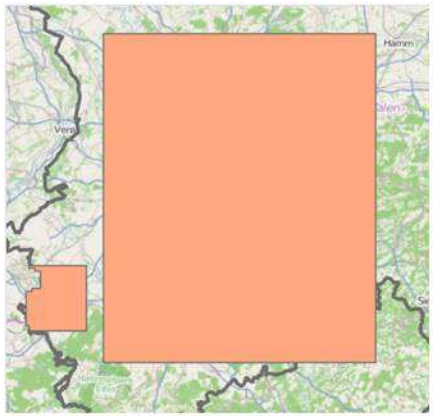


München

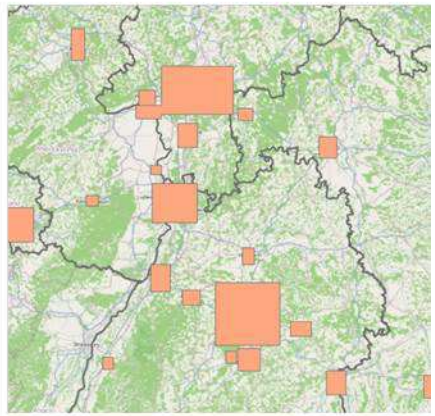
Authors´ calculation. Data source: microm

Characteristics of urban agglomerations defined by different levels of population density
Threshold value 400





Rhein-Ruhr



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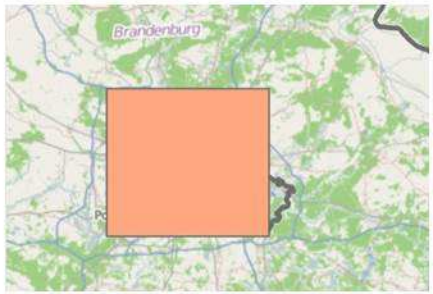
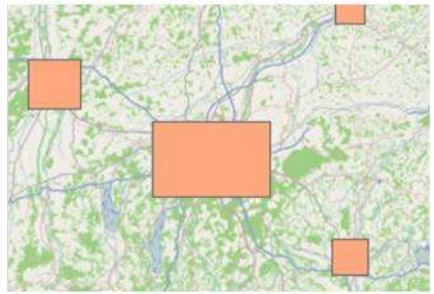


Berlin



München

Authors´ calculation. Data source: microm

Characteristics of urban agglomerations defined by different levels of population density

2010

Threshold (population per km²)	Nr. of agglomerations	Total population	Largest agglomeration		
			Name	Population	Population in high-density Cluster 12 (in %)
7,000	185	13,965,339	Berlin	1,914,616	83.2
6,000	176	14,319,030	Berlin	1,967,235	80.9
5,000	164	14,981,309	Berlin	2,385,504	71.6
4,000	149	16,187,628	Berlin	2,722,612	69.4
3,000	134	18,746,634	Berlin	2,842,544	66.5
2,000	114	22,043,642	Berlin	3,089,858	62.3
1,000	93	27,127,718	Berlin	3,563,400	57.1
900	91	28,140,911	Berlin	3,571,532	56.9
700	88	29,859,308	Berlin	3,665,920	55.5
500	76	34,080,047	Rhine-Ruhr	9,416,105	14.9
300	70	39,207,133	Rhine-Ruhr	12,445,837	12.5

Authors´ calculation. Data source: microm

Wages and market access parameter φ for different definitions of urban agglomeration

2010, 2SLS estimation of $\log(\omega_i) = \alpha + \varphi \log(MA_i) + \varepsilon_i$

Density threshold (population per km²)	Nr. of agglomerations	Average population	φ	R^2
7,000	185	75,488	0.0254	0.0319
6,000	176	81,358	0.0248	0.0281
5,000	164	91,349	0.0287	0.0402
4,000	149	108,642	0.0271	0.0586
3,000	134	139,900	0.0235	0.0357
2,000	114	193,365	0.0130	0.0155
1,000	93	291,696	0.0215	0.0695
900	91	309,241	0.0233*	0.0774
700	88	339,310	0.0268**	0.1144
500	76	448,422	0.0460**	0.2288
300	70	560,102	0.0267*	0.2016

Authors´ calculation. ** significantly different from 0 at 1%-level, *significantly different from 0 at 10%-level. MA_i = total population of agglomeration, instrumented by averge size of other agglomerations derived by each respective density threshold in IV regressions; ω_i = income (purchasing power) per capita in agglomeration i; First stage F statistics above 10 (indicating a strong instrument) in all estimations; Data source: microm

Zipf parameter for different definitions of urban agglomeration

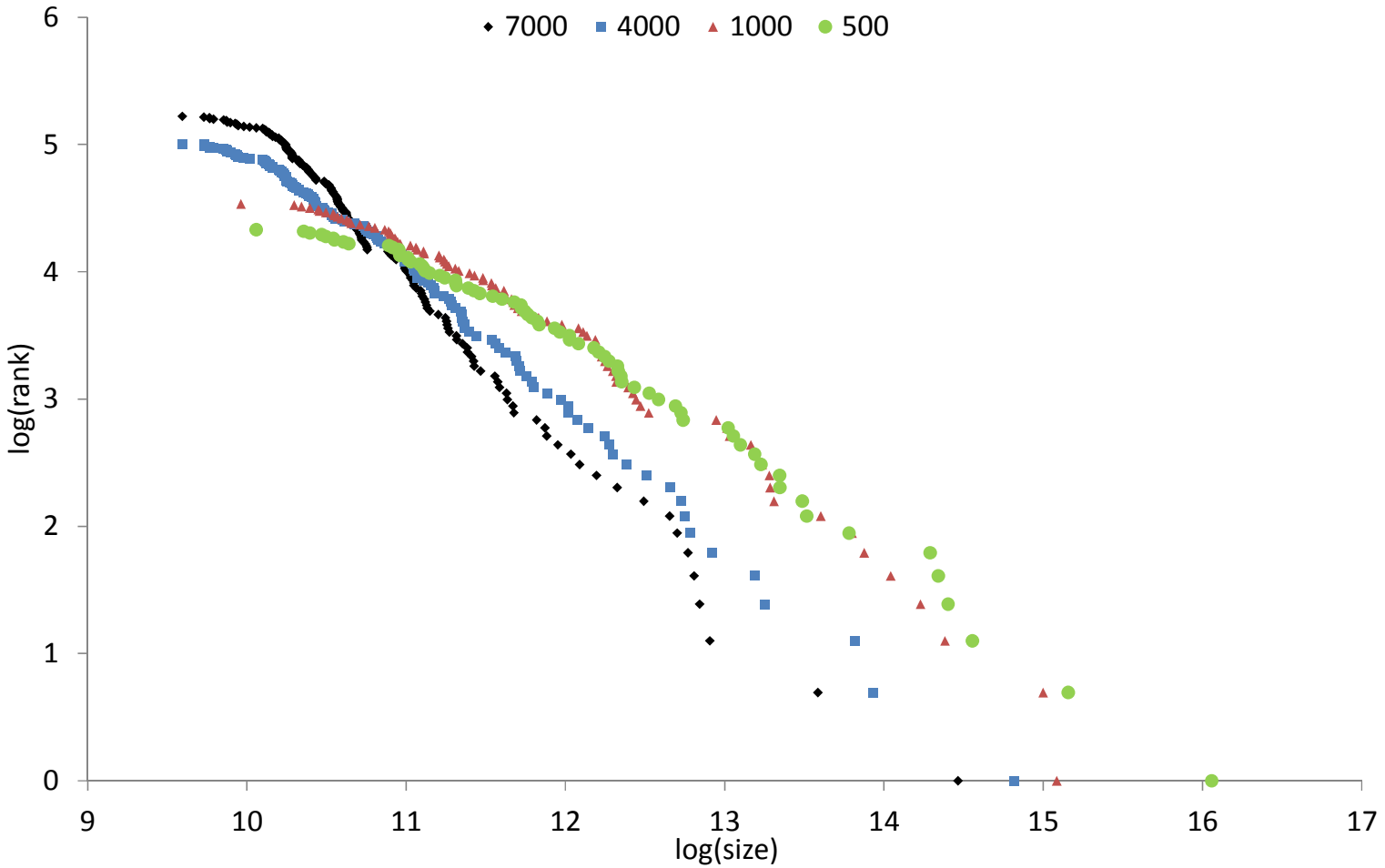
2010, OLS estimation of $\log(R_i) = \alpha - \beta \log(P_i) + \varepsilon_i$

Threshold value	Nr. of agglomerations	Average population	β	adj. R^2
7000	185	75,488	1.263***	0.986
6000	176	81,358	1.188***	0.988
5000	164	91,349	1.115***	0.990
4000	149	108,642	1.016*	0.989
3000	134	139,900	0.951***	0.968
2000	114	193,365	0.871***	0.952
1000	93	291,696	0.822***	0.968
900	91	309,241	0.798***	0.967
700	88	339,310	0.793***	0.968
500	76	448,422	0.746***	0.975
300	70	560,102	0.709***	0.961

Authors' calculation. *** significantly different from 1 at 1%-level, *significantly different from 1 at 10%-level.
R_i = size rank of agglomeration i, P_i = total population of agglomeration i
Data source: microm

Rank-Size Distribution for different definitions of urban agglomeration

Threshold values …



Authors´ calculation. Data source: microm

Zipf parameter for different definitions of urban agglomeration

2010, OLS estimation of $\log(R_i) = \alpha - \beta \log(P_i) + \varepsilon_i$

Ranking	Number of cities	Average population (2010[1])	β	adj. R^2
Municipalities: Kreisfreie Städte	109	236,865	0.971***	0.946
Municipalities: Kreisfreie Städte (top 70)	70	337,909	1.221***	0.985
Labour market regions (BBSR[2])	258	312,108	1.242***	0.965
Labour market regions (BBSR) (top 100)	100	583,136	1.529***	0.990
Metropolitan regions (MKRO)	11	4,516,633	1.560***	0.956
RWI Regions (300 threshold)	70	560,102	0.709***	0.961

Authors´ calculation, [1]Metropolitan regions: 2004; [2]Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) ***significantly different from 0 at 1%-level

4. Conclusions

i. Different approaches to defining cities in Germany arrive at a size distribution conforming with Zipf´s law

ii. If cities are defined according to population density in 1 km-grids, **increasing returns to scale** (a decrease in the slope of the Zipf curve) are measured if large zones are defined as “urban”

iii. Grid-based city definition reveals a much **stronger agglomeration** in largest conurbation than urban regions defined for planning purposes (labour market regions, metropolitan regions) would suggest

iv. Intra-urban differentials: congestion diseconomies inhibit growth of very densely populated **urban core** zones beyond certain size; but due to reurbanisation urban cores of some large cities may expand

v. Next steps: time horizon (city growth), neighbourhood typology (intra-city differentials and change)