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Small Project Working Paper

Rethinking place to understand spatial productivity patterns

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About PIN

The Productivity Insights Network was established in January 2018 and is funded by the Economic and Social Research Council. As a multi-disciplinary network of social science researchers engaged with public, private, and third sector partners, our aim is to change the tone of the productivity debate in theory and practice. It is led by the University of Sheffield, with co-investigators at Cambridge Econometrics, Cardiff University, Durham University, University of Sunderland, SQW, University of Cambridge, University of Essex, University of Glasgow, University of Leeds and University of Stirling. The support of the funder is acknowledged. The views expressed in this report are those of the authors and do not necessarily represent those of the funders.

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Recent research demonstrates that the UK is very spatially unequal when it comes to productivity with 72% of regions (NUTS3, 2016) performing below the UK average(McCann, 2020; Nguyen, 2019; Zymek & Jones, 2020).[1] A 2019 UK2070 Commission report points to lagging urban areas as an important source of these gaps(Martin et al., 2019).[2] In 2020, the OECD noted the underperformance of UK core cities relative to international peers, while Core Cities UK found that these places were not living up to their growth potential. The Centre for Cities quantifies the impact of urban underperformance noting that if the eight largest laggards alone closed their output gap the UK economy would be £47.4 billion larger(Cambridge Econometrics, 2018; OECD, 2020; Swinney & Enenkel, 2020).[3]

Prior to COVID-19, tackling these patterns of spatial inequality were a high priority forming the rationale behind the 'levelling up' agenda of the current administration. However, regional inequalities have taken on a new degree of urgency as productivity will likely be an important element of post-COVID-19 economic recovery and resilience(Sena, 2020).[4] Spatial patterns of productivity can offer a clue as to which places hold the most promise and face the most peril and understanding these dynamics is critical to crafting place-based approaches and interventions(Arestis, 2020; Tsvetkova et al., 2020).[5] However, we argue that our current methodologies are producing an incomplete picture of the productivity landscape and diluting the value of inter-city and inter-regional comparisons. The spatial boundaries currently in use[6] – such as primary urban areas (PUAs) for urban cores - tend to distort our perception of economic performance of places to the extent that, because of their methodological construction based largely on jurisdictional areas, the analysis based upon them can reach misleading conclusions. A new approach is required.

Spatial measurement and mismeasurement?

The significance of any statistical finding depends in large measure on the choice and relevance of the spatial unit in terms of the level of aggregation as well as the type of a region. Level refers to the scale from which the data is aggregated from (e.g. postcodes or local authority districts) while type refers to the nature of the region's boundaries (e.g. administrative

[1] Nguyen, D. (2019). *Regional disparities and development in the UK, National Institute of Economic and Social Research* Retrieved from https://www.niesr.ac.uk/publications/regional-economic-disparities-and-development-uk. See also McCann, P. (2020). Perceptions of regional inequality and the geography of discontent: insights from the UK. *Regional Studies*, 54(2), 256-267 and Zymek, R., & Jones, B. (2020). UK Regional Productivity Differences: An Evidence Review. Retrieved from https://industrialstrategycouncil.org/sites/default/files/attachments/UK%20Regional%20Productivity%20Differences%20-%20An%20Evidence%20Review_0.pdf

[2] Martin, R., Bailey, D., Evenhuis, E., Gardiner, B., Pike, A., Sunley, P., & Tyler, P. (2019). *The Economic Performance of Britain's Cities: Patterns, Processes and Policy Implications. Structural Transformation, Adaptability and City Economic Evolutions*. Retrieved from https://www.centreforcities.org/wp-content/uploads/2019/02/The-Evolving-Economic-Performance-of-Britain%E2%80%99s-Cities-Patterns-Processes-and-Policy-Implications.pdf

[3] Swinney, P., & Enenkel, K. (2020). *Why big cities are crucial to levelling up*. Retrieved from https://www.centreforcities.org/publication/why-big-cities-are-crucial-to-levelling-up/ . See also OECD. (2020). *Enhancing Productivity in UK Core Cities: Connecting Local and Regional Growth*. Policy Highlights. Retrieved from: https://www.oecd.org/cfe/cities/UK-Core-Cities-PH-Final.pdf and Cambridge Econometrics. (2018). *The Economic Performance and Resilience of the UK's Core Cities*. Retrieved from https://www.camecon.com/wp-content/uploads/2019/05/Core-Cities-Final-Report.pdf

[4] Sena, V. (2020). *Does productivity still matter?* Retrieved from https://productivityinsightsnetwork.co.uk/2020/05/does-productivity-still-matter/

[5] Tsvetkova, A., Ahrend, R., Martins, J. O., Lembcke, A. C., Knutsson, P., Jong, D., & Terzidis, N. (2020). *The spatial dimension of productivity*. doi:doi:https://doi.org/10.1787/ba5edb47-en and Arestis, P. (2020). Productivity and inequality in the UK: a political economy perspective. *Review of Evolutionary Political Economy*, 1(2), 183-197. doi:10.1007/s43253-020-00006-3

[6] This study focuses specifically on the scalar definitions used in productivity studies in the UK and OECD. However, it should be noted that there are *many* other spatial definitions in use (see the most recent Hierarchical Representation of UK Statistical Geographies ONS (2020). Hierarchical Representation of UK Statistical Geographies. from ONS https://geoportal.statistics.gov.uk/datasets/9c04ff58854040d09a5a7ce146ab59b4).

vs. functional) (Gardiner, 2019; Nguyen, 2019).[7] This is the heart of the modifiable areal unit problem (MAUP). Ideally, research on spatial productivity requires specifying urban areas of based on functional economic significance. Functional spatial units include spaces like local labour markets or employment areas that account for commuting patterns of people. However, these seldom map to administrative boundaries. The MAUP refers to the very significant fact that aggregated values will vary according to how we draw area boundaries. This research highlights the degree to which current research has been limited

To their credit, the studies on UK urban productivity cited above each base their analyses on a version of functional economic space. They do not fall into the trap of measuring urban productivity within the administrative boundaries of UK cities but attempt to encompass the broader space of economic activity. Box 1 lists these measures, how they were constructed (see also Table 1), and by whom. We argue that while these definitions of urban areas are justified in their aim of capturing functional economic space (type) their effectiveness is ultimately hamstrung by both their reliance on large administrative units as building blocks, and a tendency to use spatial configurations based on non-economic criteria as the basis of investigating economic phenomena.[8]

BOX 1: Summary of the aims of a selection of alternative spatial methodologies

Functional urban areas (FUAs)
Developed jointly by the OECD and European Commission. Using population density and travel-to-work, a FUA consists of a densely inhabited city and of a surrounding area (commuting zone) whose labour market is highly integrated with the city. The aim of this approach to functional urban areas is to create a harmonised definition of cities and their areas of influence for international comparisons as well as for policy analysis on topics related to urban development.

Travel to Work Areas (TTWAs)
Developed by the Office of National Statistics (ONS) in partnership with Newcastle University. TTWAs approximate labour market areas. They were developed to reflect self-contained areas in which most people both live and work and to explore local labour markets, market analysis, and to explore the spatial mismatch between labour supply and demand.

Primary Urban Areas (PUAs)
Developed in partnership with Newcastle University, PUAs focus on areas of economic concentration. They aim to capture the large amounts of economic activity that happen in small amounts of space in the heart of urban areas and generate agglomeration economies.

Major Towns and Cities (MT&C)
Developed as an experimental measure by the ONS, MT&Cs are meant to more accurately capture (as the name suggests) the geography of

[7] Nguyen, D., Regional disparities and development in the UK. See also Gardiner, B. (2019). *Long-Run Growth Dynamics of British Cities and their Role in the Economy*. (Doctor of Philosophy (PhD)), University of Cambridge.
[8] Note that this phenomenon is not unique to the UK – in addition to the OECD standard FUA other countries also rely on spatial definitions anchored in jurisdictional boundaries. For example, in the United States the most frequently used measures, Core Based Statistical Areas (CBSAs), which include Metropolitan (MSAs) and Micropolitan Statistical Areas (mSAs), are aggregations of counties that meet population and commuting thresholds. Canada uses a similar methodology based on contiguous municipalities to calculate Census Metropolitan Areas (CMAs).

Table 1: Comparison of spatial methodologies

Method	Core	Boundaries
Functional Urban Areas (FUA)[9] Based on data from: 2011	"City" - Local Authority Unit where 50% of population lives an urban centre (defined as a cluster of contiguous grid cells of 1 km2 with a density of at least 1,500 inhabitants per km2 and a population of at least 50,000 inhabitants overall)	"Commuting zone" - composed of the Local Administrative Units for which at least 15% of their workforce commute to the city. Commuting zones of the functional areas are identified based on commuting data (travel from home-to-work). Commuting data are also used to defined whether more than one city share the same commuting zone in a single polycentric functional urban area.
Travel to Work Areas (TTWA) 2011	Cores are usually associated with larger urban areas or cities and are algorithmically defined	Algorithmically established - at least 75% of an area's resident workforce work in the area and at least 75% of the people who work in the area also live in the area. The area must also have a working population of at least 3,500. However, for areas with a working population in excess of 25,000, self-containment rates as low as 66.7% are accepted. TTWA boundaries are non-overlapping, are contiguous and cover the whole of the UK.
Primary Urban Areas (PUA) 2016	Built-up land with a minimum area of 20 hectares. while settlements within 200 metres of each other are linked.	Snapped to nearest local authority district boundaries. Sometimes this involves including large swathes areas of additional un-built up land, on other occasions it requires excluding a significant portion of a city's suburbs and urban fringe.
Major Towns and Cities (MT&C) 2016	The geography is based on the built-up areas (BUAs) dataset that was created for 2011 Census outputs in England and Wales. This dataset provides a good starting point as it captured the built environment to identify settlements, without reference to the boundaries of administrative areas. Given the wealth of detailed 2011 Census data already published for these areas (and available from the Nomis website), it made sense to retain the link to BUAs wherever possible. These were supplemented, where it made sense, with BUA subdivisions (BUASDs).	A population size threshold was used to define the towns and cities that should be included. This was set at 75,000 usual resident population or workday population (as at 2011 Census).
Cores (HDCs and MDCs) 2018	We have adopted two definitions of urban(ised) cores – a medium density core with a minimum of 100 jobs/km^2 (MDC) and a high-density core with a minimum of 1,000 jobs/km^2 (HDC). These are made up of all contiguous lower layer super output areas (LSOAs) that satisfy that minimum employment density threshold. They can be a single LSOA but generally consist of agglomerations of more than 2 units.	These cores are interesting in themselves but also function as the building blocks for the second element of our spatial typology - Commuting Zones (CZs) – see below. While cores can form the kernels of CZs they can occur outside of these areas and there *can* be more than one (HD or MD) core within any given CZ area.
Commuting Zones (CZs) 2018	Commuting zones (CZs) are built from the cores described above. As there are two different core densities (high and medium) we can generate CZs are two different scales – MDCZ and HDCZ.	CZ boundaries are based on 2018 NOMIS origin-destination commuting data[8] and includes all LSOAs with at least 25% residents commuting to any LSOA in the core (HDC for HDCZ and MDC for MDCZs). These LSOAs are generally contiguous but exclaves are possible. This method also allows for overlaps.

[9] Note that the basis of this definition varies by country. The definition here is what is specified for the UK in: http://www.oecd.org/cfe/regionaldevelopment/United%20Kingdom.pdf

An introduction to Cores (HDCs and MDCs) and Commuting Zones (CZs)

Our central claim is that appropriate spatial definitions for investigating economic phenomena should be based on two criteria: that the variables used as the basis of any definition should be as closely matched as possible to the economic concepts being investigated, and they should be defined at as low a spatial level as possible in order to capture the underlying economic reality as accurately as possible.

Investigations into economic geography often focus on variables such as gross value added, employment by sector and occupation, labour and total factor productivity, as well as exploring concepts such as agglomeration, innovation and competitiveness. Our proposition therefore is that the distribution of *employment* is the fundamental foundation for analyses of these phenomena, rather than the distribution of resident population or buildings, as this most accurately defines the location of economic activity over space(Arbabi, Mayfield, & McCann, 2020; Jones, 2016).[10] Note that our analysis and spatial forms are based on data from 2018 and, therefore, predates the COVID-19 crisis that will likely have long term impacts on the spatial distribution of employment and enterprises in the UK. While we recognise that this data and our maps may no longer be accurate representations of current realities, the methodology we have developed here can be easily updated and its basic building blocks will continue to be relevant as post-COVID geographies of work evolve.

For the purposes of our analysis, we use the lower-layer super output area (LSOAs), which is the lowest level of spatial disaggregation widely available within Great Britain(Morrill, Cromartie, & Hart, 1999).[11] LSOAs were introduced in 2001 and have mean populations of 1,500(ONS, 2016).[12] We begin from these smallest possible units in order to get the most granular boundaries of economic space possible. Significantly, these units were not constructed using administrative boundaries and so enable us to not only most accurately pinpoint the limits of the economic areas that interest us but also do so in a jurisdictionally agnostic manner.

We started from the core question: where are the largest build-ups of employment activity in Britain? Our metric of choice is employment density, measured in jobs/square kilometre. We focus on two different metrics: the largest contiguous aggregations of “high density” activity (>1,000jobs/ km^2), and the largest contiguous aggregations of “medium density” activity (>100jobs/ km^2).[13] The medium density measure represents LSOAs that are in the region of,

[10] We are not the first, nor will we be the last, to critique existing spatial definitions or propose our own alternatives. See Jones, C. (2016). Spatial economy and the geography of functional economic areas. *Environment and Planning B: Urban Analytics and City Science*, 44(3), 486-503. This source compiles new geographical boundaries based on commuting, migration flows, and market locations. Arbabi, H., Mayfield, M., & McCann, P. (2020). Productivity, infrastructure and urban density—an allometric comparison of three European city regions across scales. *Journal of the Royal Statistical Society: Series A* (Statistics in Society), 183(1), 211-228. This paper uses algorithmically derived regions based on population densities.

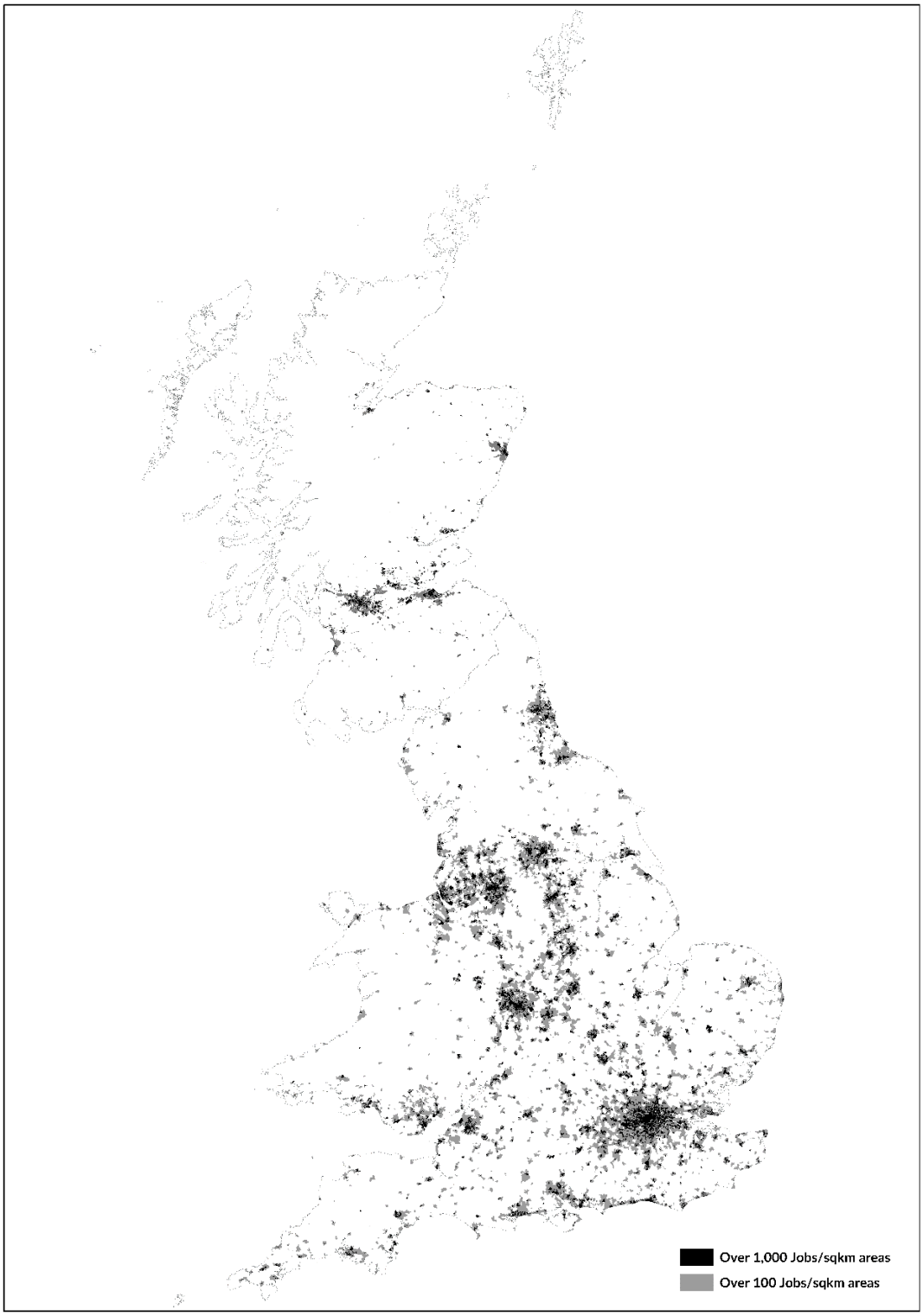
[11] A similar approach has been applied in the United States using census tracts to identify American commuting areas at different scales. Our approach differs in that our LCA cores are based on employment density versus population counts/density. See Morrill, R., Cromartie, J., & Hart, G. (1999). Metropolitan, Urban, and Rural Commuting Areas: Toward a Better Depiction of the United States Settlement System. *Urban Geography*, 20(8), 727-748.

[12] These are constructed based on adjacent unit postcodes and designed to aggregate postcodes that have similar population sizes and are as socially homogenous as possible based on tenure of household and dwelling type (homogeneity was not used as a factor in Scotland). The minimum size of an LSOA is 100 people or 40 households while the maximum is 3,000 people or 1,200 households. Note that while these were originally designed to align with parish/other local administrative boundaries and to be reasonably simply shaped, those requirements have since been modified. For more information, see ONS. (2016). Census geography: An overview of the various geographies used in the production of statistics collected via the UK census. Retrieved from https://www.ons.gov.uk/methodology/geography/ukgeographies/censusgeography#output-area-oa

[13] We selected these thresholds after experimenting with various densities, including 3,000 jobs/ km^2 and 500 jobs/ km^2. Given our knowledge of economic activity and urban morphology in the UK, we felt that the 1,000 and 100

or slightly above, the mean GB employment density figure of 127 jobs/km^2.

Figure 1: Employment density in the UK (2018) [click for full size image]



jobs/ km^2 densities provided the closest possible approximations of the spaces that we intended to capture – namely, dense urban cores and extended urban employment areas, respectively. Our decisions were also driven by practical concerns, below 100 jobs/km^2 boundaries become quite diffuse while above 1,000 jobs/km^2 some important core places no longer appear on the map. That said, thresholds are always a bit arbitrary (we tend to favour round numbers at regular intervals, etc etc.) and so we acknowledge that some may reasonably disagree with our decisions. In that event, it is relatively easy to adopt our methodology with different core density levels.

Figure 1 shows the distribution of economic activity across GB at the LSOA level. The map shows high employment density LSOAs (>1000jobs/km^2) in black, medium employment density LSOAs (100-1000jobs/ km^2) in grey and low density LSOAs (<100jobs/km^2) in white.

Table 2: Area and share of jobs by LSOA employment density (2018)

Category	Description	Area	Proportion of Land	Jobs	Proportion of Jobs
High Density	>=1000 jobs/sqkm	6,025.53	3%	20,395,525.00	69%
Medium Density	>=100 jobs/sqkm<1000 jobs/sqkm	20,550.45	9%	6,361,705.00	22%
Low density	<100 Jobs/sqkm	205,535.01	89%	2,765,520.00	9%
Total		232,111.00	100%	29,522,750.00	100%

Table 2 shows just how significant this categorisation can be. High density LSOAs cover just 3% of GB land area yet contain 69% of all jobs. At the other end of the spectrum, low density LSOAs cover 89% of GB land area, yet host just 9% of all employment.

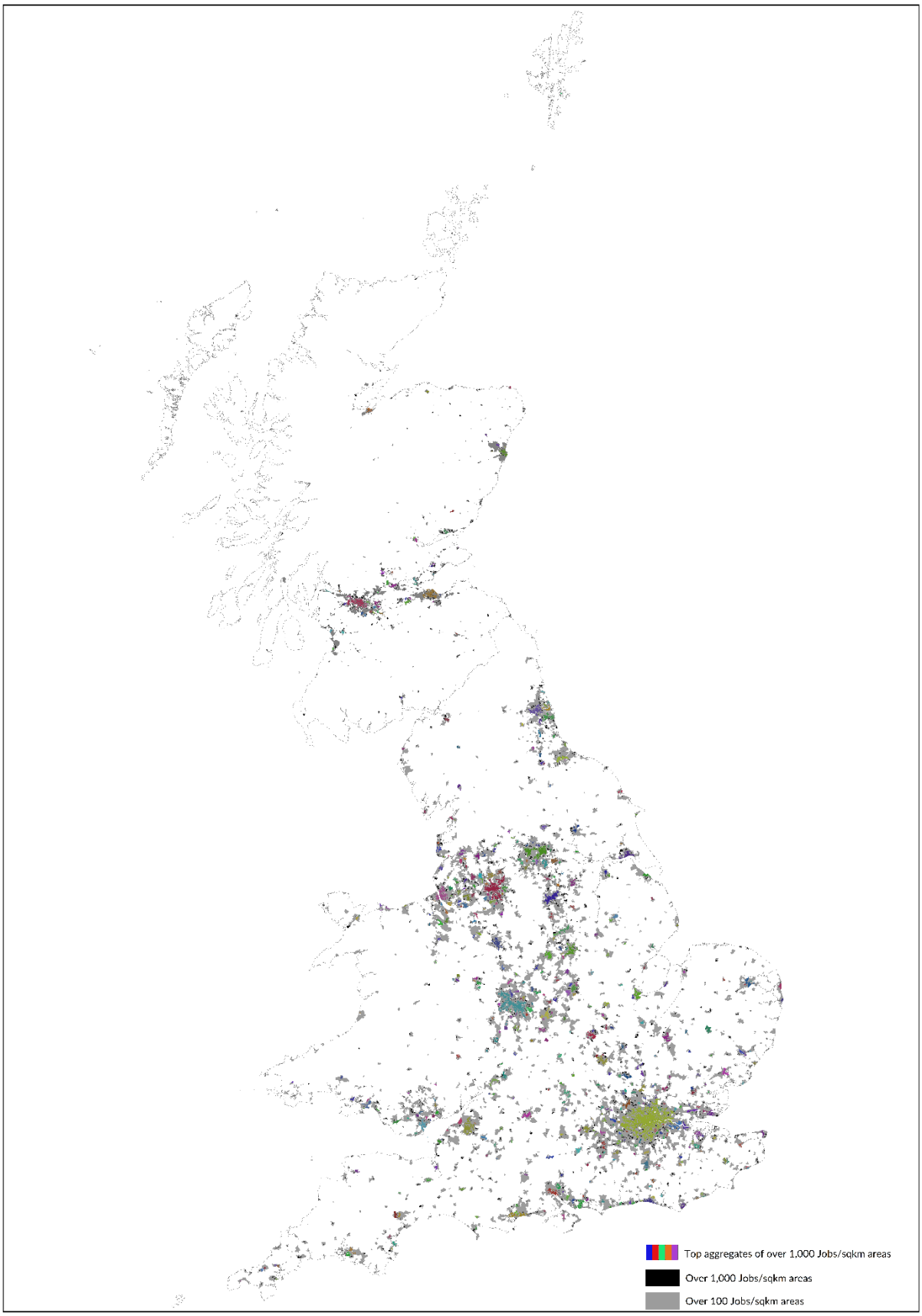
The expected distribution of economic activity around the country is clearly visible: in Figure 1, we see a large aggregation of activity in London, an elongated oval of activity covering a ring of cities in the midlands and the north, the Scottish central belt, smaller conurbations in North East England and South Wales, and beyond this a spattering of smaller cities and market towns distributed across the rest of the country, although most visibly present south of a line from the Severn estuary to the Wash. More sparsely populated areas, often corresponding to national parks, are visible for being almost entirely void of employment density.

The immediate obvious challenge is to identify the largest single aggregations of high- and medium- density employment within Britain. In order to categorise these areas in a manageable fashion, we introduce a lower cut-off in terms of total employment across contiguous LSOAs in order to be classified as an employment core. For high density cores (HDCs), we set this threshold as 5,000 jobs. For medium density cores (MDCs), with its more relaxed employment density criteria, we set this total threshold correspondingly higher, at 10,000 total jobs. We find that 194 medium density cores and 587 high density cores meet these two criteria. The higher density measure (HDCs) captures denser employment zones that typically, but not exclusively correspond to urban centres. Showing these wherever they occur in an urban area allows us to explore differences in the spatial configuration of places and acknowledge that significant and dense employment areas exist (sometimes far) outside of traditionally defined urban centres. We conceptualise the mid-range density areas (MDCs) as the more generalised economic centre of gravity of urban regions. These are not necessarily the geographical “centres” of broader urban areas (see the discussion of Commuting Zones, below) but we think capture the most relevant areas of economic activity. Note that many of these are polycentric – they encompass parts of several different political jurisdictions, and even extend in some cases across several major cities.

High Density Aggregates

All high-density aggregates with greater than 5,000 total jobs are shown in figure 2, highlighted in individual colours. We denote these as high-density cores (HDCs); there are 587 such cores within Great Britain.

Figure 2: All high-density cores (HDCs), 2018 [click for larger image]
Coloured areas indicate aggregates with over 5,000 jobs.



The top 30 high-density aggregates are listed in Table 3. London tops the list, with a high-density core of 4.5m workers, followed by Birmingham and Manchester, almost neck-and-neck with 666,000 and 656,000 workers respectively. In total, there are 24 areas of high-employment density with over 100,000 workers in Britain, and a further 29 with between 50,000 and 100,000. We don't make any attempt to restrict entry in this list to recognised "cities", and large urban-fringe employment sites, for example around airports or groups of business parks, often represent a larger aggregation of employment in a single area than many more traditional town centres. *Edge cities*(Ding & Bingham, 2000; Garreau, 1991)[14], for instance, are defined as significant employment areas on urban fringes that typically have few residents and are often amorphous and lack centres, yet are important nodes in the economic life of urban areas. Many of our 587 HDCs capture the existence of these geographies within GB.

Table 3: Employment in the top 30 largest HDCs (2018)

ID	NAME	Jobs	ID	NAME	Jobs
HDC1	London	4,588,260	HDC16	Stoke-on-Trent	116,530
HDC2	Birmingham	665,815	HDC17	Brighton and Hove	115,525
HDC3	Manchester	655,590	HDC18	Kingston upon Hull	112,565
HDC4	Leeds	425,625	HDC19	Leicester	111,955
HDC5	Glasgow	398,080	HDC20	Derby	110,695
HDC6	Bristol	300,665	HDC21	Oxford	110,445
HDC7	Edinburgh	284,960	HDC22	Aberdeen	110,430
HDC8	Liverpool	252,935	HDC23	Reading	106,365
HDC9	Sheffield	231,395	HDC24	Portsmouth	103,190
HDC10	Newcastle upon Tyne	223,440	HDC25	Coventry	96,640
HDC11	Nottingham	204,010	HDC26	Southampton	94,740
HDC12	Cardiff	192,860	HDC27	Dartford	93,075
HDC13	Bournemouth	122,690	HDC28	Cambridge	88,900
HDC14	Watford	117,335	HDC29	Northampton	86,025
HDC15	Milton Keynes	116,755	HDC30	Norwich	84,610

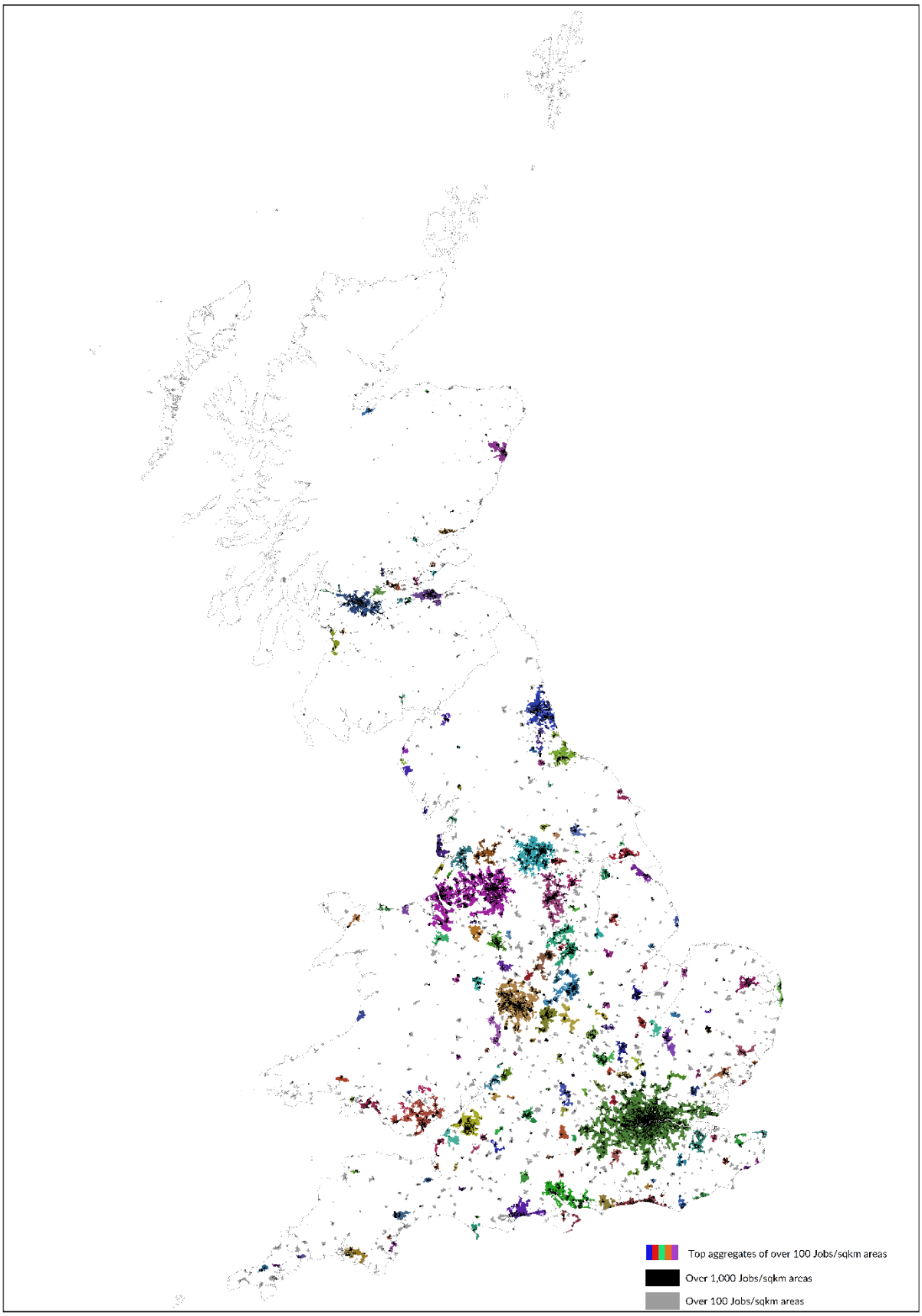
Medium-Density Aggregates

An alternative measure, of equal interest and validity, is to look at the aggregates of *medium-density* employment in Britain (MDCs). Rather than just capturing city centres and large high-density sites like airports, this measure also captures moderately dense semi-urban employment sites, trade, research and retail parks. The result of this is a measure that individual aggregate – for example by this definition, London expands from 4.5m workers to 7.3m.[15]

[14] See Garreau, J. (1991). *Edge city: life on the new frontier*. New York: Doubleday and Ding, C., & Bingham, R. D. (2000). Beyond Edge Cities: Job Decentralization and Urban Sprawl. *Urban Affairs Review, 35*(6), 837-855.

[15] The approach is not without problems. An initial visual inspection of the mapped aggregates revealed that due to the heterogeneous shape of LSOAs, a small handful of methodological artifacts were apparent. Firstly, some aggregates can be extremely close together, but due to a single thin LSOA of low employment density, they remain unaggregated, and listed separated. Secondly, the opposite issue also occurs, in which a thin chain of medium density LSOAs can form a bridge between two otherwise separate aggregates, joining them together. Sometimes this happens multiple times, creating "snakes" of aggregates.
In order to sensitivity check this problem, an investigation was undertaken to identify the number of aggregates that would split in two if a single LSOA was "flipped" to low density, and, similarly, the number of aggregates that would join together if a single LSOA was "flipped" from low density to medium density. Our decision was to manually separate three aggregates that were connected by a single LSOA to form a snake, in order to assist the algorithm in reflecting reality.

Figure 3: All medium-density cores (MDCs), 2018 [click for larger image]
Coloured areas indicate aggregates with over 10,000 jobs.



Again, we find that London is the largest employment area in Britain. However, the most striking result is found in the 2nd row of Table 4: Manchester and Liverpool form a single conurbation of medium-density employment, with two large high-density employment poles at each end (and numerous smaller high-density poles in between, for example Warrington). This should not be a surprise; indeed, the ONS identify the Liverpool-Manchester corridor as a joined major urban conurbation. Although, significantly, these areas are not joined in any of the other definitions we profile here. A number of other mergers are visible. Birmingham merges with the Black Country (but not Coventry), Southampton with Portsmouth, Newcastle with Sunderland, and Nottingham with Mansfield (but not Derby). There are 37 areas in with contiguous medium employment density of over 100,000 total workers, and a further 23 with between 50,000 and 100,000.

Table 4: Employment in the top 30 largest MDCs (2018)

ID	NAME	Jobs	ID	NAME	Jobs
MDC1	London	7,265,790	MDC16	Brighton and Hove	230,995
MDC2	Manchester-Liverpool	2,320,990	MDC17	Derby	196,405
MDC3	Birmingham	1,297,855	MDC18	Middlesbrough	192,670
MDC4	Leeds	912,115	MDC19	Milton Keynes	181,955
MDC5	Glasgow	722,985	MDC20	Blackburn	181,065
MDC6	Newcastle upon Tyne	580,755	MDC21	Aberdeen	179,685
MDC7	Sheffield	499,035	MDC22	Preston	175,280
MDC8	Cardiff	468,620	MDC23	Rochester	173,305
MDC9	Southampton	466,620	MDC24	Stoke-on-Trent	164,165
MDC10	Nottingham	449,505	MDC25	Kingston upon Hull	163,575
MDC11	Bristol	435,780	MDC26	Oxford	156,325
MDC12	Edinburgh	376,405	MDC27	Norwich	150,100
MDC13	Leicester	361,610	MDC28	Cambridge	148,270
MDC14	Coventry	265,455	MDC29	Northampton	140,690
MDC15	Bournemouth	237,095	MDC30	Swansea	131,990

Commuting zones

We feel that HDCs and MDCs are worthy and useful *economic* measures and definitions of city geographies, that are the most appropriate tool to use when measuring, calculating or discussing any concept or indicator that is most directly related to the location of firms and workers, as opposed to residents or physical constructions. Thus, concepts such as employment, productivity and turnover, sectoral structure and business base characteristics, agglomeration and innovation, would all be more appropriately captured using these definitions. Either the high-density or medium-density definitions - or both - could be selected as appropriate.

Important concepts in economic geography such as the functional economic market area, the housing market area, or the wider hinterland of an urban settlement all attempt to identify and define an area beyond that of the central core, but that has a strong economic relationship with it, particularly in terms of movement of people and commuters. Our definitions make ideal cores for this type of analysis. We have chosen to undertake some analysis of this here, specifically looking at commuting patterns into our core areas – asking where do the people who work in these HDCs and MDCs live?

The following analysis presents the Commuting Zones (abbreviated CZs) for both the high-density and medium-density versions of the cores. We calculated these by using 2011 commuting figures updated by a double adjustment process to 2018 data.

In order to mark lines on a map, its necessary to identify a cut-off criterion, beyond which an LSOA is no longer considered part of the CZ of a particular core. After some experimentation, we chose to define this as *25% of employed residents within that LSOA list their main workplace as within that core*; if this criterion is not met, the LSOA is excluded. Using this method, we can both define a CZ for each core (where appropriate[16]), but also to count the total employment and population within this wider area.

The map in Figure 4 shows the high-density cores in block colour, with corresponding CZs outlined around it in the same colour (click map to enlarge). This reveals relatively "tight" definitions of urban areas, with limited overlaps between neighbouring zones and large areas of the country excluded from CZs. This definition is an accurate metric for urban Britain – that is those areas where a significant proportion of residents work in one of the major high-density employment cores.

[16] Recall that not all cores have associated commuter zones. Some, for instance, are embedded in and form a part of the CZ of other cores in the area while others exist outside the boundaries of CZs. In cases where there are significant labour pull factors from much larger, neighbouring cores, the spatial coverage of a smaller cores commuting zone may be smaller than the core itself.

Figure 4: Top 100 HDCZs built from high-density HDCs (2018) [click to enlarge image]

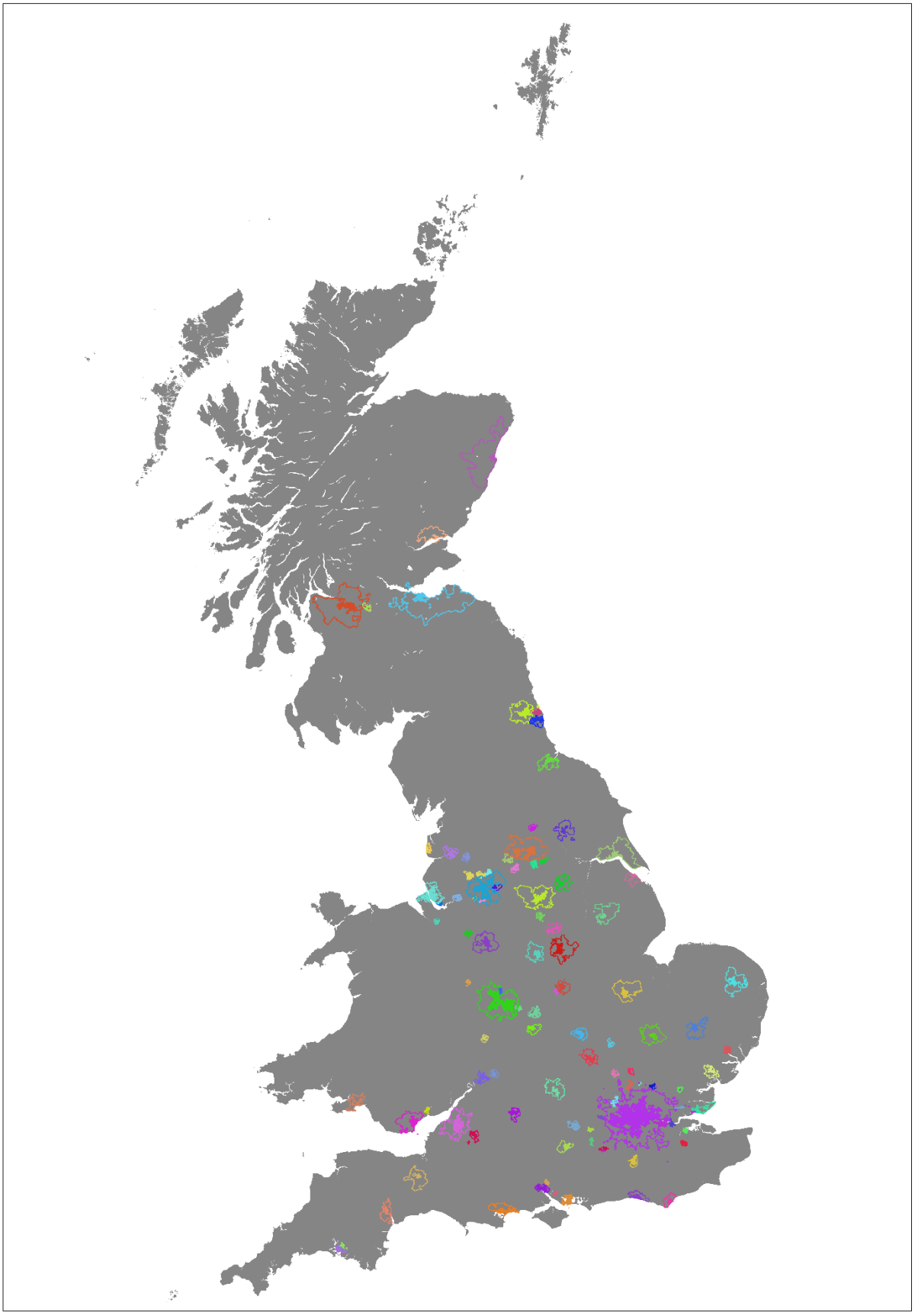


Table 5: Ranking of top 30 HDCs and HDCZs by employment (2018)[17]

ID	NAME	JOBS	ID	NAME	JOBS
HDC1	London	4,588,260	HDCZ1	London	5,650,855
HDC2	Birmingham	665,815	HDCZ2	Birmingham	969,200
HDC3	Manchester	655,590	HDCZ3	Manchester	932,490
HDC4	Leeds	425,625	HDCZ4	Leeds	618,280
HDC5	Glasgow	398,080	HDCZ5	Glasgow	583,220
HDC6	Bristol	300,665	HDCZ6	Bristol	417,770
HDC7	Edinburgh	284,960	HDCZ7	Edinburgh	395,865
HDC8	Liverpool	252,935	HDCZ8	Liverpool	338,045
HDC9	Sheffield	231,395	HDCZ9	Sheffield	327,245
HDC10	Newcastle upon Tyne	223,440	HDCZ10	Newcastle upon Tyne	310,765
HDC11	Nottingham	204,010	HDCZ11	Nottingham	286,780
HDC12	Cardiff	192,860	HDCZ12	Cardiff	250,235
HDC13	Bournemouth	122,690	HDCZ16	Bournemouth	172,280
HDC14	Watford	117,335	HDCZ33	Watford	97,635
HDC15	Milton Keynes	116,755	HDCZ15	Milton Keynes	175,055
HDC16	Stoke-on-Trent	116,530	HDCZ18	Stoke-on-Trent	165,950
HDC17	Brighton and Hove	115,525	HDCZ22	Brighton and Hove	138,900
HDC18	Kingston upon Hull	112,565	HDCZ17	Kingston upon Hull	166,455
HDC19	Leicester	111,955	HDCZ18	Leicester	175,230
HDC20	Derby	110,695	HDCZ21	Derby	143,785
HDC21	Oxford	110,445	HDCZ20	Oxford	143,810
HDC22	Aberdeen	110,430	HDCZ13	Aberdeen	183,820
HDC23	Reading	106,365	HDCZ25	Reading	124,970
HDC24	Portsmouth	103,190	HDCZ28	Portsmouth	117,805
HDC25	Coventry	96,640	HDCZ26	Coventry	120,625
HDC26	Southampton	94,740	HDCZ30	Southampton	115,830
HDC27	Dartford	93,075	HDCZ81	Dartford	36,155
HDC28	Cambridge	88,900	HDCZ19	Cambridge	145,900
HDC29	Northampton	86,025	HDCZ23	Northampton	135,670
HDC30	Norwich	84,610	HDCZ24	Norwich	135,480

The corresponding map of MDCZs (Figure 5) shows a very different picture, with much greater coverage of the space of the UK, and greater likelihood of contiguities or overlaps between neighbouring CZs. More rural areas of the country, for example the Highlands, Snowdonia, the Lake District, the North York Moors and Dartmoor & Exmoor all stand out.

While for legibility, these maps contain only the top 100 of any given measure, it is worth noting that our methodology allows us to identify multiple cores within the boundaries of CZs. This permits analysis of polycentricity based on employment centres outside of the most central urban cores and a more nuanced understanding of economic activities within urban areas.

[17] Note that this list is ranked by the total employment in the HDCs. The ranking for the HDCZ is often different and listed in the fourth column.

Figure 5: Top 100 MDCZs built from MDCs (2018) [click for larger image]

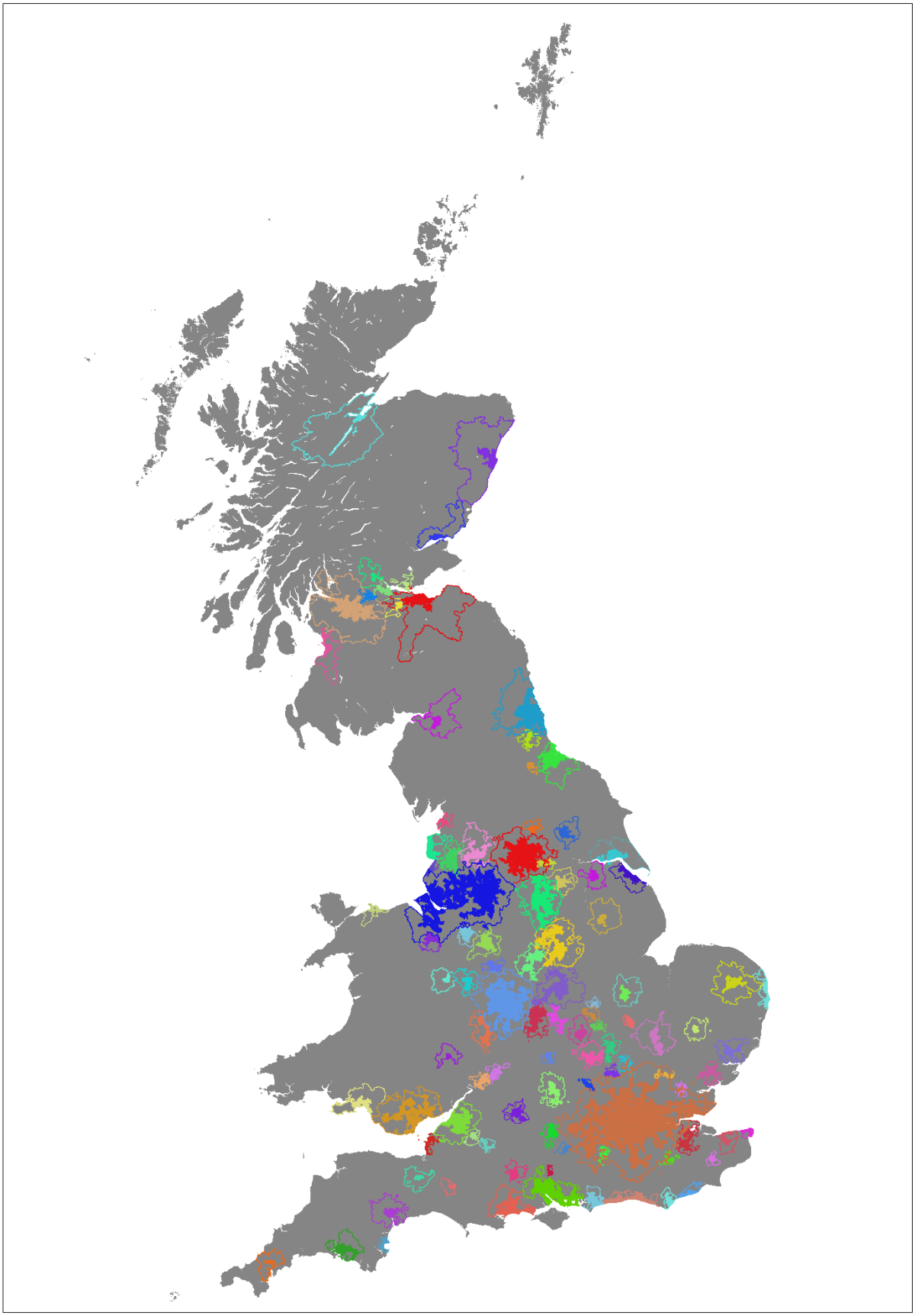


Table 6: Ranking of top 30 MDCs and MDCZs by employment (2018)[18]

ID	NAME	JOBS	ID	NAME	JOBS
MDC1	London	7,265,790	MDCZ1	London	7,821,600
MDC2	Manchester-Liverpool	2,320,990	MDCZ2	Manchester-Liverpool	2,473,660
MDC3	Birmingham	1,297,855	MDCZ3	Birmingham	1,370,735
MDC4	Leeds	912,115	MDCZ4	Leeds	1,014,510
MDC5	Glasgow	722,985	MDCZ5	Glasgow	814,645
MDC6	Newcastle upon Tyne	580,755	MDCZ6	Newcastle upon Tyne	630,060
MDC7	Sheffield	499,035	MDCZ7	Sheffield	534,595
MDC8	Cardiff	468,620	MDCZ8	Cardiff	552,130
MDC9	Southampton	466,620	MDCZ10	Southampton	490,140
MDC10	Nottingham	449,505	MDCZ9	Nottingham	521,830
MDC11	Bristol	435,780	MDCZ11	Bristol	475,600
MDC12	Edinburgh	376,405	MDCZ12	Edinburgh	422,725
MDC13	Leicester	361,610	MDCZ13	Leicester	394,255
MDC14	Coventry	265,455	MDCZ14	Coventry	280,240
MDC15	Bournemouth	237,095	MDCZ15	Bournemouth	253,540
MDC16	Brighton and Hove	230,995	MDCZ16	Brighton and Hove	238,710
MDC17	Derby	196,405	MDCZ18	Derby	215,050
MDC18	Middlesbrough	192,670	MDCZ19	Middlesbrough	213,180
MDC19	Milton Keynes	181,955	MDCZ21	Milton Keynes	194,560
MDC20	Blackburn	181,065	MDCZ20	Blackburn	206,100
MDC21	Aberdeen	179,685	MDCZ17	Aberdeen	233,375
MDC22	Preston	175,280	MDCZ24	Preston	184,255
MDC23	Rochester	173,305	MDCZ22	Rochester	187,770
MDC24	Stoke-on-Trent	164,165	MDCZ28	Stoke-on-Trent	177,255
MDC25	Kingston upon Hull	163,575	MDCZ23	Kingston upon Hull	184,965
MDC26	Oxford	156,325	MDCZ27	Oxford	179,955
MDC27	Norwich	150,100	MDCZ26	Norwich	180,445
MDC28	Cambridge	148,270	MDCZ25	Cambridge	182,725
MDC29	Northampton	140,690	MDCZ29	Northampton	157,060
MDC30	Swansea	131,990	MDCZ30	Swansea	156,785

The implications of a new perspective on urban areas: too small, too big, not quite

While we want to stress that these new proposed measures for urban space are not appropriate for every application, we think that they provide a more suitable framework for research and comparisons of urban places focused on economic measures. In this section, we draw on case studies to demonstrate how different alternative measures give sometimes very different pictures of economic performance and how relying on these can skew perceptions of the relative strengths and standings of places.

For this exercise, we focus on three groups of cases: (1) Manchester-Liverpool-Warrington, (2) Nottingham, and (3) Oxford and Cambridge. While we could have selected any number of interesting examples, each of these groups are illustrative of specific limitations of existing measures and their consequences.

[18] As with the previous table, this list is ranked by the total employment in the HDCs. The ranking for the HDCZ is often different and listed in the fourth column.

The Manchester-Liverpool conurbation, for example, is one that is typically considered separate from a statistical point of view. Even the broadest interpretation of metropolitan areas currently in use in the UK, TTWAs, divides that urbanised corridor into many distinctive areas. However, on a practical level, there is wide recognition that the conurbation essentially functions as a single economic centre of gravity.

Nottingham is a slightly different example of a similar issue. Measures relying on jurisdictional divisions somewhat arbitrarily truncate the area – separating it from affluent suburbs and areas of significant employment concentration.

Cambridge is seen as highly successful economic area but is spatially quite different from many peer cities. Again, existing measures tend to either focus disproportionally on its jurisdictionally defined cores leaving out not only rapidly developing peripheries but also significant employment areas or include them in relatively large commuting areas that tend to dilute their impacts.

For all of these a Goldilocks analogy applies. In the first instance, we think existing measures do not capture the full extent of the Manchester area's economic space. In Nottingham definitions are spatially about the right size but not quite properly aligned. Finally, in Cambridge definitions are either too small or too large.

While the insights from the following cases vary, they all serve to demonstrate the significant differences in spatial interpretations and highlight the consequences that these might have for economic analysis.

Manchester-Liverpool-Warrington

All of the alternative measures developed in the UK treat Manchester, Liverpool, and the variety of communities that surround and bridge them, as separate entities for statistical purposes. However, as Figure 9 shows, all of our medium density definitions based on employment data (MDC, represented by the light blue area, and MDCZ, outlined in purple) link them as part of a broader functional employment area. While our high-density definitions divide the area into the two major cities – Manchester and Liverpool – and numerous other employment cores these do not correspond well to the pattern of alternative measures.

The range of high-density cores and their associated commuting areas in the Liverpool-Manchester-Warrington corridor are shown in Figure 6. As a generally densely populated area of the country, there are clearly a whole range of different towns and cities captured here, with various levels of overlap between them. The Figures below (7 and 8) show the PUAs and TTWAs covering the same area; what is clear is that these constructed areas miss the majority of the economic complexity and nuance of this region, with a large degree of arbitrariness as to which employment cores (as depicted in Figure 6) are linked together and which are not. Both measures capture a significant amount of low-density employment areas, whilst overlooking other quite significant high-employment areas. Around Liverpool, for example, the Birkenhead PUA capture swaths of low-density employment to the south around Heswall but truncates dense employment and commuting sources stretching inland from the northeast coast. The Manchester PUA encompasses the entire Manchester HDCZ but also that of Bolton. TTWAs are generally larger but also divide up the area between Manchester and Liverpool. In general, TTWAs tend to attach much more low-density employment commuting space to smaller places, like the Northwich-Middlewich corridor while omitting parts of the bigger metropolitan commutershed.

In essence, the PUA and TTWA geographies simultaneously capture neither the accuracy and detail of our HDC and HDCZs, nor the holistic regional pattern of economic activity captured by our MDC and MDCZ definitions.

Figure 6: High Density Cores (solid areas) and commuting zones (corresponding coloured lines) in the Manchester-Liverpool-Warrington area

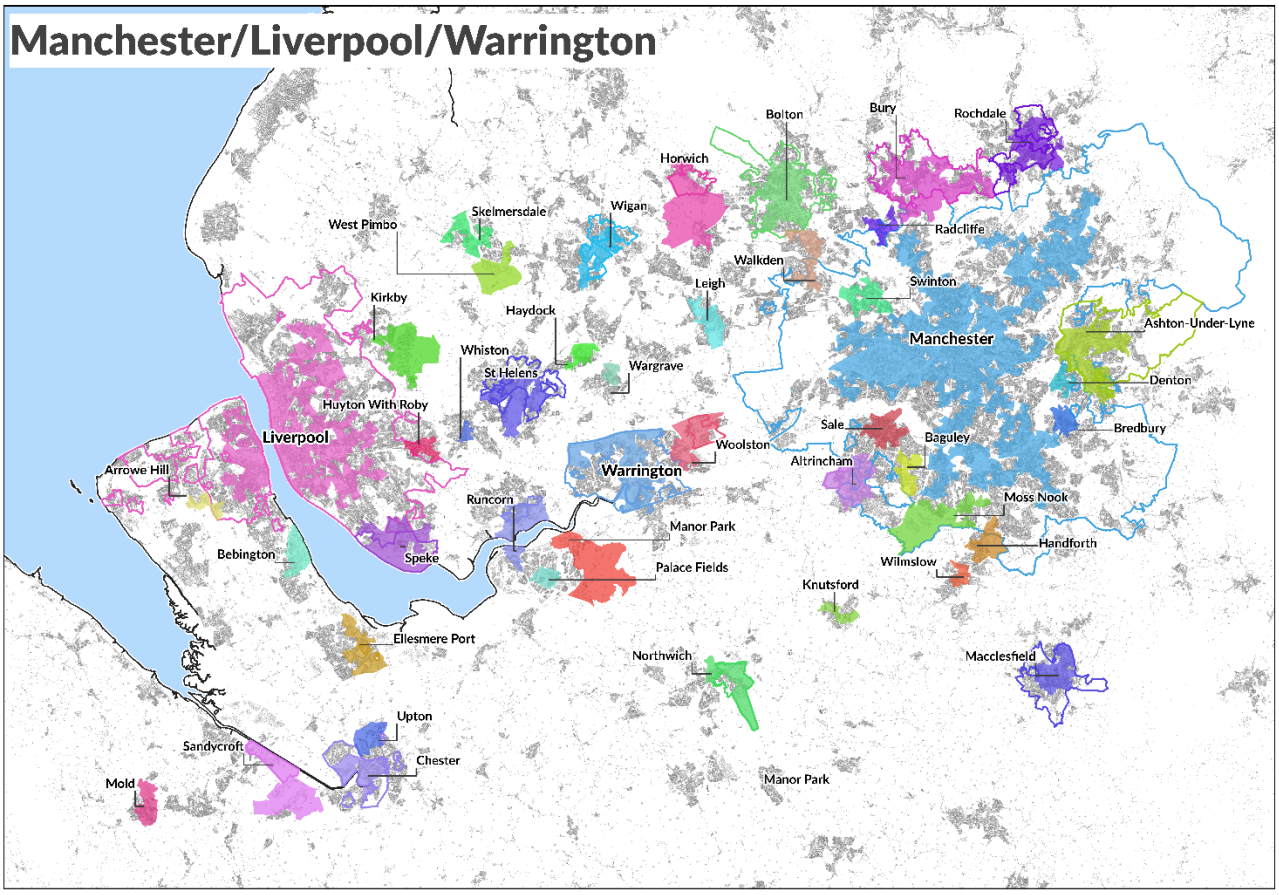
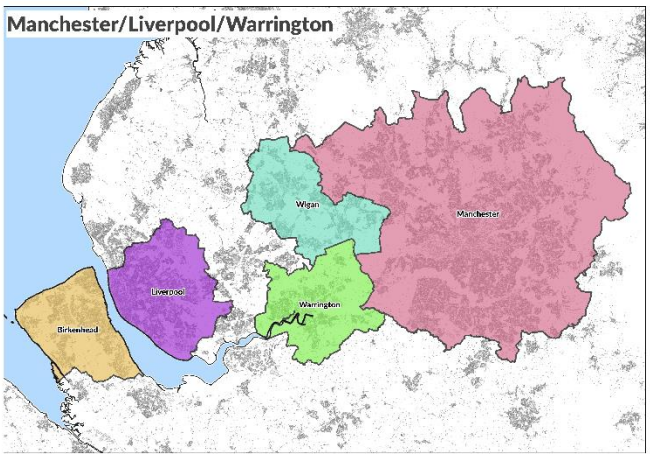


Figure 7 and 8: PUAs and TTWAs in the Manchester-Liverpool-Warrington area



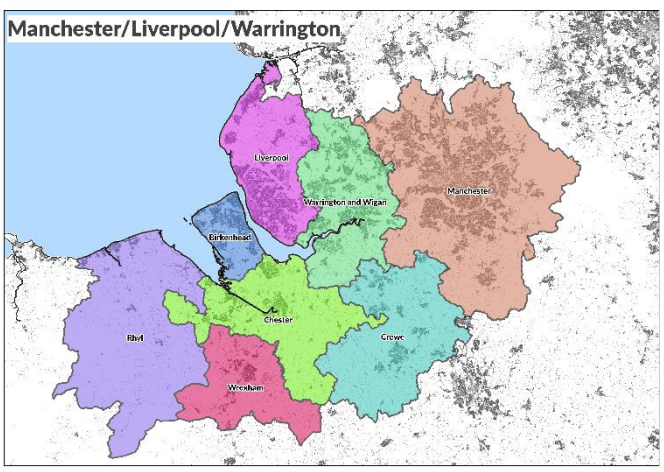
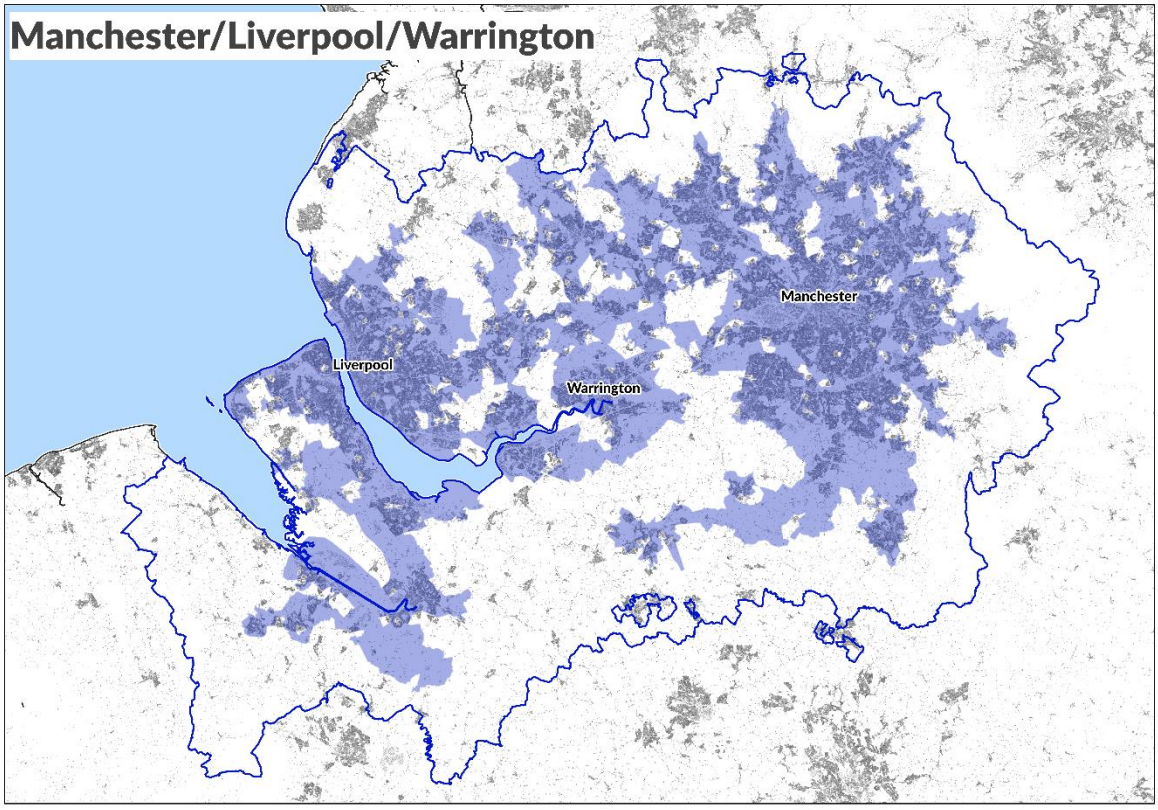


Figure 9: Manchester-Liverpool-Warrington MDC (solid area) and MDCZ (corresponding coloured line)



The different economic footprints captured by our measures has important consequences for economic analysis. Our MDCZ is notable for narrowing the gap between London and the country's second most significant conurbation in terms of both population and employment. Significantly, this urban area supplants the Birmingham conurbation in national significance. This approach also permits researchers to think differently, and more critically, about the distribution of economic activity in the region. Rather than minimizing the area to the two major cities at its core – Manchester and its "second city" of Liverpool – using HDCZs we can conceptualise the area as highly polycentric with multiple significant economic cores that, although they are dwarfed by the largest urban cores, are nonetheless centres of gravity in their own rights.

Nottingham

The Nottingham case also highlights how alternative spatial definitions can tend to distort perceptions of place and, by extension, economic analysis. Here, the most interesting contrasts exist between our high-density definitions (HDCs and HDCZs) and PUAs, however, the contrast with TTWAs is also significant. Figure 8 displays the high-density cores (HDCs - solid fill) and commuting zones (HDCZs – coloured lines) for the same area as Figure 9 showing PUAs below. As with the PUA map, our HDC/HDCZ map shows three larger cores in the area – Nottingham, Mansfield, and Derby. However, their footprints differ substantially. The

Nottingham PUA completely fails to capture the size, shape and coverage of the underlying economic geography, excluding part of the high-density core, and capturing instead part of the Derby HDCZ, making it entirely unfit-for-purpose as an economic definition of the Nottingham economic area. There is a nearly 200,000 job difference between MDC and PUA and a similar gap in terms of populations captured. The Mansfield PUA is similarly awkwardly shaped, capturing swathes of lower employment density to the north, and alarmingly, a large section of the Nottingham HDCZ and even part of the HDC itself.

Figure 8: High Density Cores (solid areas) and commuting zones (corresponding coloured lines) in the Nottingham-Mansfield -Derby area

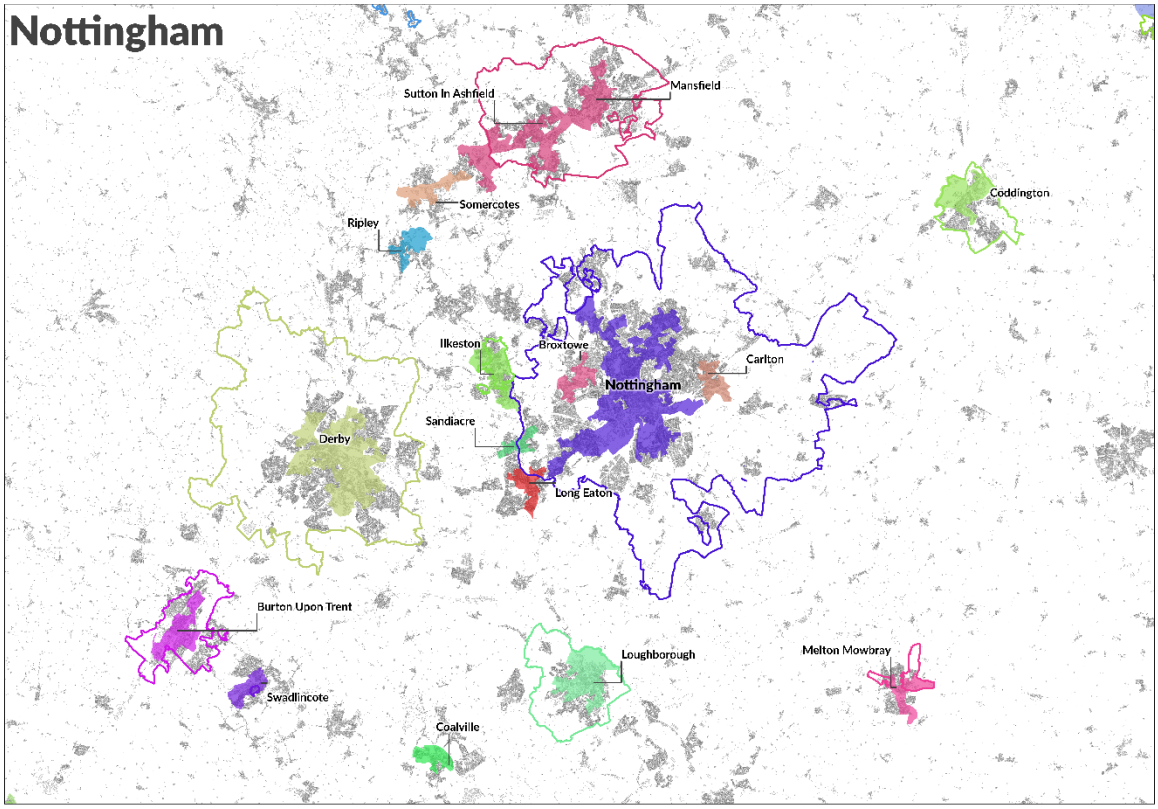
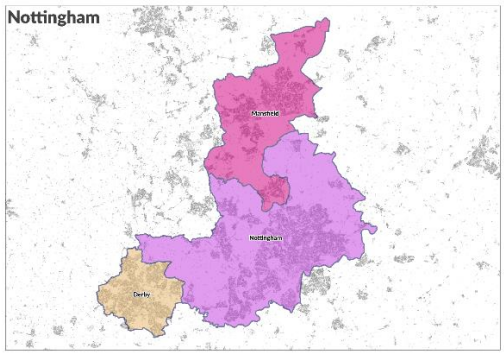
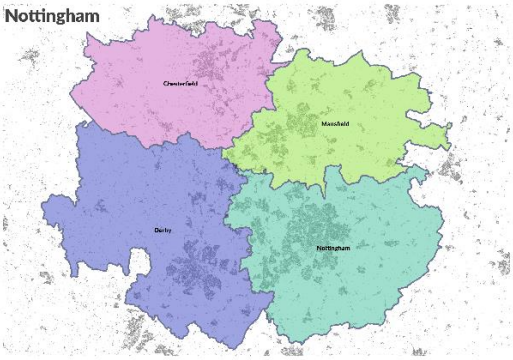


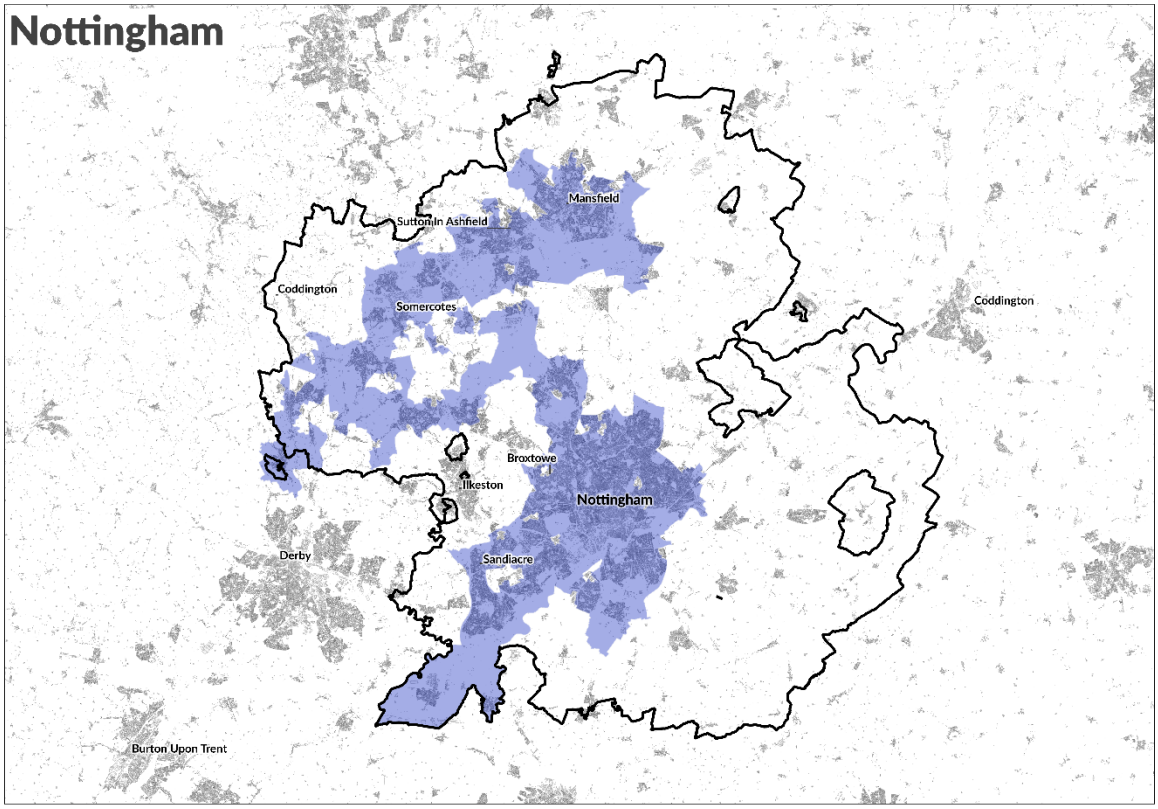
Figure 9 and 10: PUAs and TTWAs in the Manchester-Liverpool-Warrington area





The TTWAs offer a less distorted view of the underlying economic geography of the area. As Figure 10 shows, they divide it into four almost equal parts despite significant differences in total employment between each division's core. This quadrisected area is united in our definition of the MDCZ (see Figure 11), which is built from an MDC that snakes down the western margins of the Mansfield and Nottingham TTWAs.

Figure 11: Nottingham-Mansfield-Sutton in Ashfield MDC (solid area) and MDCZ (corresponding coloured line)



While our definitions identify distinctive commuting zones at the high density threshold, which represents a relatively wide area around Nottingham and a tighter ring around Mansfield and Sutton in Ashfield, and interesting revelation from our spatial characterisation is the unbroken and sinuous pattern of medium density economic activity that link the cores of Nottingham in the south with the corridor to Mansfield in the north. While we want to stress that being spatially linked at medium-density thresholds does not mean that there are necessarily strong north-south economic connections it is a spatial phenomenon worth observing and investigating. Considering these two areas that are generally separated in alternative definitions this view suggests that there might be notable and possibly misunderstood economic functions and flows in the area. Finally, it is significant that all of our definitions exclude Derby. While it is significant enough to stand on its own it is important to point out that Derby and Nottingham MDCZ overlap, suggesting another level of polycentricity that we will explore in another forum.

Cambridge

The basic economic geography of Cambridge is shown in Figures 12 (HDC/HDCZ) and 13 (MDC/MDCZ). The high-density core is shown in dark blue. The medium-density core, shown in mid-blue in the next figure both immediately surrounds the high-density core and extends to the south. The commuting zones are also shown.

Figure 12: High Density Cores (solid areas) and commuting zones (corresponding coloured lines) in the Cambridge area

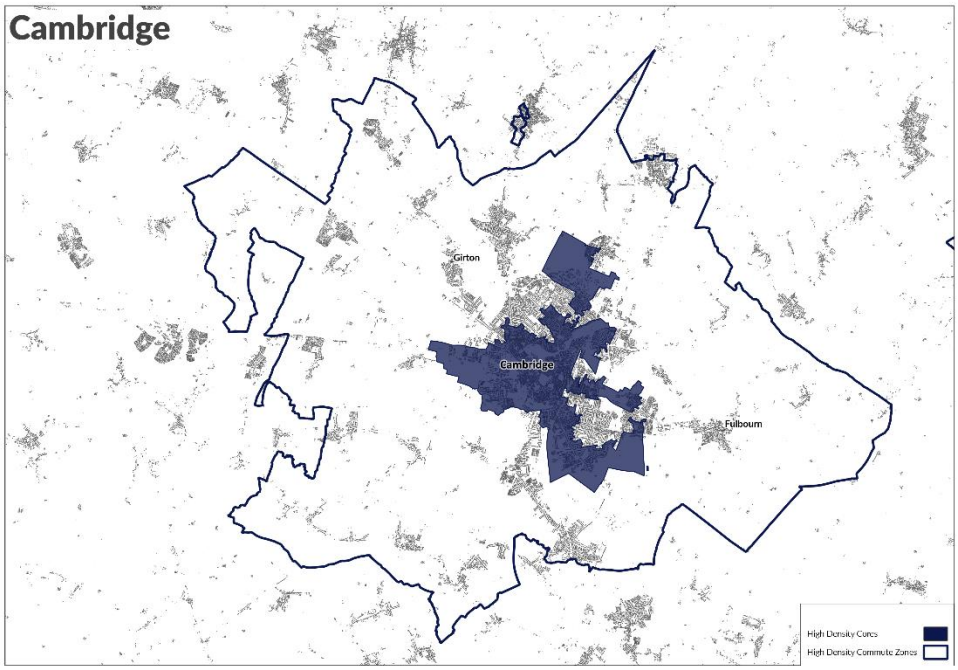


Figure 13: Medium Density Core (solid area) and commuting zone (corresponding coloured line) in the Cambridge area

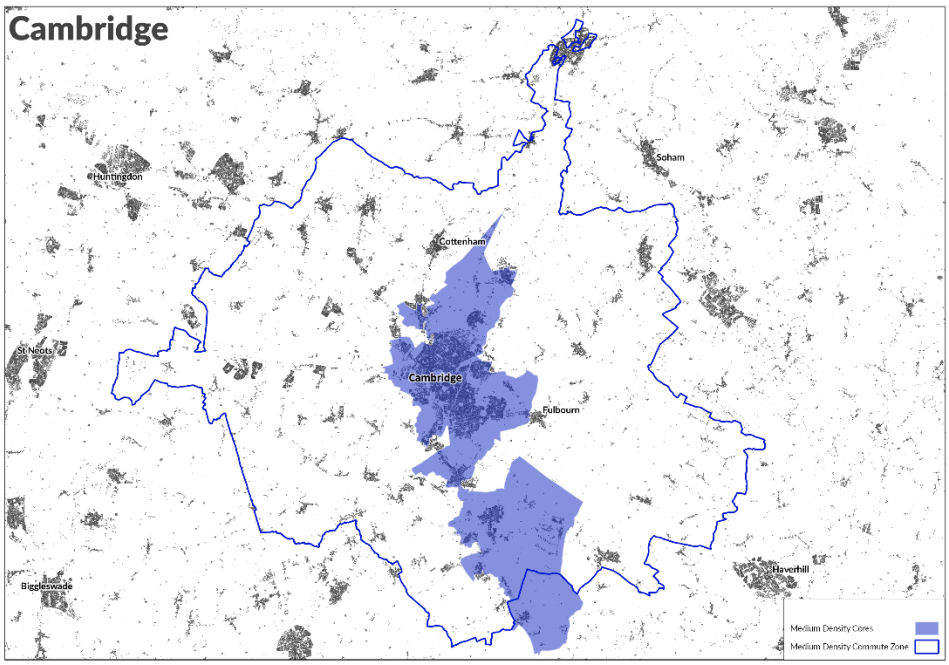
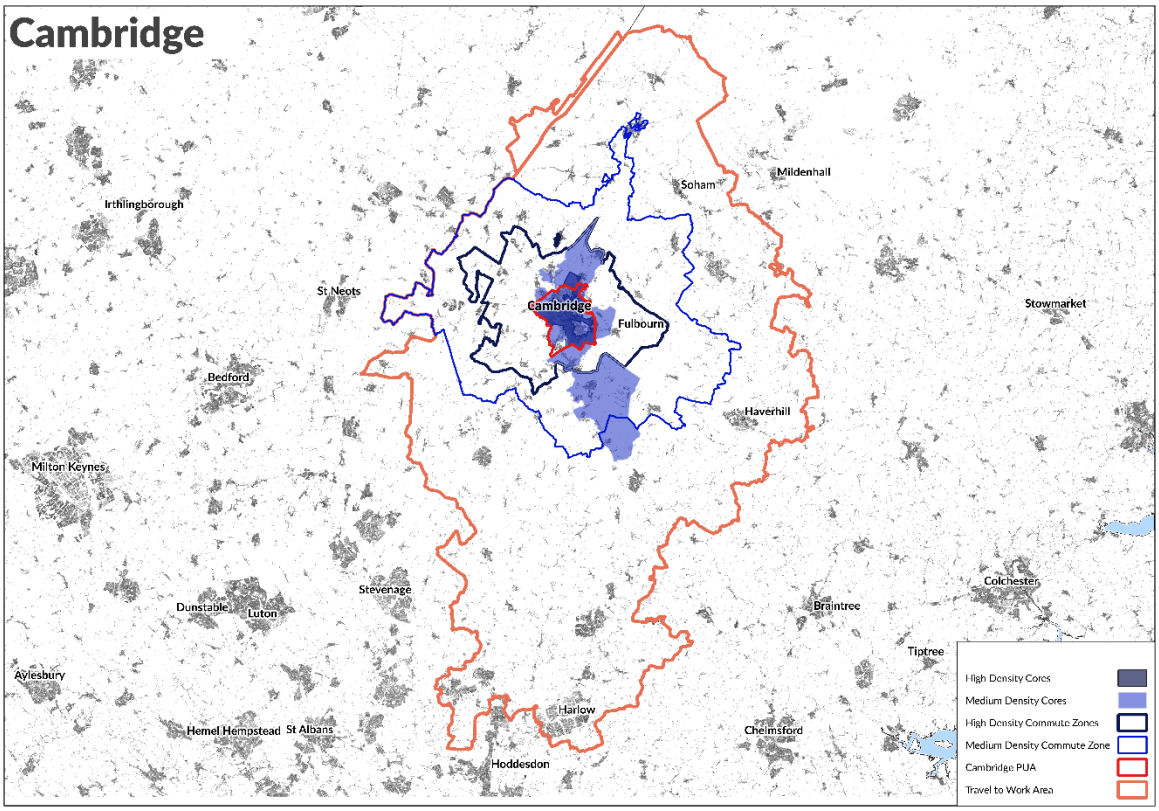
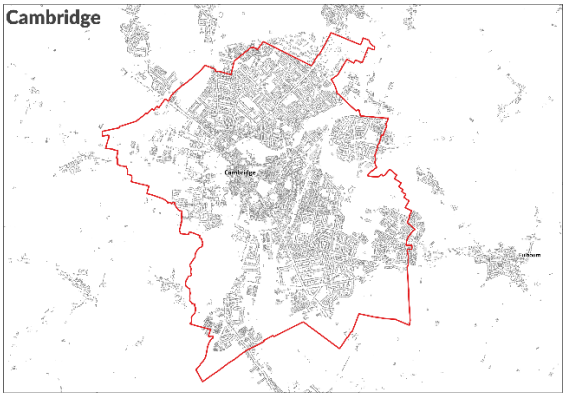
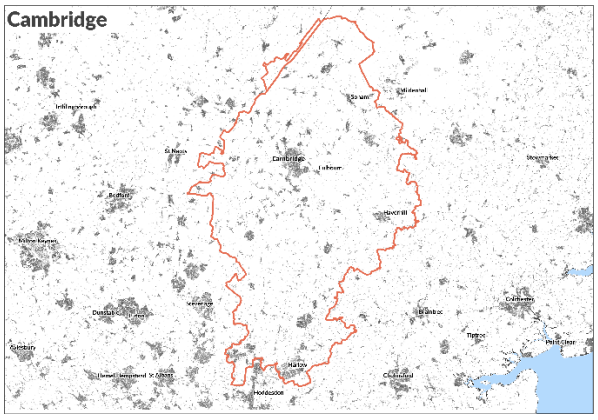


Figure 14 shows the primary urban area for Cambridge, demarked in red and the travel to work area, shown in orange in contrast with our HDC/HDCZ and MDC/MDCZ boundaries. The PUA is limited by the local authority boundary of Cambridge City, and immediately it is apparent how poorly the PUA captures the economic geography of Cambridge. The PUA is significantly smaller than both the HDCZ and the MDC and does not even cover the full extent of the HDC. The travel to work area represents the other extreme, being vastly larger than even the MDCZ, extending right down the M11 as far as Harlow. Neither the TTWA or PUA is a suitable basis upon which to analyse the economy of Cambridge.

Figure 14: Alternative definitions of space in the Cambridge area (top) and detail of the Cambridge PUA (left) and TTWA (right)







Here, as in other cases, inappropriate conceptualisations of functional economic space tend to result in misleading understandings as to the reality of local economies. Where this is most obvious are on measures of the knowledge economy – in the tables below, % of jobs in KIBS.

We see that when economic geography is accurately measuring according to appropriate, economic spatial definitions, Cambridge emerges as the GB geography with the highest proportion of KIBS employment in its medium-density core and medium density commuting zone, a fact completely missed by any alternate spatial definition based on distribution of population density or built structures.

Table 7: Rankings on employment, population, and % jobs in KIBS for alternative spatial definitions of Cambridge

CAMBRIDGE	HDC	HDCZ	MDC	MDCZ	PUA	MT&C	TTWA	FUA
Employment	28	19	28	25	42	20	13	29
Population	29	34	39	32	61	42	16	32
% KIBS	18	5	1	1	5	5	7	ND

Yet again, these cases demonstrate how looking at areas through different lenses reveals quite different data and insights into how places function. PUAs do not capture all of the activity that occurs in these areas. In these cases, TTWAs may be linking employment centres that are not involved in the more localised innovation economy. This suggests that on a range of economic, but also social measures, the story these areas' success may be being distorted by unusual geographies. We hope that by offering alternatives – HDCs and MDCs, HDCZs and MDCZs – we can look again at these functional spaces with a critical eye.

Concluding thoughts

The purpose of this paper was to introduce some new measures of urban cores and urban areas that we argue are more representative of urban functional economic spaces than some of the alternatives currently in use in the UK. This new spatial perspective is particularly useful for our purpose, which is to explore spatial variations in productivity performance, but we think it will also be useful for many applications tied to the distribution of economic activity (particularly employment). We hope that this contribution will inspire new research at these spatial scales and encourage debate about how we perceive and measure economic space and its role in shaping industrial, innovation, and productivity policy. This methodology will be of use to anyone involved in policy research that explores differences in economic performance between places.

We argue that in order to effectively investigate core questions in economic geography - relying on indicators such as gross value added, employment by sector and occupation, labour and total factor productivity - that the scale at which we measure economic performance should be matched as closely as possible to the economic concepts in question. Furthermore, spatial definitions should be based on as low a spatial level as possible in order to capture economic reality as accurately as possible. Implicit in this latter proposition is that these spatial definitions will be based on functional economic spaces, however they are configured, and should not be built using administrative units. We contend that the distribution of employment is the fundamental foundation for analyses of these phenomena, rather than the distribution of resident population or buildings, as this most accurately defines the location of economic activity over space and use this principle to develop our own measures of urban cores and urban regions (CZs).

The case studies presented in the preceding section are just a first attempt to demonstrate how our measures (cores and commuting zones) capture different geographies than some

other frequently used definitions of urban space and shows how this affects how places rank on a few basic measures. While our definitions overlap in core areas with many alternative measures because they focus on where people work (cores) and where they travel from (the broader commuting area) at a finer level of detail (LSOAs), in many places they ultimately encompass very different spaces – including contiguous suburban employment centres truncated by jurisdictional boundaries by some definitions and providing a more detailed understanding of commuter catchment areas. This has a lot of value – knowing how economic activity actually spills across jurisdictional boundaries is fundamental for planning and development policy(Jeffrey, 2020).[19] The result is that, in many cases, rankings of our measures across indicators, and the totals upon which they are based, differ substantially from alternative measures and the maps contrasting the different definitions clearly illustrate why. This is neither good nor bad. However, it does indicate that our measures offer a substantially different vision of functional space that may play an important role in place-based economic analyses.

While we think that these new definitions of urban space are most appropriate to frame our research on spatial patterns of productivity in the UK and questions of economic inequality, we want to stress that we are not advocating these as replacements for other definitions in currency. As with our measures, each of the alternative spatial definitions have analytical advantages and disadvantages. The work for which these definitions were developed focuses on understanding productivity performance at microscales and aims to test various hypotheses about how and why higher productivity activities are distributed across urban areas. The next phase of this research will connect data on productivity from the business structure database (BSD) our functional urban areas to gain new insights on the UK productivity puzzle.

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[19] See this discussed most recently in the context of local government reorganisation: Jeffrey, S. (2020). *Levelling up local government in England*. Retrieved from https://www.centreforcities.org/publication/levelling-up-local-government-in-england/

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