System boundaries and urban indicators in a global World: a regional UK?

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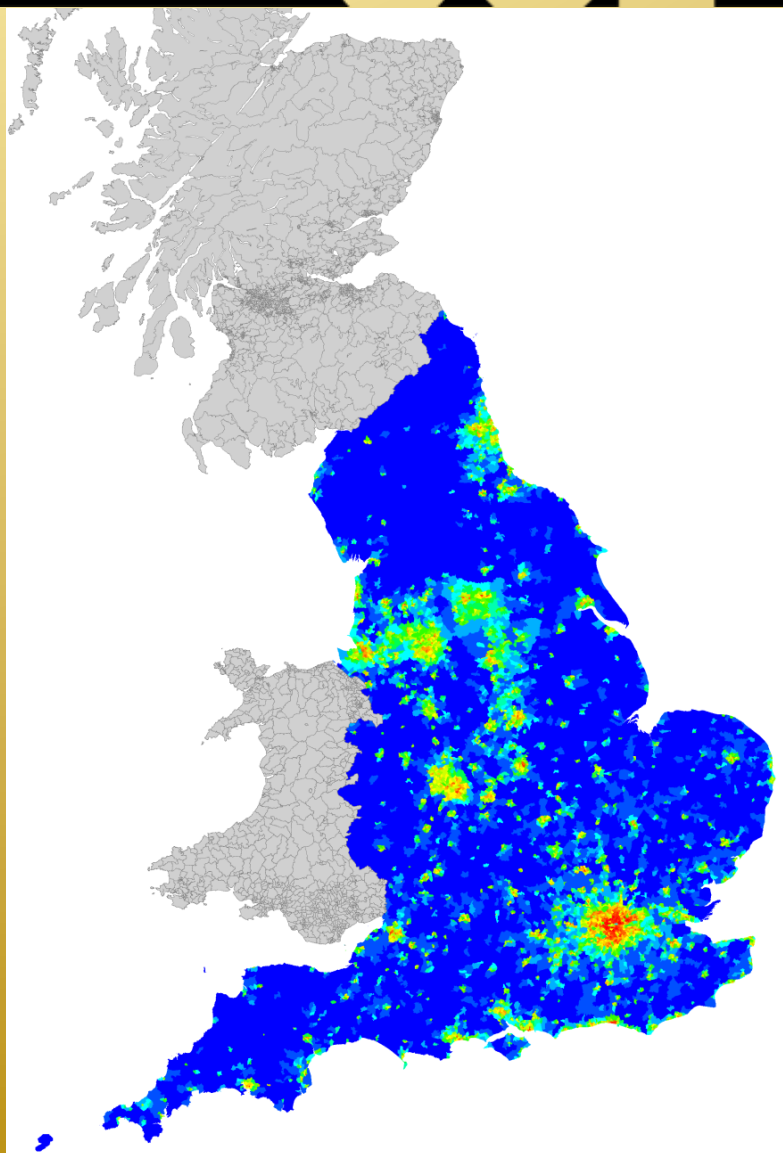


Scaling laws for urban indicators: $A \sim N^{\beta}$

- $\beta > 1$: superlinear regime (increasing returns)

Properties derived from the interactions between individuals

e.g. wealth, crime, innovation, etc

- $\beta \approx 1$: linear regime (proportional to population)

Properties encoding the basic individual needs

e.g. electricity consumption, number of households, etc.

- $\beta < 1$: sublinear regime (economies of scale)

Properties related to services and infrastructure

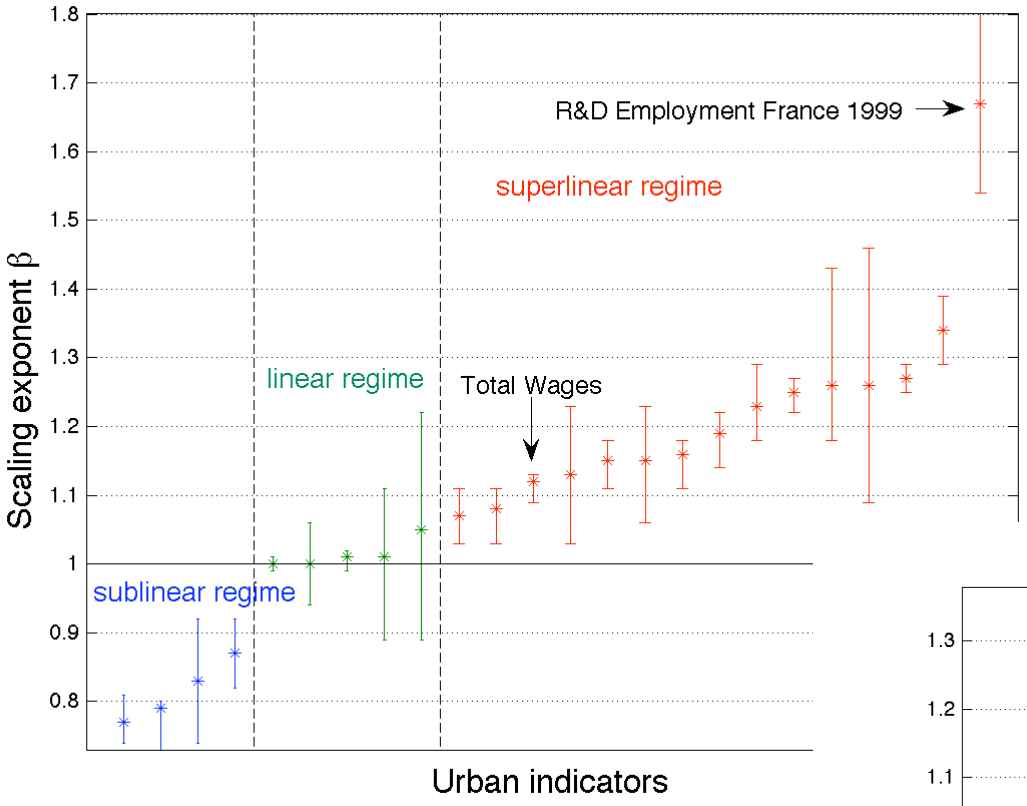
e.g.length of roads, number of gas stations, etc.

Table 1. Scaling exponents for urban indicators vs. city size

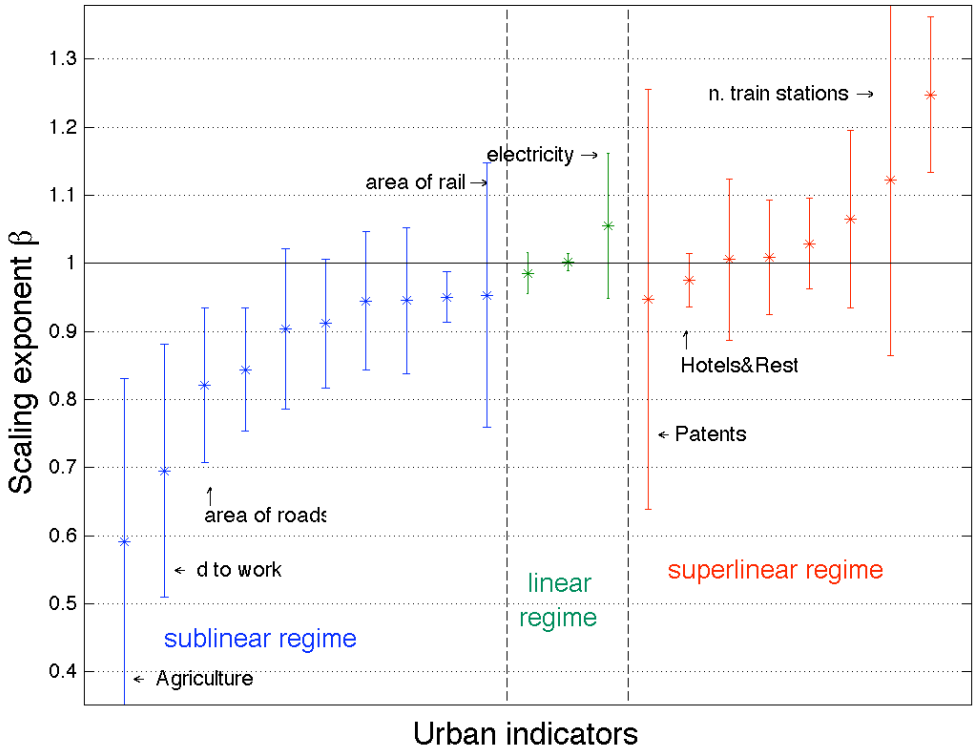
Y	β	95% CI	Adj-R^2	Observations	Country–year
New patents	1.27	[1.25,1.29]	0.72	331	U.S. 2001
Inventors	1.25	[1.22,1.27]	0.76	331	U.S. 2001
Private R&D employment	1.34	[1.29,1.39]	0.92	266	U.S. 2002
"Supercreative" employment	1.15	[1.11,1.18]	0.89	287	U.S. 2003
R&D establishments	1.19	[1.14,1.22]	0.77	287	U.S. 1997
R&D employment	1.26	[1.18,1.43]	0.93	295	China 2002
Total wages	1.12	[1.09,1.13]	0.96	361	U.S. 2002
Total bank deposits	1.08	[1.03,1.11]	0.91	267	U.S. 1996
GDP	1.15	[1.06,1.23]	0.96	295	China 2002
GDP	1.26	[1.09,1.46]	0.64	196	EU 1999–2003
GDP	1.13	[1.03,1.23]	0.94	37	Germany 2003
Total electrical consumption	1.07	[1.03,1.11]	0.88	392	Germany 2002
New AIDS cases	1.23	[1.18,1.29]	0.76	93	U.S. 2002–2003
Serious crimes	1.16	[1.11, 1.18]	0.89	287	U.S. 2003
Total housing	1.00	[0.99,1.01]	0.99	316	U.S. 1990
Total employment	1.01	[0.99,1.02]	0.98	331	U.S. 2001
Household electrical consumption	1.00	[0.94,1.06]	0.88	377	Germany 2002
Household electrical consumption	1.05	[0.89,1.22]	0.91	295	China 2002
Household water consumption	1.01	[0.89,1.11]	0.96	295	China 2002
Gasoline stations	0.77	[0.74,0.81]	0.93	318	U.S. 2001
Gasoline sales	0.79	[0.73,0.80]	0.94	318	U.S. 2001
Length of electrical cables	0.87	[0.82,0.92]	0.75	380	Germany 2002
Road surface	0.83	[0.74,0.92]	0.87	29	Germany 2002

L. Bettencourt et al, PNAS 2007.

Results from Bettencourt et al PNAS 2007



Results for Larger Urban Zones in the UK (LUZ)



How is the theory tested? → Observables need to be classified

Urban indicators for LUZ, UK census 2001	beta	95%CI		R2	observations
Employed in financial intermediation	1.25	1.13	1.36	0.96	21
n. Train Stations	1.12	0.86	1.38	0.81	21
Employed in real estate, business activities	1.06	0.93	1.20	0.94	21
<Total income> (weekly)	1.03	0.96	1.10	0.98	21
Employed as managers and senior officials	1.01	0.92	1.09	0.97	21
Employed in professional occupations	1.01	0.89	1.12	0.94	21
Employed in hotels and restaurants	0.97	0.94	1.01	0.99	21
Total number of Patents (2000-2011)	0.95	0.64	1.26	0.68	21
All people aged 16-74 in employment	0.99	0.96	1.02	1.00	21
All household spaces	1.00	0.99	1.01	1.00	21
Consumption of domestic electricity	1.06	0.95	1.16	0.96	21
Employed in agriculture, hunting and forestry	0.59	0.35	0.83	0.58	21
Distance to work (km)	0.70	0.51	0.88	0.76	21
Area of Road (1000m^2)*	0.82	0.71	0.93	0.93	19
Area of Domestic Gardens (1000m^2)*	0.84	0.75	0.93	0.96	19
Employed in manufacturing	0.90	0.79	1.02	0.93	21
n. Bus stops	0.91	0.82	1.01	0.96	21
Area of Path (1000m^2)*	0.94	0.84	1.05	0.96	19
Employed: process; plant & machine op.	0.95	0.84	1.05	0.95	21
Employed in elementary occupations	0.95	0.91	0.99	0.99	21
Area of Rail (1000m^2)*	0.95	0.76	1.15	0.86	19

Can all the observables be classified into 3 universality classes?

Is there a need to distinguish between indicators providing interaction information WITHIN a city VS BETWEEN cities in the face of globalisation?

How are observables such as infrastructure development towards more interaction between cities classified? E.g. rail?

Urban indicators for LUZ, UK census 2001	beta	95%CI		R2	observations
Employment in admin and secretarial occ.	1.05	1.01	1.09	0.99	21
Employment in sales and customer service occ.	0.99	0.95	1.04	0.99	21
Employment in personal service occupations	0.97	0.94	1.01	0.99	21
Employed in construction	0.97	0.92	1.02	0.99	21
Employment in education	0.96	0.87	1.05	0.96	21
n. of Coach Stations	0.95	0.53	1.38	0.54	21
Employed: public admin & defence, social security	0.94	0.81	1.08	0.92	21
Total number of cars and vans	0.94	0.90	0.99	0.99	21
Employment in skilled trades occupations	0.92	0.86	0.98	0.98	21
Area of Domestic Buildings (1000m^2)	0.89	0.84	0.95	0.99	19
Area of Non Domestic Buildings (1000m^2)	0.88	0.81	0.95	0.98	19

Problems with city definition in terms of LUZ:

- random selection of cities
- arbitrary extension of boundaries

➔ Is poor performance the result of ill-defined system of cities?

➔ Is the scaling exponent robust or too sensitive to boundary-definitions?

Re-defining cities in terms of the most basic parameter:

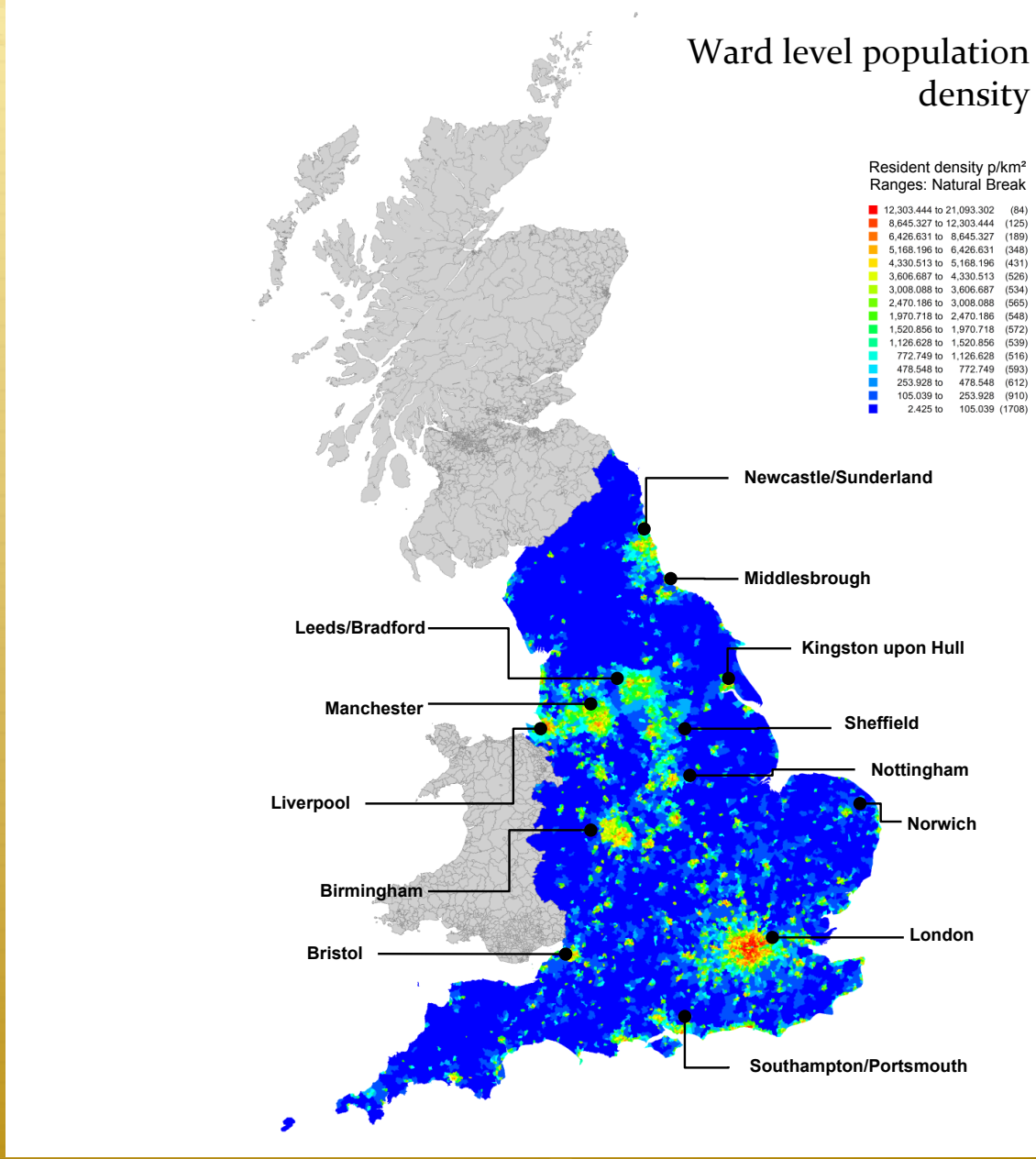
DENSITY

1) Start from smallest unit used in the census: WARDS

2) Cluster wards of density above a specific threshold

3) Choose a density cutoff for system of cities such that:

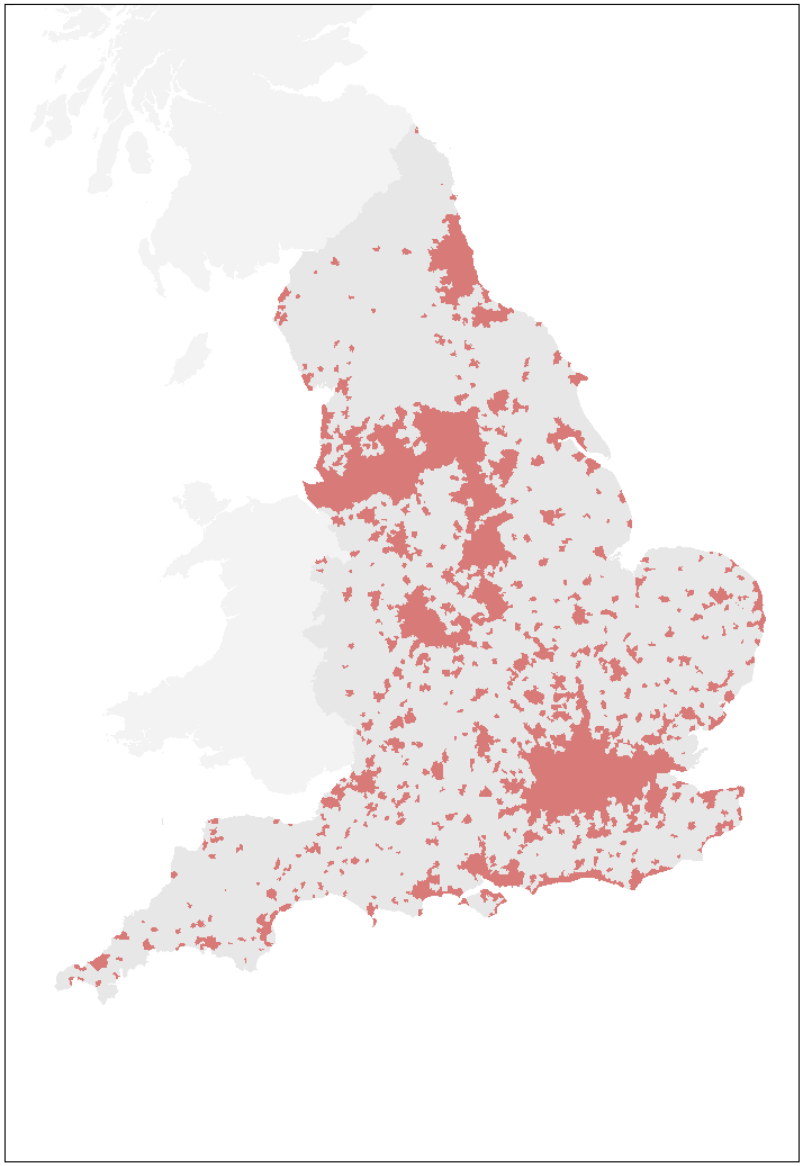
- Greater London Area recovered from cluster
- Liverpool and Manchester are two different clusters

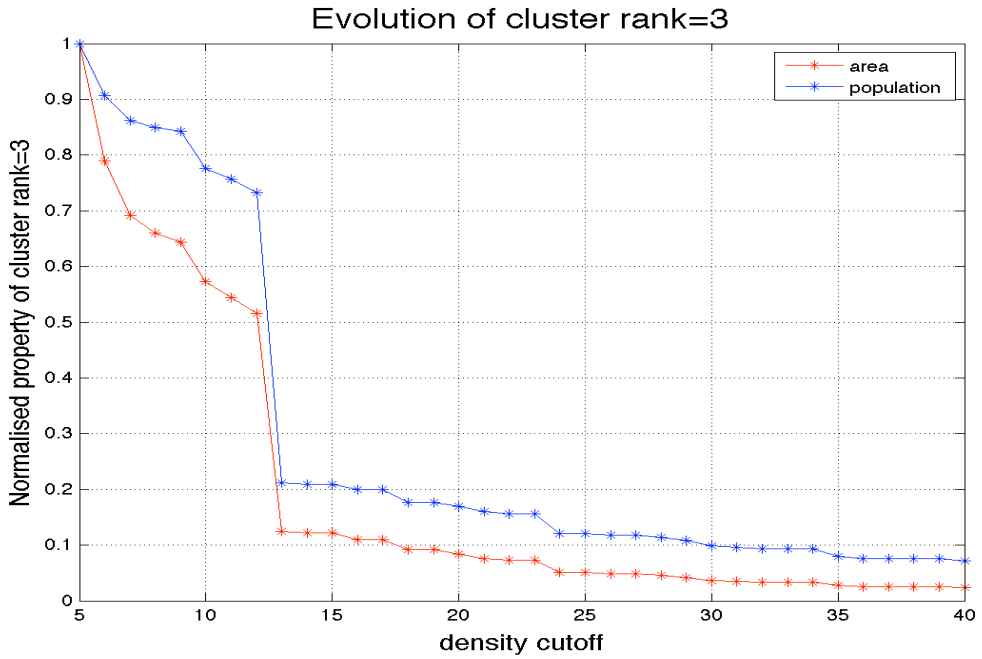


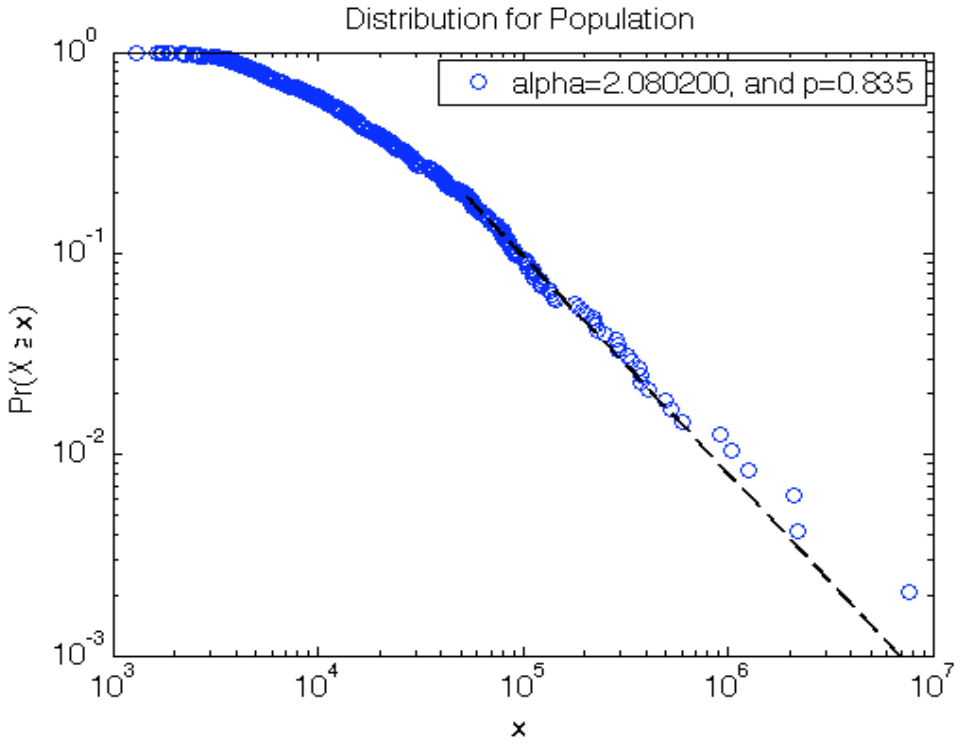
Is the lack of abiding to expected scaling laws due to a bad definition of cities?

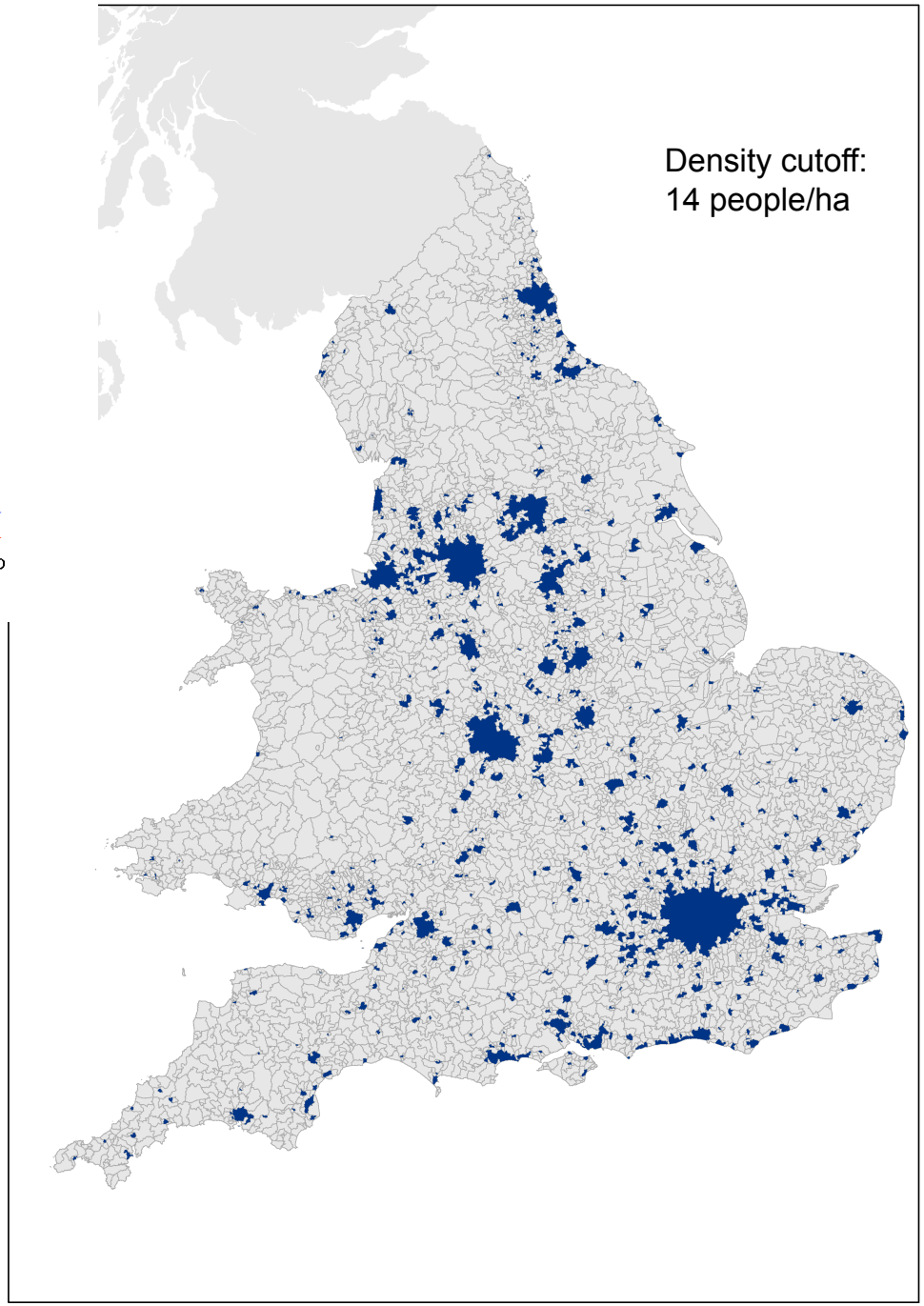
Test scaling over all range of cluster cutoffs:

- from cores of cities
- to clusters merging cities



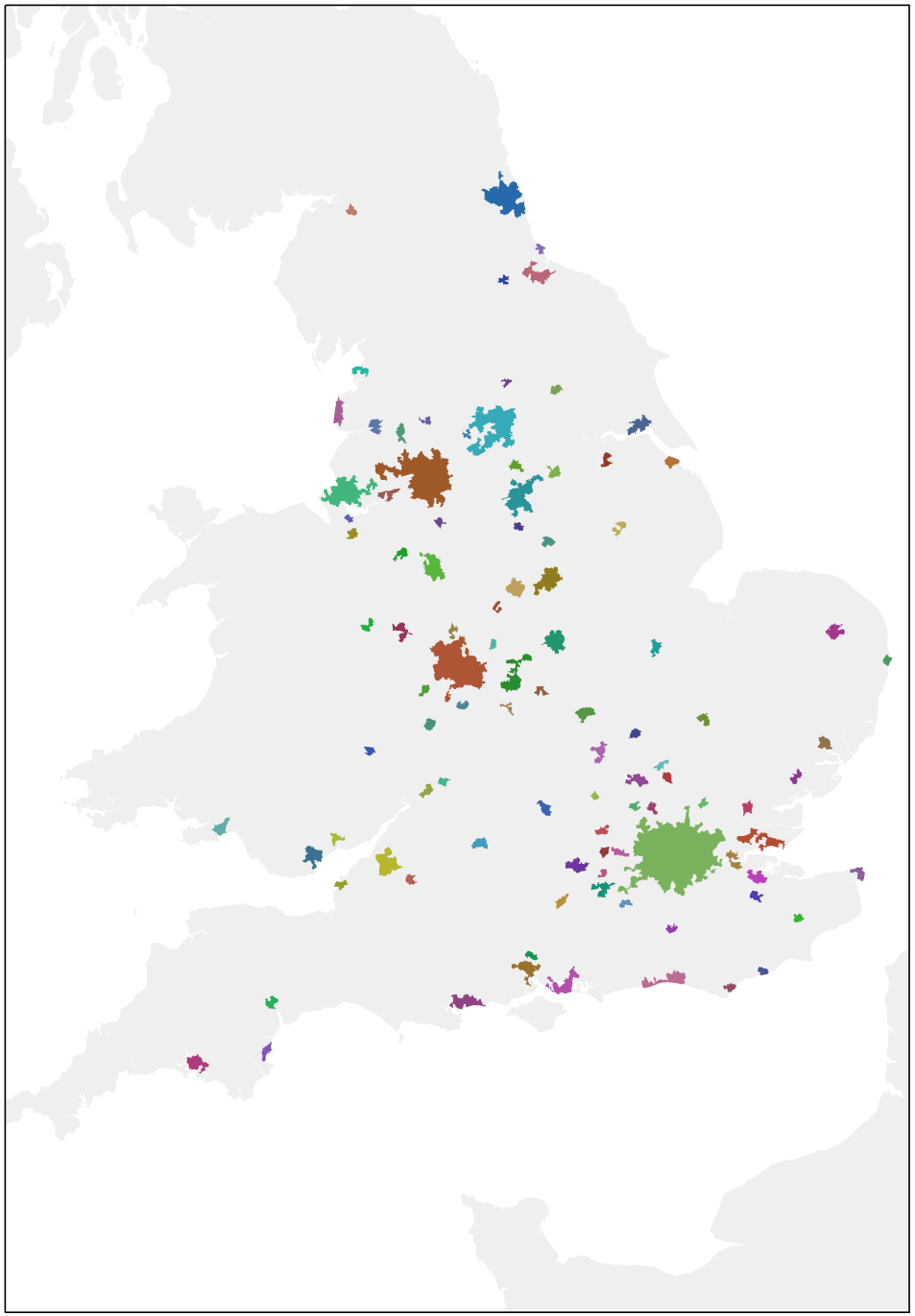

Evolution of cluster rank=3
area
population
Normalised property of cluster rank=3
density cutoff
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
5
10
15
20
25
30
35
40


Distribution for Population
alpha=2.080200, and p=0.835
Pr(X ≥ x)
x
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}


Density cutoff:
14 people/ha

Extend clusters to include areas contributing economically

Defined through the proportion of commuters for different thresholds



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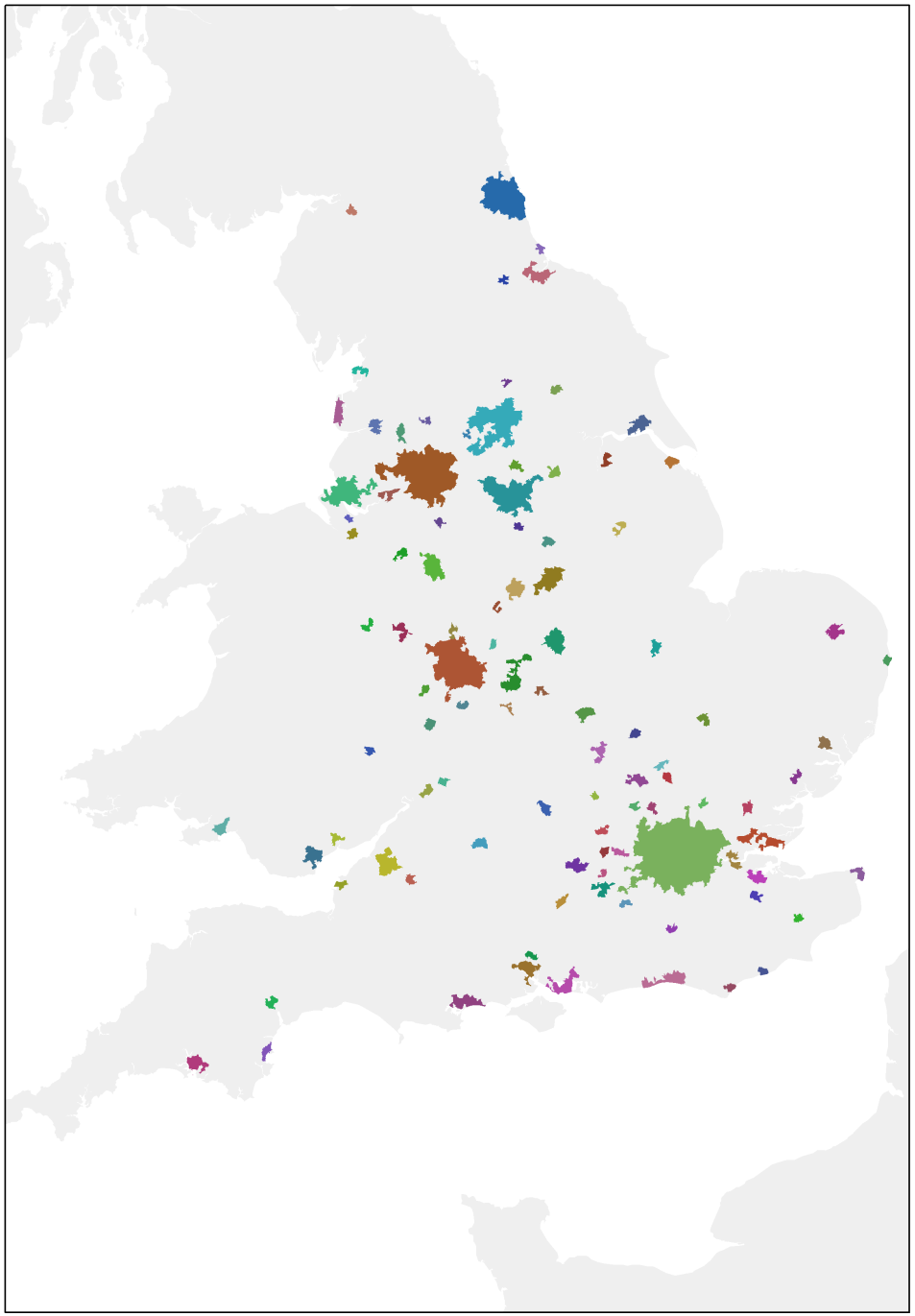

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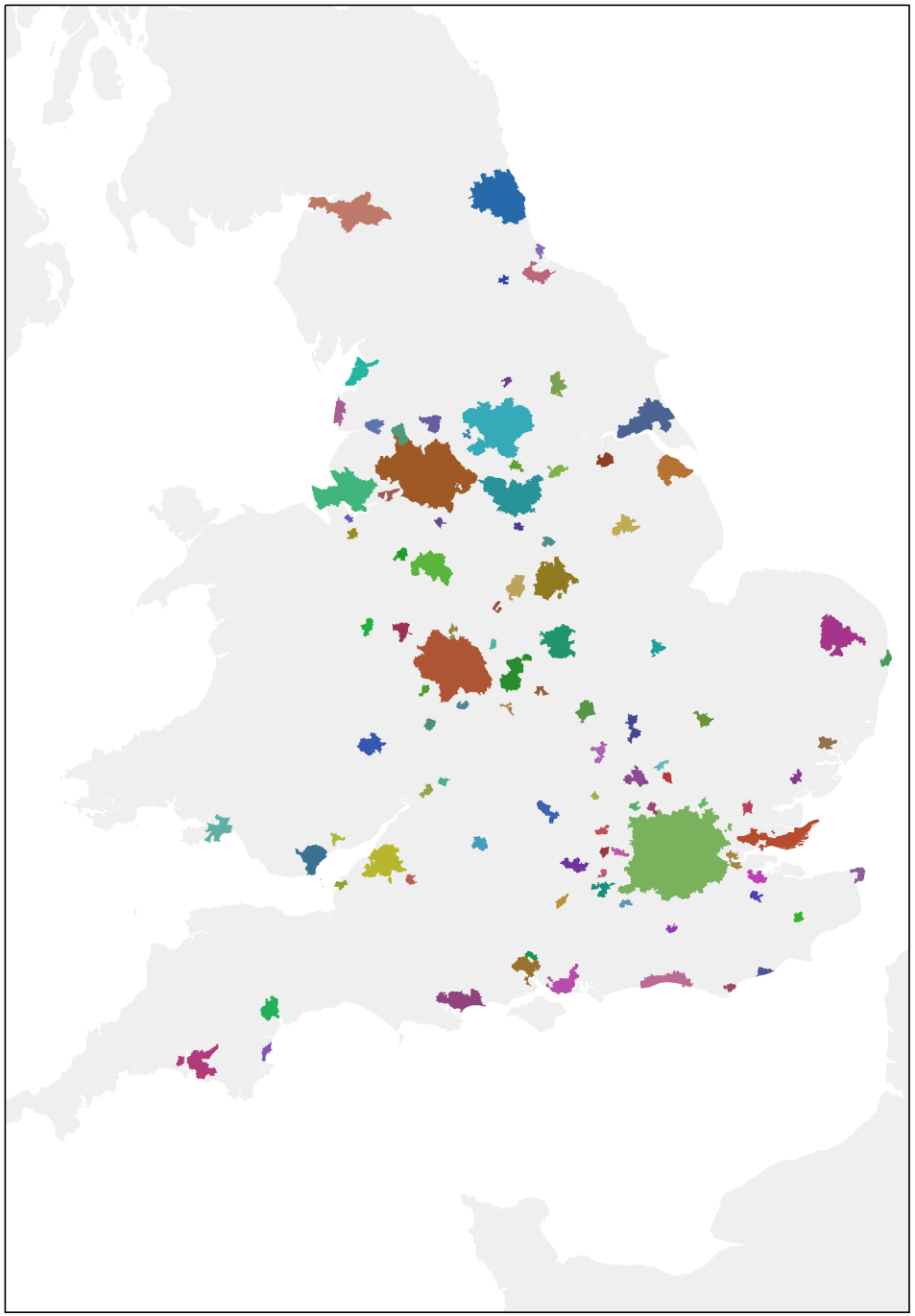

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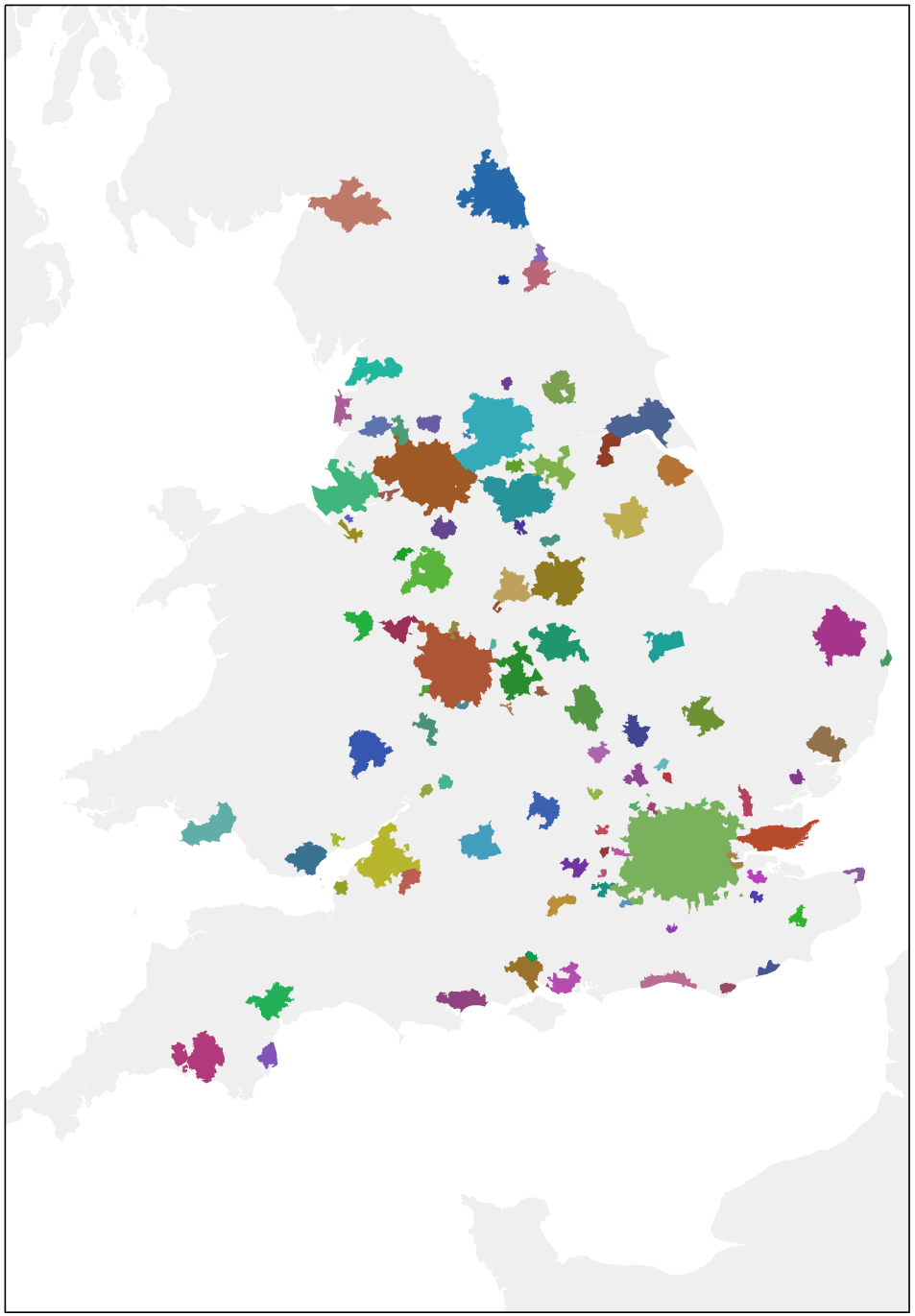

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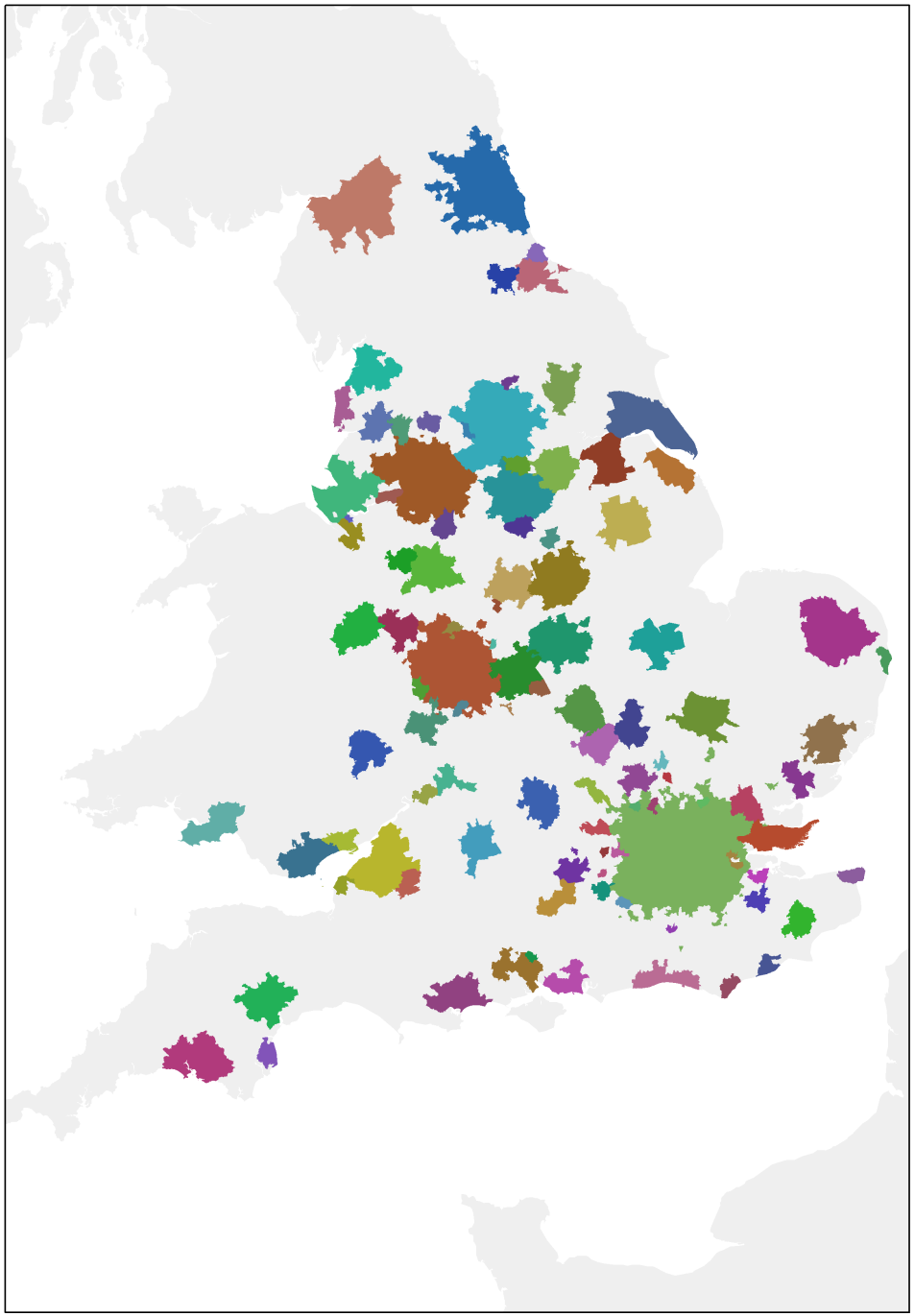

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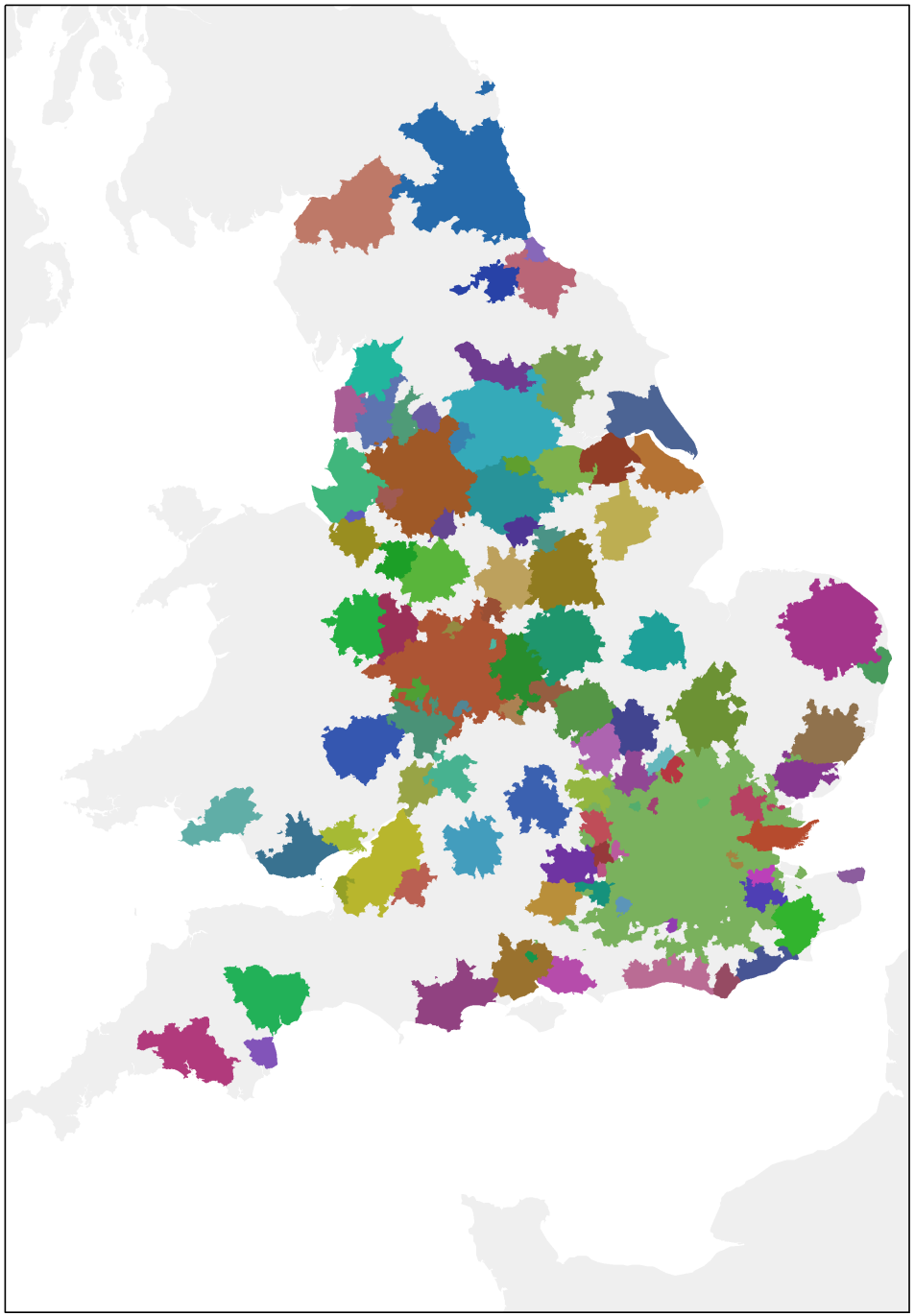

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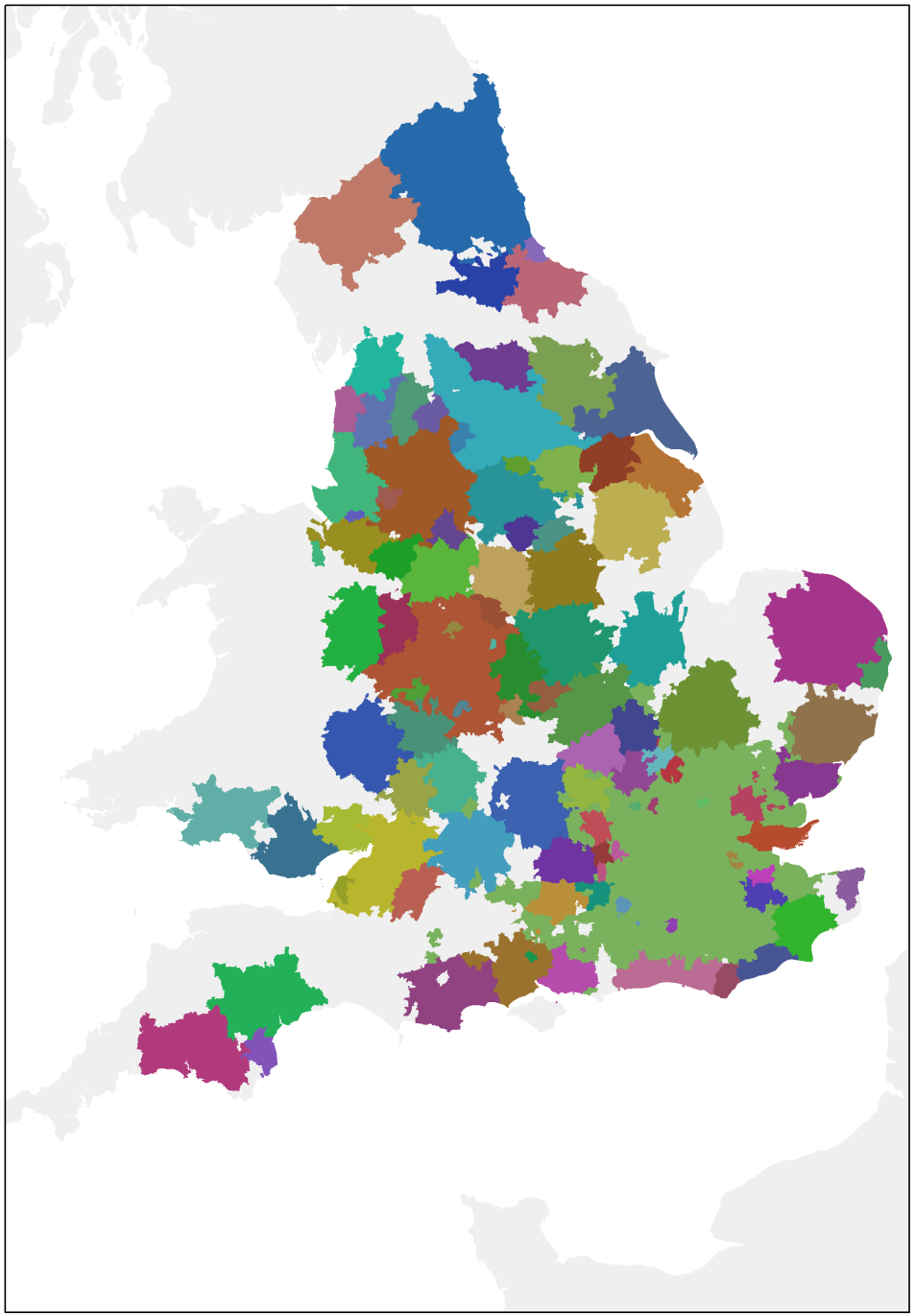

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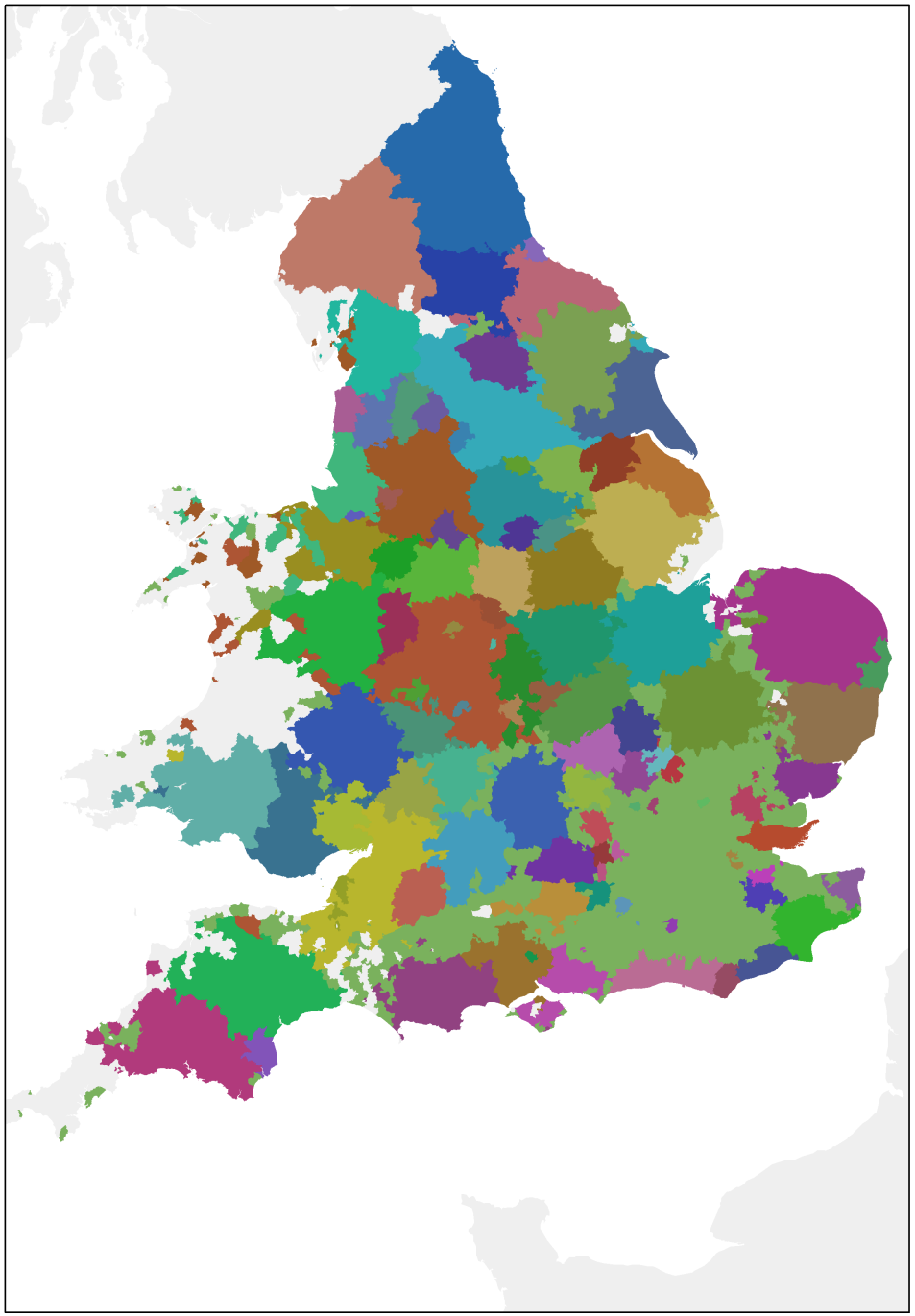

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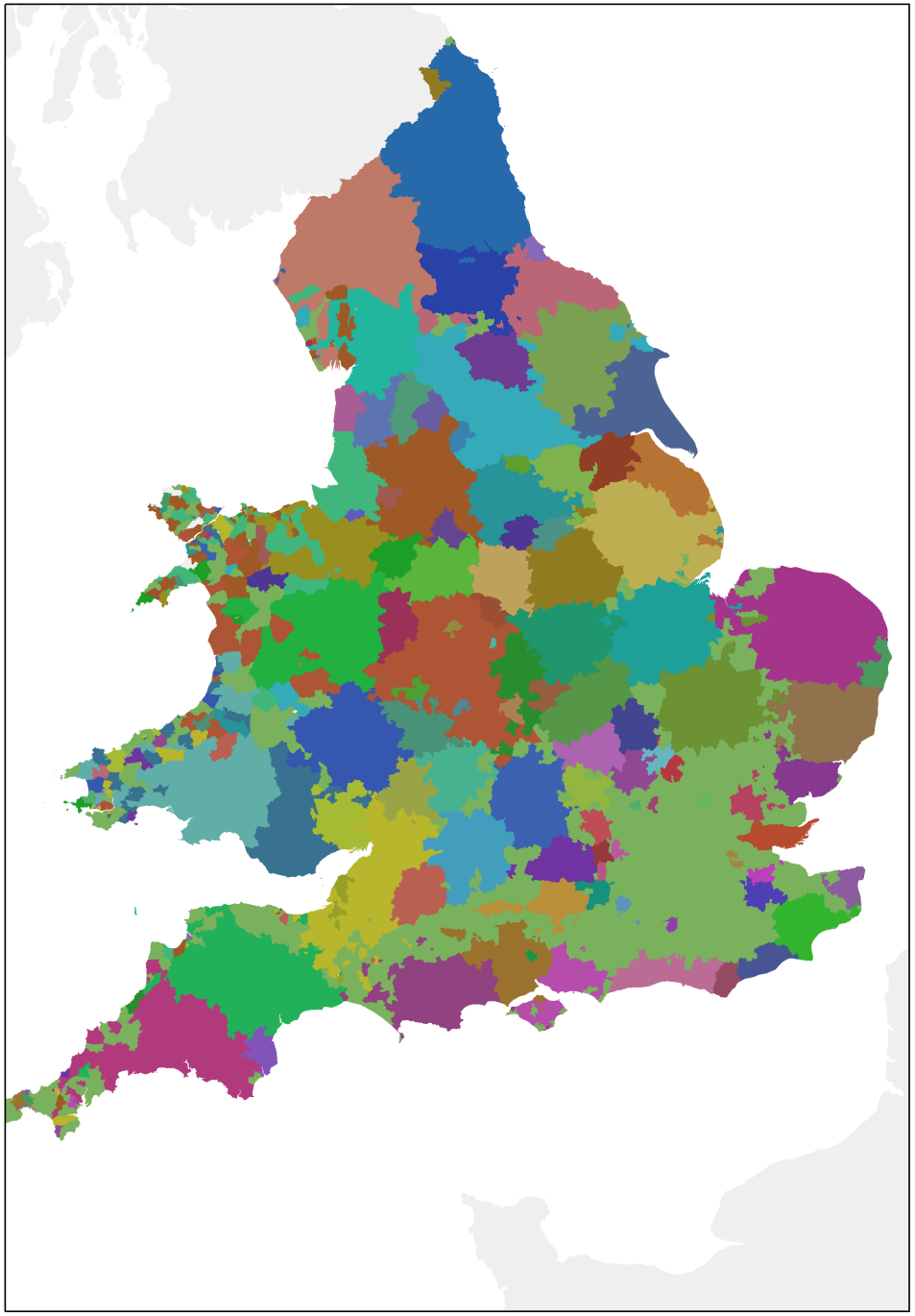
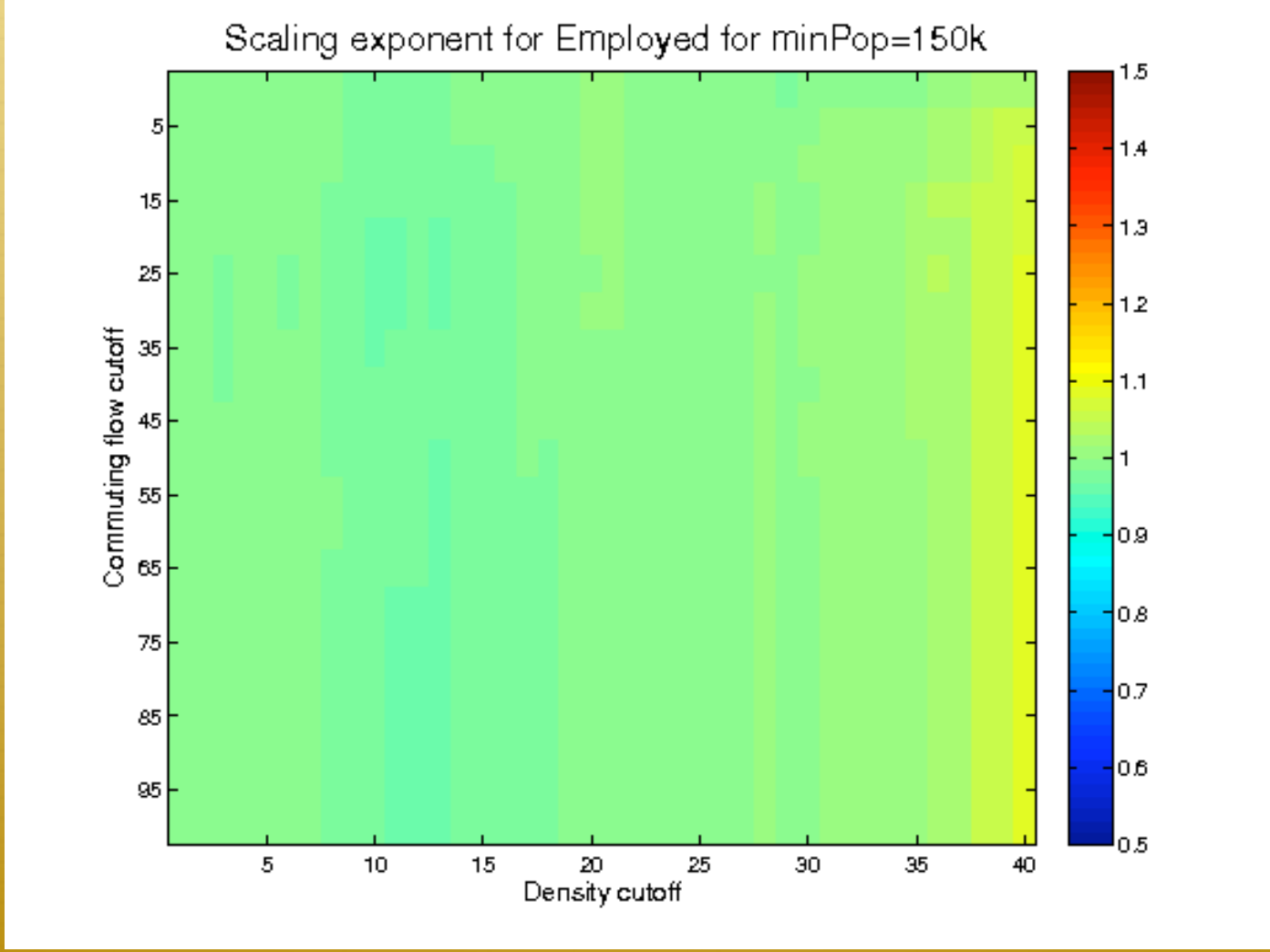


Results robust to city boundaries if $\beta \approx 1$



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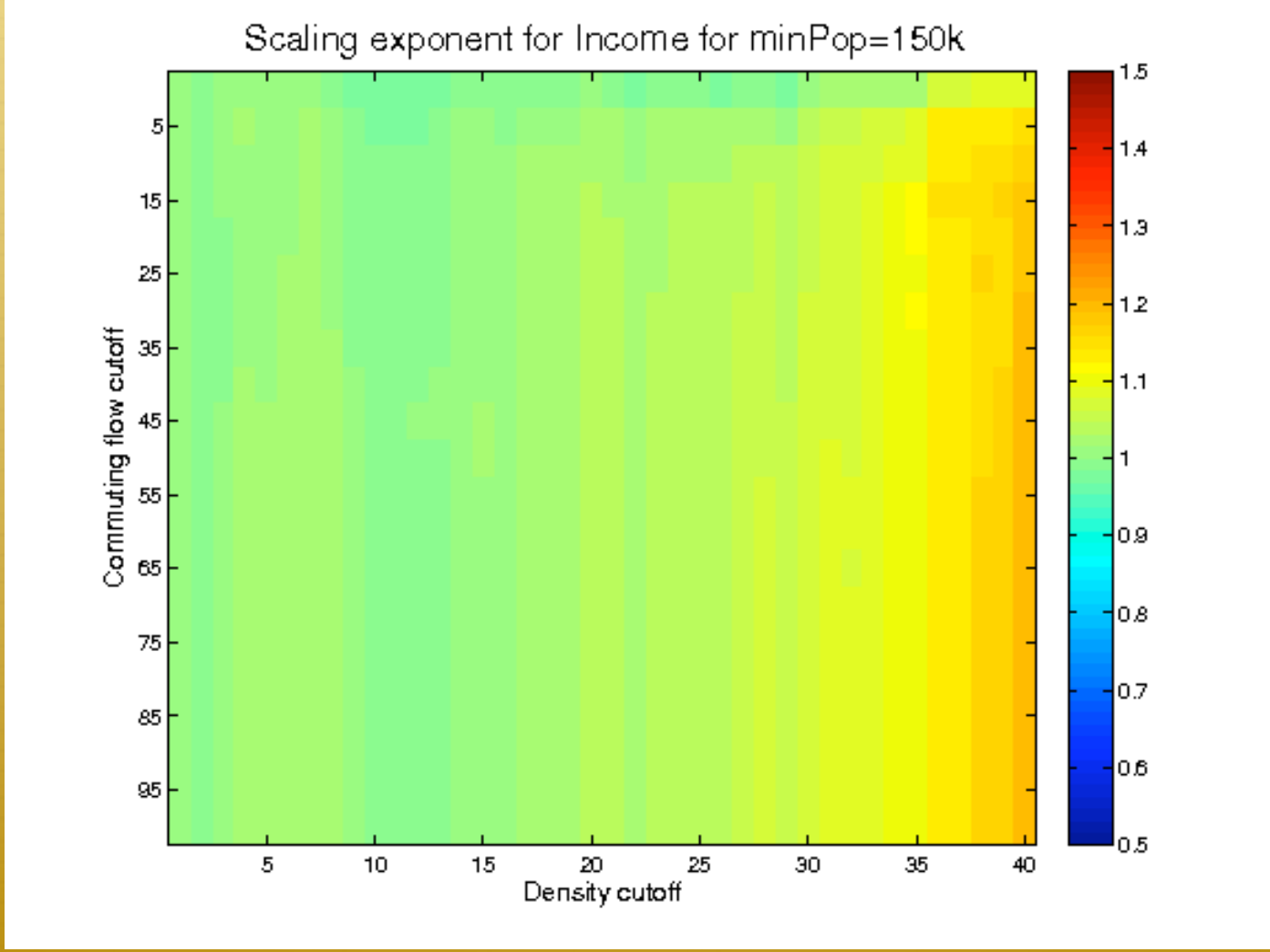

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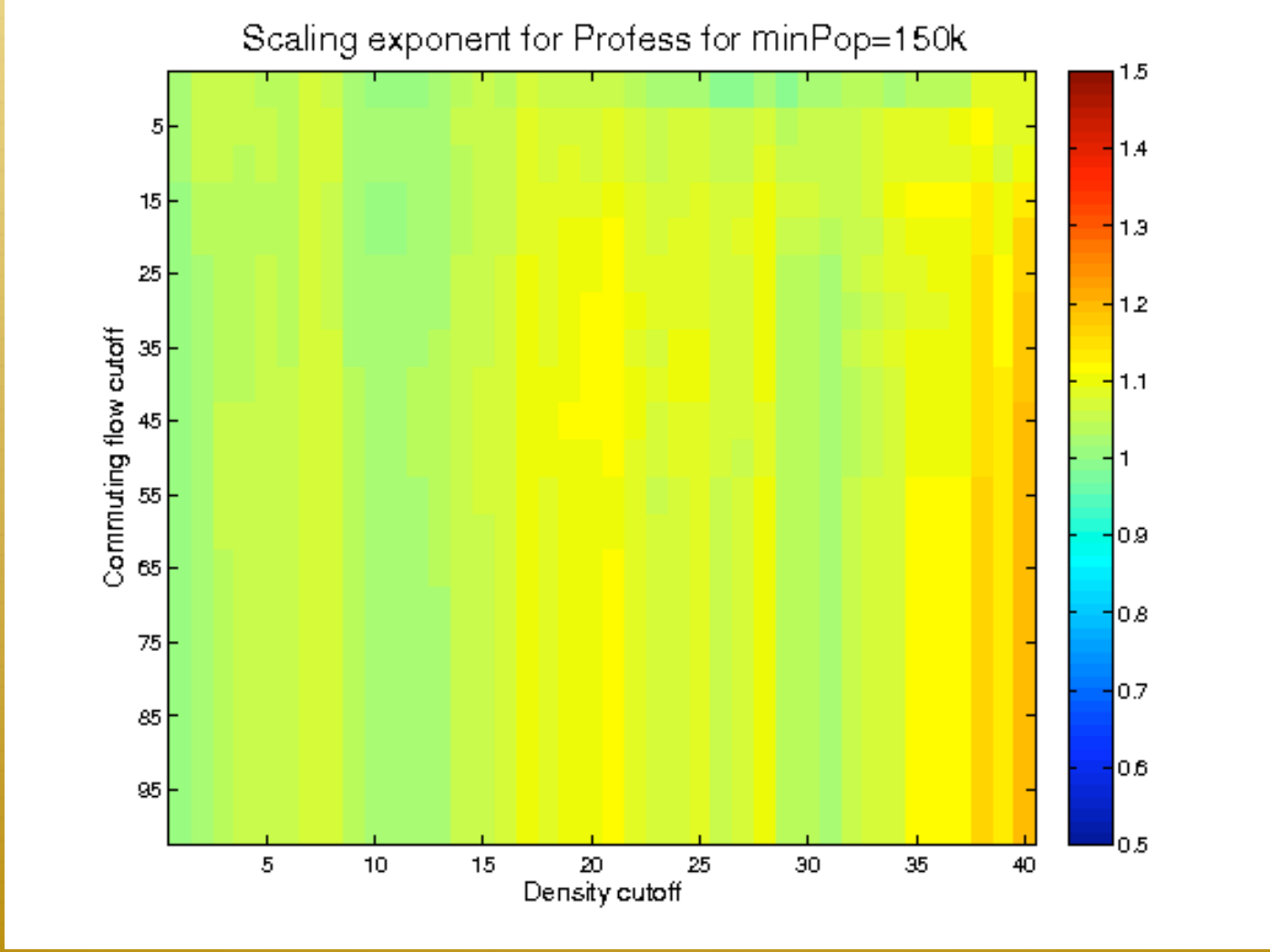

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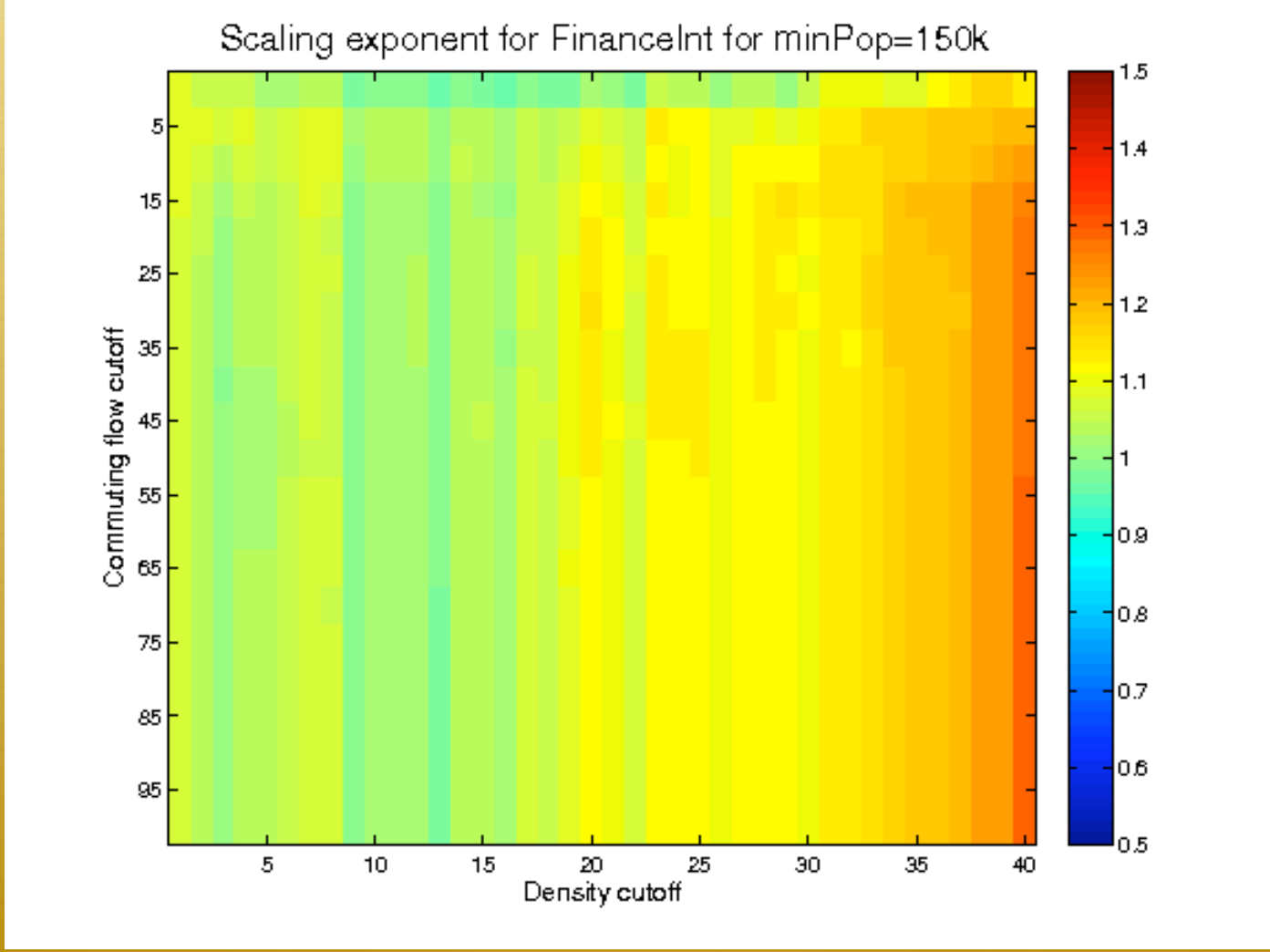
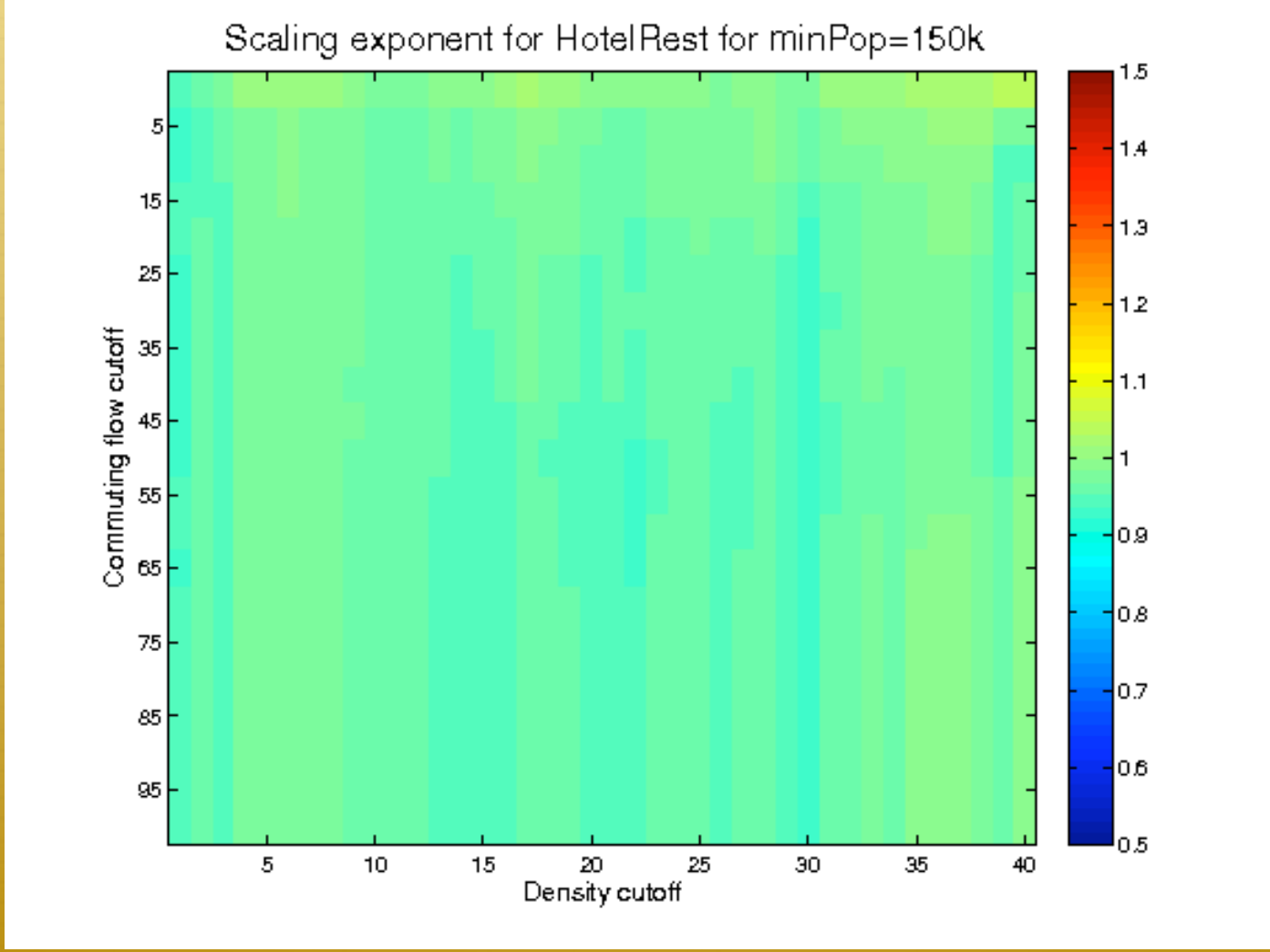
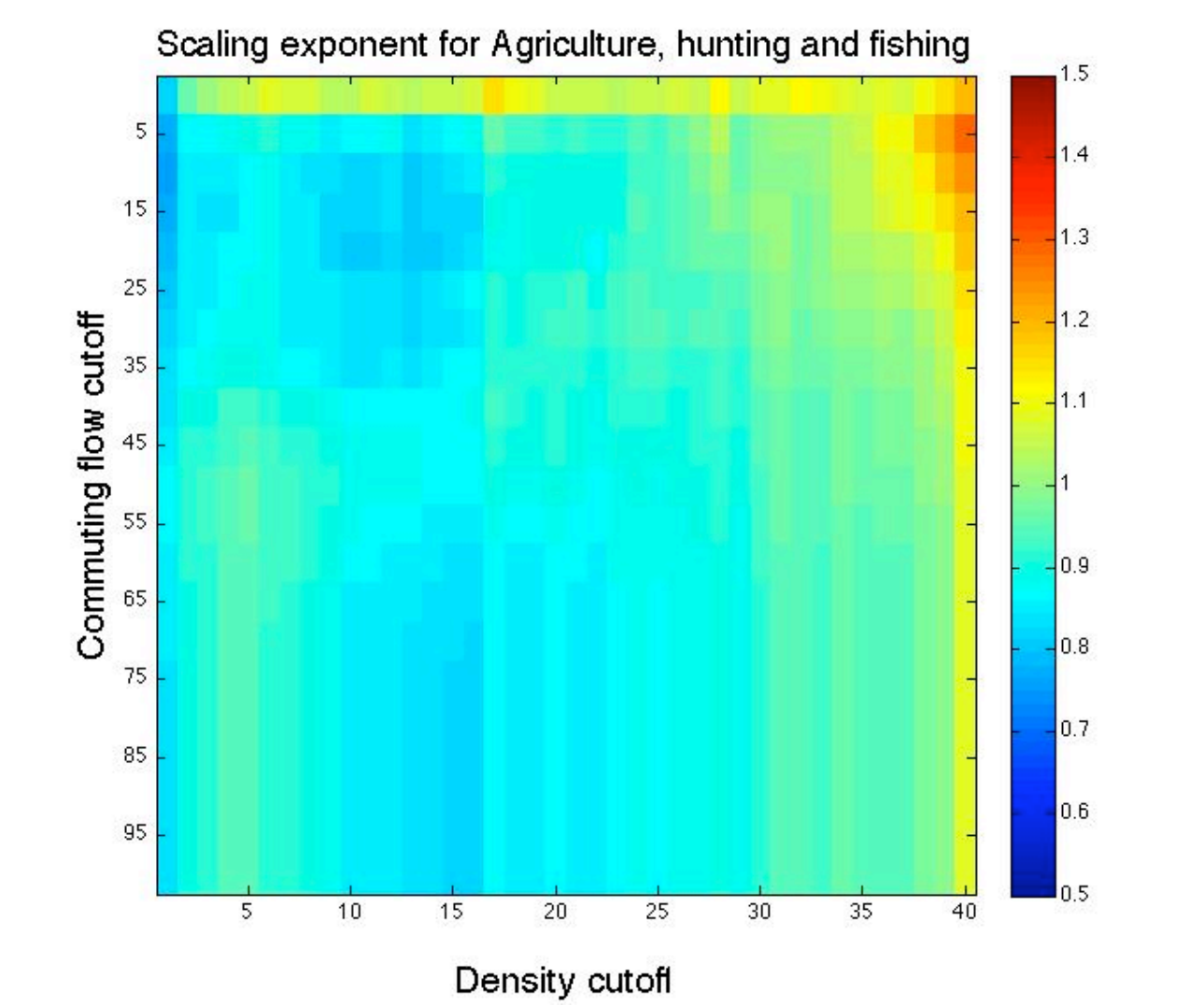


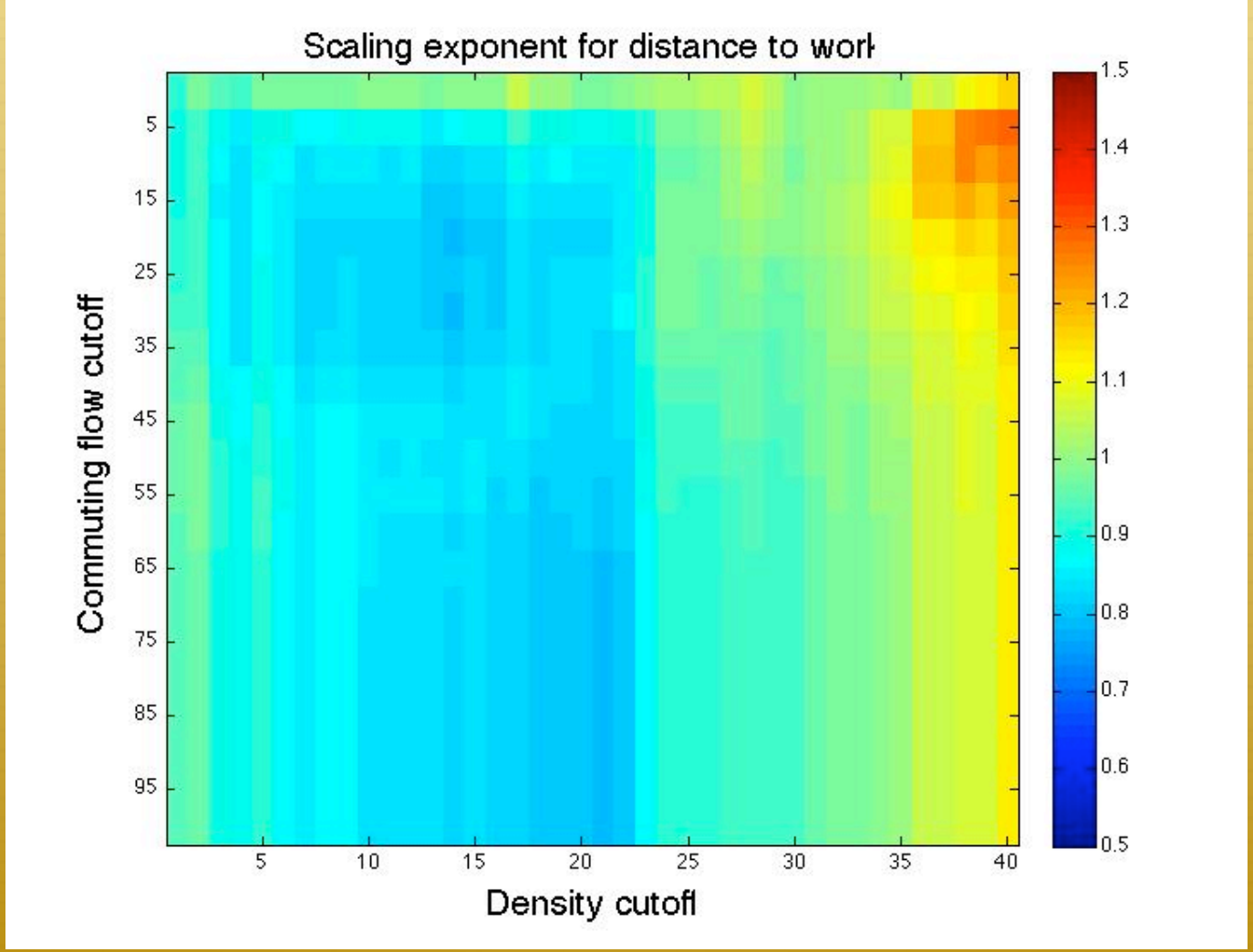
Results robust to city boundaries if β≈1



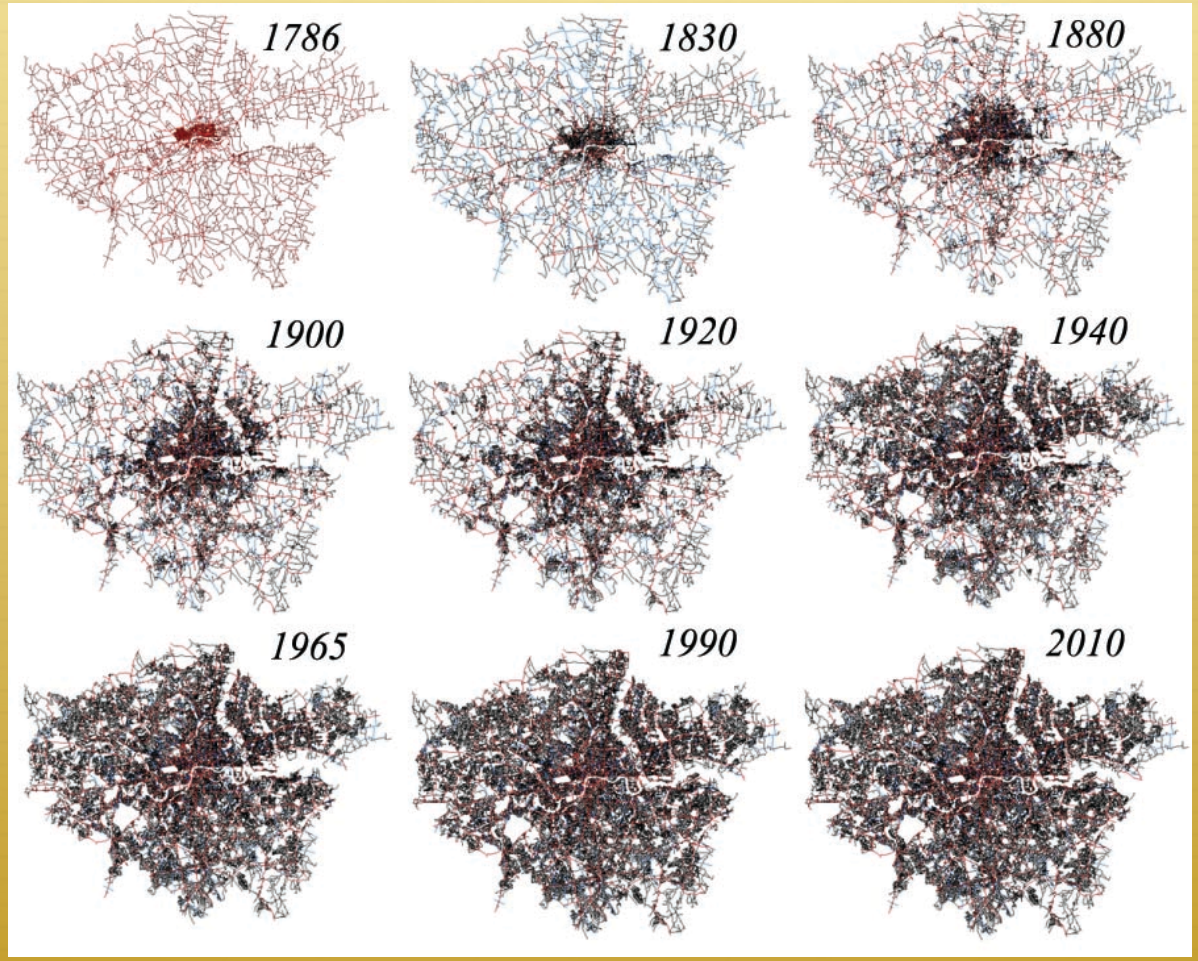
Results robust to city boundaries if β≈1



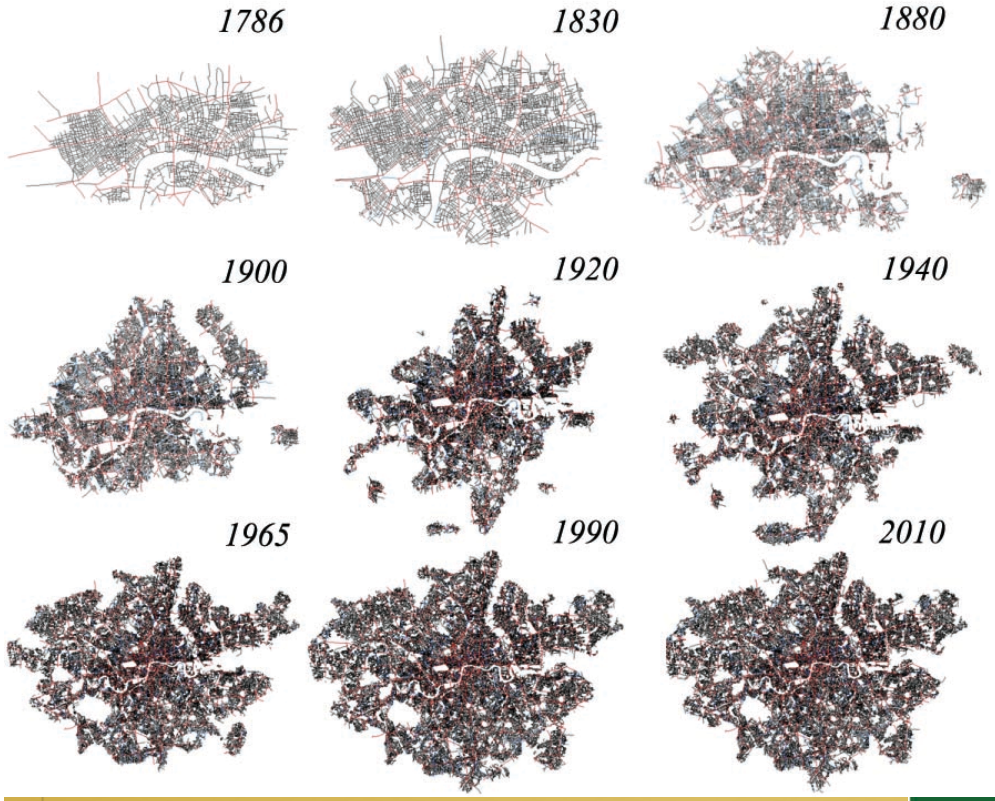
Results robust to city boundaries if $\beta \approx 1$



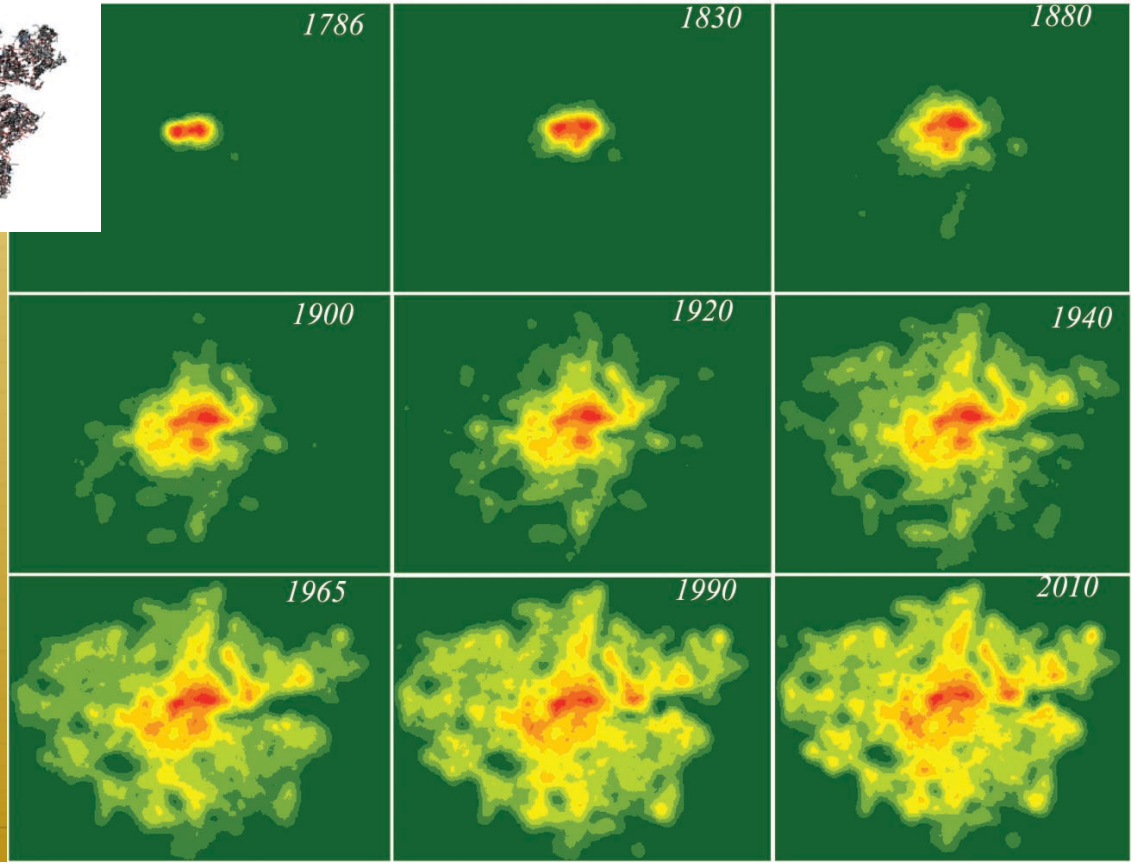
Other results sensible to city boundaries



Paolo Masucci, Kiril Stanilov, Michael Batty
arXiv:1206.5298



UCL



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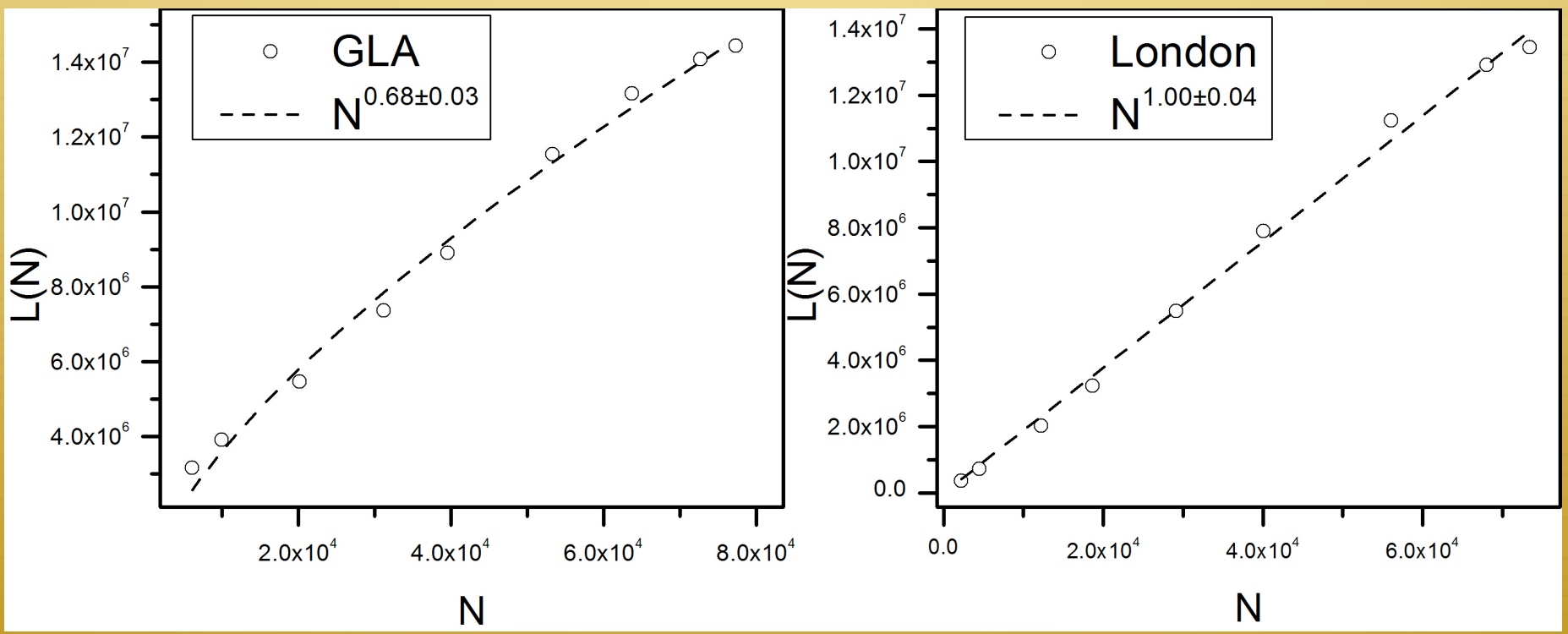
Exponent for physical quantities is very sensitive to city definition!!!



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Conclusions

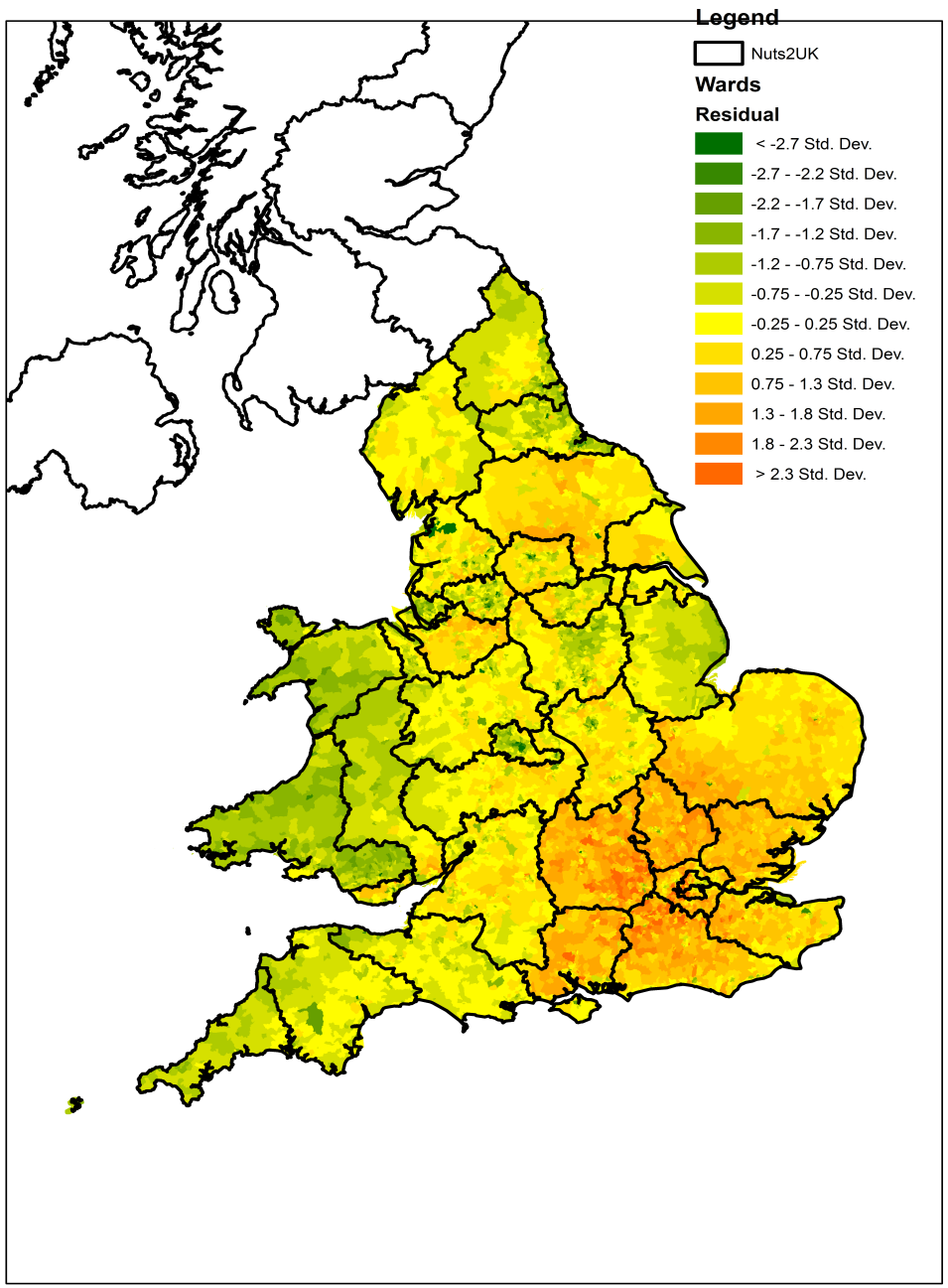
◆ How robust the scaling exponent needs to be with respect to city definition in order the reflect universality?

◆Clear identification of urban indicators in order to understand which properties can be transferred between systems

◆ Incorporate properties of cities in the global context

◆Maybe need to think about different regimes in a theory:

1) System of cities with no primate city
2) General laws for primate cities


Legend
Nuts2UK
Wards
Residual
< -2.7 Std. Dev.
-2.7 - -2.2 Std. Dev.
-2.2 - -1.7 Std. Dev.
-1.7 - -1.2 Std. Dev.
-1.2 - -0.75 Std. Dev.
-0.75 - -0.25 Std. Dev.
-0.25 - 0.25 Std. Dev.
0.25 - 0.75 Std. Dev.
0.75 - 1.3 Std. Dev.
1.3 - 1.8 Std. Dev.
1.8 - 2.3 Std. Dev.
> 2.3 Std. Dev.

Thank you!