

Table S1: Cold spots of city-regional purchasing power (99% sign.): total households v. households in cold spots for the 33 largest city regions in Germany (data source: RWI Essen based on small-area estimates by microm Mikromarketing and Consult GmbH)

City region	Total 1x1 km cells	Total cold spots	Share of cold spots	Total households 2009	Total households 2017	Total households in cold spots 2009	Total households in cold spots 2017	Share of households (in percent) in cold spots in 2009	Share of households (in percent) in cold spots in 2017
Aachen	810	49	6,0%	409.372	415.749	57.382	55.867	14,0%	13,4%
Augsburg	1.620	43	2,7%	426.242	450.944	30.608	31.831	7,2%	7,1%
Berlin	3.580	174	4,9%	2.458.891	2.565.188	328.149	332.580	13,3%	13,0%
Bielefeld	2.299	129	5,6%	603.787	603.358	70.898	68.427	11,7%	11,3%
Bochum	2.149	314	14,6%	2.027.512	2.025.382	495.871	494.788	24,5%	24,4%
Bonn	2.001	107	5,3%	1.278.318	1.296.726	101.582	101.809	7,9%	7,9%
Braunschweig	1.315	56	4,3%	473.245	480.191	32.232	32.263	6,8%	6,7%
Bremen	2.239	105	4,7%	683.356	696.632	89.937	91.548	13,2%	13,1%
Chemnitz	1.477	116	7,9%	375.869	380.015	31.424	30.959	8,4%	8,1%
Dortmund	2.583	291	11,3%	2.014.597	1.998.487	451.013	446.329	22,4%	22,3%
Dresden	1.988	39	2,0%	552.037	560.529	12.094	11.971	2,2%	2,1%
Duisburg	2.891	382	13,2%	2.129.052	2.150.619	561.523	565.663	26,4%	26,3%
Düsseldorf	4.523	405	9,0%	3.438.333	3.480.453	644.186	650.418	18,7%	18,7%
Erfurt	564	1	0,2%	168.092	181.037	11	17	0,0%	0,0%
Essen	3.380	537	15,9%	2.969.692	2.999.806	796.971	803.562	26,8%	26,8%
Frankfurt am Main	3.555	46	1,3%	2.126.319	2.207.347	50.430	49.685	2,4%	2,3%
Freiburg im Breisgau	965	26	2,7%	320.983	331.006	31.799	31.616	9,9%	9,6%
Hamburg	4.622	153	3,3%	1.903.579	1.951.387	111.221	112.554	5,8%	5,8%
Hannover	2.262	51	2,3%	886.902	891.983	67.036	66.430	7,6%	7,4%
Karlsruhe	1.534	35	2,3%	782.147	804.446	30.136	30.196	3,9%	3,8%
Kassel	859	12	1,4%	281.036	276.071	22.456	22.163	8,0%	8,0%

City region	Total 1x1 km cells	Total cold spots	Share of cold spots	Total households 2009	Total households 2017	Total households in cold spots 2009	Total households in cold spots 2017	Share of households (in percent) in cold spots in 2009	Share of households (in percent) in cold spots in 2017
Kiel	1.218	39	3,2%	341.325	343.234	59.551	58.702	17,4%	17,1%
Köln	4.559	234	5,1%	2.649.980	2.678.803	161.816	159.184	6,1%	5,9%
Leipzig	1.825	78	4,3%	605.295	618.096	79.826	79.608	13,2%	12,9%
Magdeburg	725	30	4,1%	227.208	228.181	9.360	8.898	4,1%	3,9%
Mainz	1.125	8	0,7%	684.223	705.555	8.019	8.456	1,2%	1,2%
Mannheim	1.858	110	5,9%	1.054.707	1.091.212	153.236	163.230	14,5%	15,0%
München	5.087	110	2,2%	1.866.788	2.021.003	97.506	101.271	5,2%	5,0%
Münster	1.661	161	9,7%	416.459	426.386	50.855	51.006	12,2%	12,0%
Nürnberg	2.577	54	2,1%	793.451	819.508	4.144	4.184	0,5%	0,5%
Stuttgart	2.909	139	4,8%	1.669.307	1.702.465	88.169	89.048	5,3%	5,2%
Wiesbaden	1.254	6	0,5%	740.319	761.228	7.744	8.161	1,0%	1,1%
Wuppertal	2.011	261	13,0%	1.778.462	1.780.675	502.118	494.802	28,2%	27,8%

Table S2: Population in total and in cold spots for the 33 largest city regions in Germany (data source: RWI Essen based on small-area estimates by microm Mikromarketing and Consult GmbH)

City region	Total population 2009	Total population 2011	Total population 2017	Total population in cold spots 2009	Total population in cold spots 2011	Total population in cold spots 2017	Share of population (in percent) in cold spots 2009	Share of population (in percent) in cold spots 2011	Share of population (in percent) in cold spots 2017
Aachen	820.222	815.495	797.459	117.974	115.413	114.437	14,4%	14,2%	14,4%
Augsburg	894.341	896.169	943.053	56.214	53.196	58.290	6,3%	5,9%	6,2%
Berlin	4.648.923	4.686.768	4.857.367	607.579	633.990	656.568	13,1%	13,5%	13,5%
Bielefeld	1.258.070	1.252.760	1.277.428	139.535	138.146	141.094	11,1%	11,0%	11,0%
Bochum	4.094.581	4.049.233	4.036.138	1.002.382	985.035	996.826	24,5%	24,3%	24,7%
Bonn	2.515.337	2.533.818	2.610.683	200.540	208.865	217.809	8,0%	8,2%	8,3%
Braunschweig	931.123	927.513	931.574	66.568	63.942	65.268	7,1%	6,9%	7,0%
Bremen	1.315.124	1.315.806	1.345.098	167.901	162.667	171.087	12,8%	12,4%	12,7%
Chemnitz	759.067	746.281	718.297	64.439	62.722	58.092	8,5%	8,4%	8,1%
Dortmund	4.064.526	4.019.458	3.976.788	907.174	890.696	899.252	22,3%	22,2%	22,6%
Dresden	1.080.222	1.083.539	1.095.742	23.338	22.895	22.113	2,2%	2,1%	2,0%
Duisburg	4.291.835	4.264.933	4.293.040	1.156.567	1.142.690	1.163.711	26,9%	26,8%	27,1%
Düsseldorf	6.887.065	6.866.608	6.970.421	1.317.546	1.299.387	1.332.399	19,1%	18,9%	19,1%
Erfurt	353.334	353.173	355.134	25	24	37	0,0%	0,0%	0,0%
Essen	5.981.701	5.936.564	5.948.585	1.633.697	1.608.910	1.626.844	27,3%	27,1%	27,3%
Frankfurt am Main	4.267.452	4.291.161	4.460.150	95.362	95.401	98.818	2,2%	2,2%	2,2%
Freiburg im Breisgau	635.686	642.216	660.958	57.738	59.877	60.989	9,1%	9,3%	9,2%
Hamburg	3.660.564	3.679.442	3.761.774	206.240	204.310	208.479	5,6%	5,6%	5,5%
Hannover	1.710.290	1.705.967	1.720.307	121.329	118.982	120.070	7,1%	7,0%	7,0%
Karlsruhe	1.590.515	1.593.716	1.637.278	62.281	62.719	64.269	3,9%	3,9%	3,9%
Kassel	567.879	565.325	568.215	41.389	40.063	41.868	7,3%	7,1%	7,4%

City region	Total population 2009	Total population 2011	Total population 2017	Total population in cold spots 2009	Total population in cold spots 2011	Total population in cold spots 2017	Share of population (in percent) in cold spots 2009	Share of population (in percent) in cold spots 2011	Share of population (in percent) in cold spots 2017
Kiel	653.182	652.817	661.157	108.541	103.131	107.785	16,6%	15,8%	16,3%
Köln	5.262.032	5.270.753	5.361.510	326.534	326.796	331.984	6,2%	6,2%	6,2%
Leipzig	1.158.808	1.152.567	1.175.854	149.553	141.974	150.226	12,9%	12,3%	12,8%
Magdeburg	457.080	454.003	450.541	18.350	17.746	16.357	4,0%	3,9%	3,6%
Mainz	1.372.543	1.376.760	1.424.739	15.685	14.860	15.539	1,1%	1,1%	1,1%
Mannheim	2.151.953	2.155.275	2.191.504	307.966	311.410	316.231	14,3%	14,4%	14,4%
München	3.636.119	3.681.195	3.925.998	180.351	176.209	190.673	5,0%	4,8%	4,9%
Münster	864.533	867.380	898.154	112.860	111.530	109.242	13,1%	12,9%	12,2%
Nürnberg	1.596.424	1.597.815	1.636.526	9.863	9.768	9.823	0,6%	0,6%	0,6%
Stuttgart	3.430.463	3.435.305	3.528.546	177.329	177.924	180.183	5,2%	5,2%	5,1%
Wiesbaden	1.486.180	1.490.729	1.541.967	15.139	14.343	15.031	1,0%	1,0%	1,0%

Table S3: Purchasing power of total populations and populations in cold spots for the 33 largest city regions in Germany (data source: RWI Essen based on small area estimates by microm Mikromarketing and Consult GmbH)

City region	Average annual purchasing power per inhabitant 2009	Average annual purchasing power per inhabitant 2017	Average annual purchasing power per cold spot inhabitant 2009	Average annual purchasing power per cold spot inhabitant 2017	Average deviation (in percent) from the city-regional average 2009	Average deviation (in percent) from the city-regional average 2017
Aachen	18.250 €	21.796 €	16.105 €	18.896 €	-11,8%	-13,3%
Augsburg	20.345 €	24.424 €	17.384 €	21.824 €	-14,6%	-10,6%
Berlin	17.766 €	22.273 €	14.446 €	18.879 €	-18,7%	-15,2%
Bielefeld	19.580 €	22.819 €	16.967 €	19.680 €	-13,3%	-13,8%
Bochum	18.711 €	21.968 €	15.990 €	19.063 €	-14,5%	-13,2%
Bonn	21.036 €	25.212 €	16.893 €	20.504 €	-19,7%	-18,7%
Braunschweig	19.544 €	23.904 €	16.025 €	18.845 €	-18,0%	-21,2%
Bremen	19.154 €	23.090 €	16.218 €	19.588 €	-15,3%	-15,2%
Chemnitz	16.013 €	20.241 €	14.665 €	18.237 €	-8,4%	-9,9%
Dortmund	18.598 €	21.987 €	15.840 €	18.959 €	-14,8%	-13,8%
Dresden	16.641 €	21.256 €	14.798 €	18.476 €	-11,1%	-13,1%
Duisburg	19.952 €	23.621 €	16.033 €	19.093 €	-19,6%	-19,2%
Düsseldorf	20.322 €	24.114 €	16.188 €	19.425 €	-20,3%	-19,4%
Erfurt	16.695 €	21.047 €	14.498 €	17.718 €	-13,2%	-15,8%
Essen	19.522 €	23.104 €	16.018 €	19.111 €	-17,9%	-17,3%
Frankfurt am Main	22.040 €	26.330 €	16.776 €	20.346 €	-23,9%	-22,7%
Freiburg im Breisgau	19.317 €	23.825 €	15.541 €	19.522 €	-19,5%	-18,1%
Hamburg	21.072 €	25.511 €	16.816 €	20.179 €	-20,2%	-20,9%
Hannover	19.592 €	23.440 €	15.850 €	19.124 €	-19,1%	-18,4%
Karlsruhe	20.600 €	24.866 €	17.287 €	20.710 €	-16,1%	-16,7%
Kassel	18.736 €	22.490 €	13.678 €	17.923 €	-27,0%	-20,3%
Kiel	18.408 €	22.258 €	14.724 €	17.688 €	-20,0%	-20,5%
Köln	21.270 €	25.398 €	16.763 €	20.253 €	-21,2%	-20,3%

City region	Average annual purchasing power per inhabitant 2009	Average annual purchasing power per inhabitant 2017	Average annual purchasing power per cold spot inhabitant 2009	Average annual purchasing power per cold spot inhabitant 2017	Average deviation (in percent) from the city-regional average 2009	Average deviation (in percent) from the city-regional average 2017
Leipzig	16.157 €	20.620 €	14.982 €	17.606 €	-7,3%	-14,6%
Magdeburg	16.587 €	20.826 €	14.693 €	17.571 €	-11,4%	-15,6%
Mainz	22.485 €	26.655 €	15.800 €	20.044 €	-29,7%	-24,8%
Mannheim	20.221 €	24.509 €	16.232 €	20.106 €	-19,7%	-18,0%
München	24.099 €	29.400 €	18.253 €	22.087 €	-24,3%	-24,9%
Münster	19.836 €	23.953 €	17.163 €	20.139 €	-13,5%	-15,9%
Nürnberg	20.883 €	25.314 €	17.229 €	20.134 €	-17,5%	-20,5%
Stuttgart	21.682 €	26.304 €	18.511 €	22.279 €	-14,6%	-15,3%
Wiesbaden	22.897 €	27.132 €	15.679 €	20.025 €	-31,5%	-26,2%

Table S4: Average rental price in the existing building stock in euros per square meter in the city region and in cold spots for the 33 largest city regions in Germany (data source: RWI Essen based on small area estimates from ImmobilienScout24)

City region	Average rental price (€/m ²) 2009	Average rental price (€/m ²) 2017	Average rental price (€/m ²) in cold spots 2009	Average rental price (€/m ²) in cold spots 2017	Average deviation (in percent) in cold spots from the city-regional average 2009	Average deviation (in percent) in cold spots from the city-regional average 2017
Aachen	5,9 €	8,5 €	5,1 €	6,6 €	-14%	-22,3%
Augsburg	6,5 €	10,5 €	6,7 €	11,2 €	3%	6,6%
Berlin	6,0 €	11,3 €	5,2 €	10,8 €	-13%	-4,3%
Bielefeld	5,9 €	7,4 €	6,0 €	7,7 €	1%	4,0%
Bochum	5,4 €	6,7 €	5,1 €	6,4 €	-6%	-5,0%
Bonn	7,7 €	10,7 €	7,1 €	10,1 €	-9%	-6,3%
Braunschweig	5,1 €	8,0 €	4,8 €	6,0 €	-7%	-24,6%
Bremen	5,4 €	8,6 €	5,1 €	8,4 €	-7%	-2,3%
Chemnitz	4,7 €	5,1 €	4,4 €	4,7 €	-7%	-8,5%
Dortmund	5,3 €	6,7 €	5,0 €	6,4 €	-6%	-4,7%
Dresden	5,7 €	7,7 €	4,8 €	5,8 €	-15%	-24,8%
Duisburg	6,5 €	7,9 €	5,0 €	6,1 €	-22%	-22,4%
Düsseldorf	6,8 €	8,5 €	5,4 €	6,7 €	-21%	-21,9%
Erfurt	5,4 €	7,3 €	-	-	-	-
Essen	6,1 €	7,6 €	5,0 €	6,3 €	-18%	-16,7%
Frankfurt am Main	8,4 €	12,2 €	7,1 €	10,7 €	-16%	-12,1%
Freiburg im Breisgau	7,8 €	11,9 €	8,8 €	13,2 €	12%	10,7%
Hamburg	7,7 €	11,0 €	5,9 €	8,4 €	-23%	-23,6%
Hannover	5,6 €	8,4 €	5,5 €	8,1 €	-2%	-2,9%
Karlsruhe	6,6 €	9,5 €	5,8 €	8,9 €	-12%	-6,4%
Kassel	4,8 €	7,4 €	4,8 €	8,4 €	-1%	12,8%
City region	5,5 €	7,9 €	5,3 €	7,2 €	-5%	-8,0%

City region	Average rental price (€/m²) 2009	Average rental price (€/m²) 2017	Average rental price (€/m²) in cold spots 2009	Average rental price (€/m²) in cold spots 2017	Average deviation (in percent) in cold spots from the city-regional average 2009	Average deviation (in percent) in cold spots from the city-regional average 2017
Kiel	7,5 €	10,0 €	6,4 €	8,2 €	-14%	-17,4%
Köln	4,9 €	7,0 €	4,4 €	6,2 €	-10%	-11,2%
Leipzig	4,5 €	5,9 €	4,3 €	5,4 €	-5%	-8,6%
Magdeburg	7,9 €	10,9 €	8,4 €	12,6 €	6%	15,9%
Mainz	6,9 €	9,6 €	6,7 €	9,7 €	-4%	0,5%
Mannheim	10,3 €	16,6 €	6,7 €	11,4 €	-35%	-31,7%
München	6,5 €	8,7 €	4,8 €	5,9 €	-26%	-32,4%
Münster	6,6 €	10,5 €	4,5 €	5,9 €	-32%	-43,6%
Nürnberg	7,8 €	13,8 €	7,2 €	11,7 €	-9%	-15,8%
Stuttgart	8,0 €	10,9 €	8,4 €	12,8 €	5%	17,2%
Wiesbaden	6,5 €	8,0 €	5,3 €	6,6 €	-19%	-18,1%

Table S5: Share of benefit recipients (of the total population aged 18 to under 65) in the city region and in cold spots for the 33 largest city regions in Germany (data source: Federal Employment Agency)

City region	Share of benefit recipients in the city region 2008	Share of benefit recipients in the city region 2019	Share of benefit recipients in cold spots of the city region 2008	Share of benefit recipients in cold spots of the city region 2019	Average deviation (in percentage points) between cold spots of the city region and the city-regional average 2008	Average deviation (in percentage points) between cold spots of the city region and the city-regional average 2019
Aachen	11,3%	11,5%	13,1%	13,7%	1,9	2,3
Augsburg	4,8%	3,7%	9,3%	6,3%	4,5	2,5
Berlin	19,2%	13,8%	21,6%	16,3%	2,4	2,5
Bielefeld	9,3%	8,7%	11,4%	10,6%	2,1	1,9
Bochum	15,5%	17,1%	16,5%	18,3%	1,0	1,1
Bonn	10,8%	10,3%	12,8%	11,9%	1,9	1,7
Braunschweig	11,6%	9,7%	14,2%	15,2%	2,5	5,5
Bremen	13,9%	14,0%	15,6%	16,1%	1,7	2,1
Chemnitz	15,4%	7,8%	18,8%	6,7%	3,3	-1,1
Dortmund	15,1%	16,4%	16,8%	18,4%	1,7	1,9
Dresden	14,4%	7,8%	16,7%	9,1%	2,2	1,3
Duisburg	13,8%	14,4%	16,4%	17,8%	2,6	3,4
Düsseldorf	13,0%	13,0%	15,3%	15,4%	2,3	2,4
Erfurt	17,1%	9,2%	10,1%	3,4%	-7,0	-5,8
Essen	14,4%	15,3%	16,4%	17,9%	2,0	2,6
Frankfurt am Main	8,6%	8,0%	12,5%	10,4%	3,9	2,4
Freiburg im Breisgau	6,0%	5,3%	8,8%	7,4%	2,7	2,2
Hamburg	11,5%	9,9%	14,4%	12,3%	2,8	2,3
Hannover	12,7%	11,7%	16,4%	14,9%	3,7	3,2

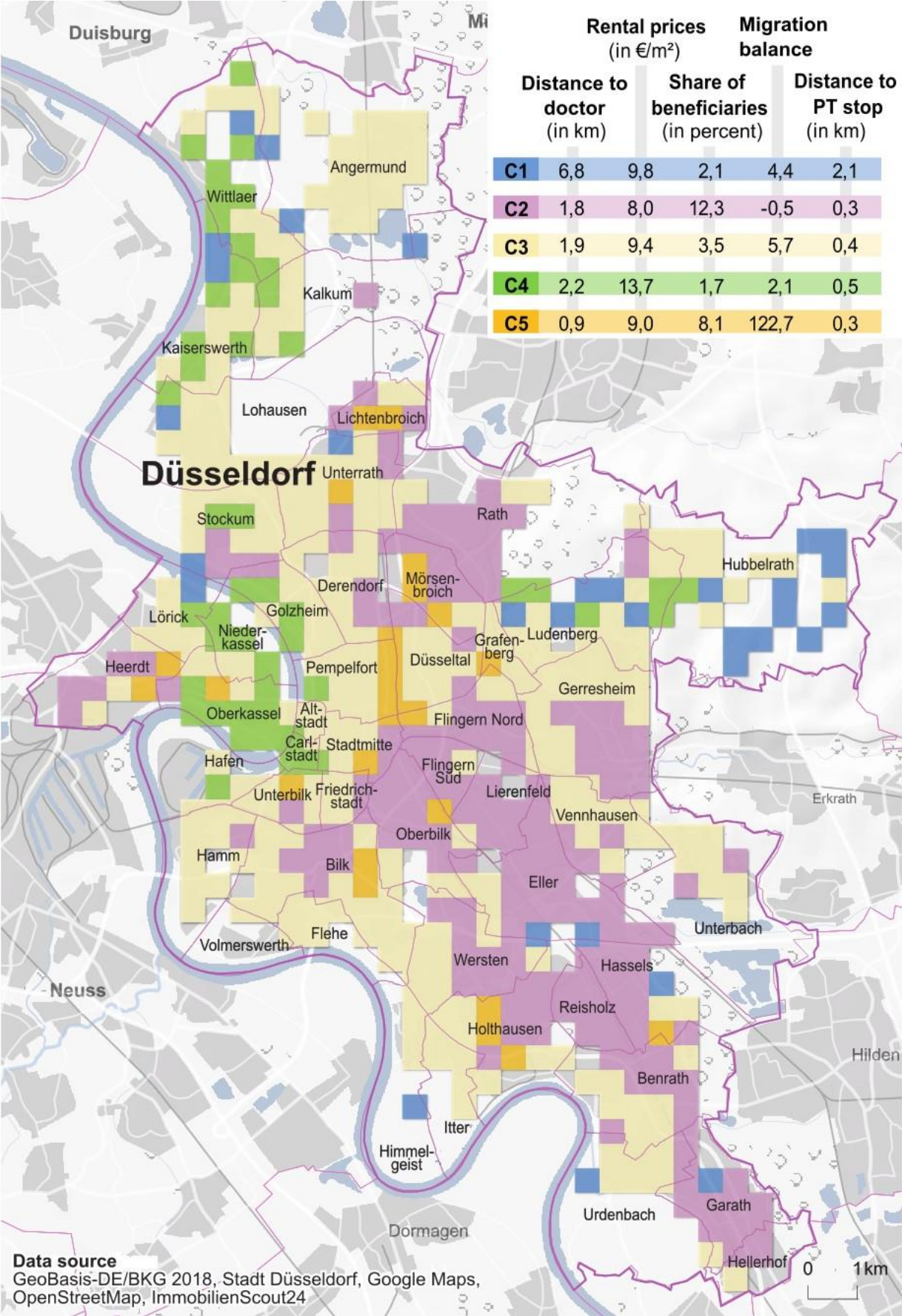
City region	Share of benefit recipients in the city region 2008	Share of benefit recipients in the city region 2019	Share of benefit recipients in cold spots of the city region 2008	Share of benefit recipients in cold spots of the city region 2019	Average deviation (in percentage points) between cold spots of the city region and the city-regional average 2008	Average deviation (in percentage points) between cold spots of the city region and the city-regional average 2019
Karlsruhe	5,7%	5,4%	8,7%	6,7%	3,0	1,4
Kassel	11,0%	9,3%	16,8%	14,4%	5,8	5,0
Kiel	12,9%	11,6%	17,9%	16,3%	5,0	4,7
Köln	10,6%	10,3%	12,5%	12,0%	1,9	1,8
Leipzig	18,7%	10,9%	21,1%	12,8%	2,4	2,0
Magdeburg	18,4%	12,2%	21,6%	12,3%	3,2	0,2
Mainz	8,3%	8,2%	9,1%	9,0%	0,8	0,8
Mannheim	7,6%	7,4%	10,7%	10,2%	3,1	2,8
München	4,5%	3,8%	8,7%	6,0%	4,2	2,2
Münster	7,1%	6,9%	9,3%	9,4%	2,2	2,5
Nürnberg	6,2%	5,3%	2,7%	2,0%	-3,5	-3,4
Stuttgart	5,5%	5,4%	7,5%	7,2%	1,9	1,8
Wiesbaden	8,1%	8,0%	9,1%	9,0%	1,0	1,0

Table S6: Employees (excluding civil servants and self-employed people not registered in the employee social security database) in the city region and in cold spots for the 33 largest city regions in Germany (data source: Federal Statistics Office)

City region	Total employees in the city region 2008	Total employees in the city region 2019	Total employees in cold spots 2008	Total employees in cold spots 2019	Share of employees living in cold spots 2008	Share of employees living in cold spots 2019	Change of employees living in cold spots 2008-2019
Aachen	257.665	312.675	77.389	92.626	30,0%	29,6%	-0,4%
Augsburg	294.370	376.598	131.430	156.752	44,6%	41,6%	-3,0%
Berlin	1.448.926	1.973.304	1.144.632	1.591.999	79,0%	80,7%	1,7%
Bielefeld	454.016	552.640	229.572	277.730	50,6%	50,3%	-0,3%
Bochum	1.277.436	1.462.991	1.052.555	1.211.464	82,4%	82,8%	0,4%
Bonn	898.503	1.127.518	710.515	892.439	79,1%	79,2%	0,1%
Braunschweig	336.556	416.135	66.393	72.782	19,7%	17,5%	-2,2%
Bremen	453.868	546.680	281.744	331.471	62,1%	60,6%	-1,4%
Chemnitz	258.699	276.040	36.224	36.381	14,0%	13,2%	-0,8%
Dortmund	1.258.977	1.458.789	938.621	1.088.615	74,6%	74,6%	0,1%
Dresden	398.737	470.329	27.127	30.590	6,8%	6,5%	-0,3%
Duisburg	1.489.713	1.730.491	812.001	923.731	54,5%	53,4%	-1,1%
Düsseldorf	2.420.874	2.858.536	1.472.765	1.742.337	60,8%	61,0%	0,1%
Erfurt	141.796	163.716	417	326	0,3%	0,2%	-0,1%
Essen	2.007.654	2.321.485	1.245.912	1.431.710	62,1%	61,7%	-0,4%
Frankfurt am Main	1.666.563	2.017.460	693.420	836.228	41,6%	41,4%	-0,2%
Freiburg im Breisgau	210.423	272.986	106.045	135.865	50,4%	49,8%	-0,6%
Hamburg	1.315.724	1.637.756	961.891	1.195.331	73,1%	73,0%	-0,1%
Hannover	584.395	699.743	353.915	422.980	60,6%	60,4%	-0,1%
Karlsruhe	602.058	712.853	216.272	250.135	35,9%	35,1%	-0,8%

City region	Total employees in the city region 2008	Total employees in the city region 2019	Total employees in cold spots 2008	Total employees in cold spots 2019	Share of employees living in cold spots 2008	Share of employees living in cold spots 2019	Change of employees living in cold spots 2008-2019
Kassel	195.484	234.550	102.690	121.057	52,5%	51,6%	-0,9%
Kiel	215.609	261.089	160.437	192.324	74,4%	73,7%	-0,7%
Köln	1.912.769	2.317.713	958.757	1.179.361	50,1%	50,9%	0,8%
Leipzig	406.092	495.658	271.796	338.451	66,9%	68,3%	1,4%
Magdeburg	170.512	188.092	28.026	29.914	16,4%	15,9%	-0,5%
Mainz	484.970	571.233	99.642	115.010	20,5%	20,1%	-0,4%
Mannheim	724.908	865.890	407.460	477.519	56,2%	55,1%	-1,1%
München	1.459.045	1.916.305	137.687	165.054	9,4%	8,6%	-0,8%
Münster	285.269	361.801	34.243	44.125	12,0%	12,2%	0,2%
Nürnberg	617.970	753.032	16.922	20.835	2,7%	2,8%	0,0%
Stuttgart	1.316.509	1.603.353	579.839	707.076	44,0%	44,1%	0,1%
Wiesbaden	522.283	628.733	99.642	115.010	19,1%	18,3%	-0,8%

Figure S1: Socio-economic disparities in Düsseldorf



Map description: The map shows a sample implementation of the geostatistical multi-criteria analysis. In this case, the purpose was to show socio-economic disparities across a city, in this case Düsseldorf (Fina et al. 2018). The method is theoretically also suitable for performing neighbourhood deprivation analyses when significant deviations from the city average can be identified.

Five variables available on different scales (address and street level data, accessibility polygons, citizen registration offices) were transposed into a 500x500 metre grid to perform a geostatistical cluster analysis.

The variables used to produce the map were:

- Pedestrian accessibility: public transport stops with a minimum average service frequency of 15 minutes throughout the day as a proxy for infrastructure quality
- Pedestrian accessibility of general practitioners as a proxy for health services
- Rental price as an average for 2011 - 2015
- Population migration balance for 2016
- Share of benefit recipients in 2016

Map interpretation: Cluster 1 (C1) is characterized by peripheral areas exposed to below-average accessibility to health services and to far-below-average accessibility to public transport. Cluster 2 (C2) is made up of areas with a very high share of benefit recipients and below average rental prices, while the migration balance is remarkably stable in comparison to the higher numbers in other clusters. Cluster 3 (C3) represents areas with average values across all variables. The highest rental prices are to be found in Cluster 4 (C4) which features up-market neighbourhoods mainly close to the Rhine. The last cluster, Cluster 5 (C5), attracts most new arrivals in comparison to the other clusters, i.e., has the highest migration balance. This influx of new residents goes hand in hand with a comparably high share of benefit recipients.

Methodological notes: The available variables were processed in a hierarchical cluster analysis using the Ward method in the open-source software package GeoDa¹. The process is subject to data analyst decisions (i.e., minimum variance and total clusters). The procedure is statistically more robust when a principal component analysis reduces potential multicollinearities in the variables before cluster analysis is performed.

Data sources and protection: The map results prove that multi-criteria analysis is possible at neighbourhood level without conflicting with German data protection law. As explained in the main text, barriers to access the data are of an organizational nature. In the case of this map, input data from the city administration was retrieved through formal agreements (share of benefit recipients), while further input data (rental price from ImmobilienScout24) was purchased from private vendors. Modern public transport and pedestrian routing services (OpenTripPlanner², OpenRouteService³) were used to model accessibility to services (public transport stops, health services). Address information on health services was sourced from OpenStreetMap and the Google Places API.

¹ <https://geodacenter.github.io/> (3 January 2023).

² <https://www.opentripplanner.org> (3 January 2023).

³ <https://openrouteservice.org/> (3 January 2023).