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PIN - Productivity Projects Fund

Small Project Report

Geographies, Geometries, and Economies of Spatial Productivity in England

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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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Introduction

Spatial inequality is a perennial concern in the UK. Recent research highlights spatial disparities in productivity with 72% of regions (NUTS3, 2016) performing below the UK average (McCann, 2020; Nguyen, 2019; Zymek & Jones, 2020). Researchers have devoted significant time to diagnosing the spatial significance of these inequalities, with some identifying lagging urban areas (Martin et al., 2019), or underperforming core cities (OECD, 2020), while others focus on "left behind places" typically located in urban and peripheral former industrial areas (Beatty & Fothergill, 2020; Tomaney, Pike, & Natarajan, 2019). The productivity of places outside of urban aggregations such as towns and rural areas may also be part of this story, but tends to be overlooked (see OECD 2020, for some comparisons).

It is thought that cities offer productivity and growth premiums through agglomeration economies generated by their scale, density and diversity. The inescapable dominance of London and its surrounding region as a powerhouse of the UK economy, through its financial, digital and knowledge-intensive business services (KIBS) reinforces this perspective and suggests an economic development model to which other places should aspire (Tomaney et al., 2019). But transferable lessons from London are difficult to extract and may contain little insight for places in dramatically different geographic and economic contexts. Part of the challenge of the current levelling up agenda, which seeks to even out regional inequalities through increases in productivity and growth, is to interrogate spatially rooted economic development orthodoxies that place a premium on economic outliers, like London, and are based on slippery concepts of urban, rural, and regional spaces. For example, the popular contention that larger places are more productive is both misleading and has been challenged by the finding that a doubling of urban density results in only a modest 3-8% increase in productivity (Evenhuis, Lee, Martin, & Tyler, 2021; Stuart S Rosenthal & Strange, 2004). As such, while arguments about the power of urban density have proved remarkably attractive to policy makers, they overlook a good deal of nuance in how agglomeration dynamics actually function.

Our current understanding of spatial inequalities may be based on an incomplete picture of the productivity landscape, one that conceptualises space at functionally larger or smaller scales than the economic activity that generates productivity takes place. The spatial boundaries currently in use[1] – such as primary urban areas (PUAs) for urban cores - tend to distort our perception of economic performance of places because they are methodologically constructed based largely on jurisdictional areas rather than functional economies spaces.

In a previous paper, we developed a new approach to defining places in the UK to serve as a foundation for an analysis of spatial productivity at the micro scale (Brown et al., 2020). These spaces, which consist of two different spaces of economic activity (high- and medium-density) and their commuting zones - are based on the employment density of the smallest units of spatial aggregation currently available enabling us to construct spatially accurate economic areas and do fine-grained analysis of the patterns that produce them. This approach reveals a very different map of the UK than alternative measures. In England, we identified 433 areas of high-density (high-density cores, HDCs) and 162 areas of medium-density economic activity (medium-density cores, MDCs). Using these geographies, we aim to explore the following questions:

[1] 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).

- What parts of the country tend to be more productive?

Here we aim to peer beneath traditional spatial aggregations to understand where the most productive places are. Here we do not take existing geographies for granted and aim to explore productivity patterns at the lowest scale possible and demonstrate that there are highly productive areas in all regions. The question then is how to replicate that success on a broader scale. This finding may also challenge the orthodoxy that productivity gains are linked to size. Furthermore, the urban focus of productivity may be missing non-urban pockets of productivity that may help us to better understand the geographies of productivity. Just because synergies are possible in denser places does not mean that they are always realized there.

- What types of places are more productive?

Does higher productivity activity tend to correspond to certain kinds of geographies? Economic geographies include the size and scales of urban areas - in this case, HDCs and MDCs as sites of economic activity. What relationship do these patterns have with employment density?

- What is the role of internal geometries?

Economic geometries describe the patterns of how the densest employment areas are configured within a region. Here we explore the impact of monocentricity and polycentricity in urban cores versus more dispersed employment patterns. An analysis of these geographies and geometries interrogates the explanatory power of spatial agglomeration and can help uncover spatial challenges to productivity outcomes.

- What is the role of sectoral specialisation and diversification?

While there may be many explanations for the patterns we observe, in this contribution we focus on sectoral structure as a source of insight. Here, we hypothesize that spaces of higher- and lower-productivity activity may experience different spatial effects depending on the degree of sectoral specialisation of activities in those areas and synergies related to clusters, supply chains, and the support services, co-specialised business bases, and labour markets that sustain them.

Our findings provide a different perspective of spatial inequalities and productivity (measured by GVA/worker at all scales of analysis). First, when we analyse productivity using our economic geographies, it produces a different picture of the most highly productive places than those based on broader urban and regional geographies. London is still near the top of the list at both HDC and MDC scales but is not the most productive geography in either.

Secondly, the microscale analysis shows that high productivity is by no means confined to urban areas, which challenges currently dominant urban-focused narratives of productivity. Our finding that there is a generally weak positive relationship between employment density and productivity reinforces this contention. Internal urban geometries do appear to play a role in outcomes. There is a stronger relationship between employment density and productivity in monocentric areas. This is particularly significant given that all of the largest urban areas, apart from London, are polycentric. This suggests that how well integrated places are may offer some clues as to why some places are more successful than others. However, geographies and geometries take on more significance when combined with a sectoral analysis. The link between sectoral productivity performance and overall productivity

is more nuanced than we expected. Having a smaller number of extremely productive sectors appears to have a greater effect than having a greater number of sectors with above average performance. This may mean that concentrating on enhancing the productivity of a few key sectors might have more productivity impacts than seeking broader productivity improvements. There is also a relationship between specialisation of tradables and productivity that does not hold for non-tradable sectors. If true, this offers some insights about where to focus policy efforts to level up places.

Case studies show how many of these dynamics play out in practice and the different degrees of influence that geographies, geometries, and sectors can have on productivity outcomes. This research challenges some deeply held orthodoxies about dimensions of spatial disparities in productivity, but it also raises some important questions for future research.

Agglomeration economies and the configuration of economic activities

We begin from the premise that there is a link between the geography and geometry of urban areas and their productivity performance and, consequently, exploring the configurations of places in combination with the types of economic activities that occur there may help explain inequalities. This report contributes to the evolving literature emphasising that importance of scale and urban configurations to understanding the effects of economic agglomeration.

An important concept within economic geography is that of agglomeration. We define agglomeration benefits as the *positive externalities that accrue from the co-location of economic actors*. There are two distinct types of agglomeration mechanisms: general or economy-wide, known as urbanisation economies, or specialised or sector-specific, known as localisation economies. Urbanisation economies flow from a diversified economy which can enhance knowledge creation and innovation through the recombination of different ideas and technologies. This underpins associated recent approaches of relatedness and related variety, where the diversity of related industries enables inter-sector learning between cognitively related industries (Frenken, Van Oort, & Verburg, 2007; Hidalgo et al., 2018). Localisation economies, formalised in the Marshall-Arrow-Romer framework are externalities that emerge from concentration of firms related industries and is associated with the phenomena of clustering and specialisation. Although distinct, these urbanisation and localisation mechanisms can be mutually reinforcing. Both sets of mechanisms can be driven by either direct physical proximity or by effective proximity, that is mediated by transport or digital connectivity. These mechanisms tend to act and develop over long periods of time – often multiple decades.

Elsewhere we have explored productivity and economic development from a systems perspective and the phenomenon of agglomeration is an example of system dynamics in operation. Viewed through this lens, agglomeration economies can be understood to be emergent properties of spatially anchored complex adaptive systems. That is, they are the largely unplanned outcomes of spontaneous individual actions, in response to socio-economic feedback loops. These self-reinforcing mechanisms are responsible for driving both urbanisation and localisation effects over time. While several feedback loops act on the system simultaneously, two of the most important to consider are:

- Spontaneous evolution of specialisation: Over time, the development of local specialised supply chains, support functions and infrastructure that provide increasing efficiencies of scope and scale for an initially small section of the firm base, allowing that niche to expand and proliferate.
- Firm base – labour market co-evolution: Accumulation over time of matched and mutually beneficial specialisations of local firm base and local skills base, for

example co-locations of clusters of R&D firms and research scientists, or manufacturing firms and skilled machinists.

Conceptualising these processes as the result of self-reinforcing loops can help explain the patterns of spatial concentration that we observe across the urban economy. From this viewpoint, the spatial heterogeneity with which agglomeration benefits appear to emerge over time can be understood as a function of the relative strengths of these underlying mechanisms between those places. Understanding outcomes as the result of interdependence between urbanisation and localisation economies also encourages us to look beyond purely sectoral explanations. We will return to this point later in our discussion of findings.

While different types and benefits of agglomeration are widely recognised the question of at what scales and densities these are invoked is still the subject of debate (Giuliano, Kang, & Yuan, 2019). Most notably, there are large variations in how economic activity is concentrated and organised within urban areas, leading Agarwal, Giuliano, and Redfearn (2012, p. 437) to remark “agglomeration economies? Sure, but at what scale?”. Rosenthal and Strange (2020) argue that agglomeration effects can operate from the organisational to the metropolitan scales, but that different types of benefits have different distance decay functions. That is, they attenuate at different rates and in different ways across sectors and markets. Crucially, they adopt Fujita and Ogawa’s (1982) critique of studies of agglomeration economies that assume monocentric urban areas and, therefore, recognise that economic activity is concentrated unevenly within urban aggregations and emphasise the importance of analysing sites of economic activity rather than using political boundaries.

In their analysis of the microfoundations of agglomeration economies, Rosenthal and Strange (2001) found that various factors tend to be more pronounced at different spatial scales, where innovation intensity was more relevant in concentrations at the zip code level, while input sharing benefits accrue due to concentration at the state level. Lavoratori and Castellani (2021) most recently explore these ideas in the UK. They find a positive relationship between both types of agglomeration economies and productivity but also that urbanisation economies function at broader spatial scales – e.g., at the city level – whereas localisation economies tend to be strongest at the neighbourhood scale. This has spawned research on about how more localised agglomeration in the form of employment subcenters form, how agglomeration effects differ across industries (and scales) (Liang & Goetz, 2018), how these subcentre dynamics affect growth (Yang, Pan, Hewings, & Jin, 2019), how these dynamics can be harnessed for smarter urban economic development planning (Boussauw et al., 2018), and has raised important questions about how subcentres relate to one another within urban areas and how these parallel research on networks of urban systems (Clark, Harrison, & Miguelez, 2018; Meijers, Hoogerbrugge, & Cardoso, 2018; Volgmann & Rusche, 2020).

These strands of research inspired our approach to understanding spatial patterns of productivity in the UK. First, by adopting a jurisdictionally agnostic approach based on microdata we can explore subregional spatial dynamics. The different economic geographies that we developed based on economic activity (see a more detailed discussion in the following section) enable us to explore agglomeration and to interrogate how meaningful effects are at different scales. We adopted lower-layer super output areas (LSOAs) as our smallest scale, but also explored effects across high-density and medium-density employment areas. While our typology includes proxies for broader metropolitan areas, we limit our analysis to these smallest and densest spatial scales for now. Combined with sectoral data, we can use these to develop hypotheses about the relative importance of urbanisation and localisation economies and the different synergies at play in each.

Finally, we develop these arguments further by exploring not only how agglomeration size affects productivity outcomes at different spatial scales, but also by looking at how spatial configurations of concentrations of economic activity may also contribute to relative performance. Interrogating the relationship of different economic *geometries* may add nuance to the link between agglomeration and outcomes by acknowledging that where activity occurs - how centralised or dispersed, and whether concentrated in one major centre or several - may strengthen or weaken agglomeration effects. This lays a foundation for future research to explore how these geographies and geometries relate to patterns of specialisation and diversity (related variety) – which we only begin to explore here – and, in particular, how centres of economic activity are linked to and related to one another, the degrees to which those produce synergy or competition, and how these patterns affect productivity.

The following section outlines how we approach and define economic geographies and geometries to explore these spatial effects in the UK context.

Measuring productivity at different spatial scales

Geographies of economic activity

In this paper, we adopt a set of alternative spatial definitions that we think better capture the economic spaces that generate productivity. The methodology is discussed in more detail in Brown et al. (2020). However, briefly, this approach argues 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 the lowest spatial level feasible in order to capture economic and spatial dynamics as accurately as possible. The distribution of *employment* is the fundamental foundation for analyses of phenomena such as agglomeration, innovation, and productivity, 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).

In order to capture data at the lowest scale widely available in Great Britain, we use lower-layer super output area (LSOAs) (Morrill, Cromartie, & Hart, 1999).[2] LSOAs were introduced in 2001 and have mean populations of 1,500 (ONS, 2016).[3] 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.

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[2] A similar approach has been applied in the United States using census tracts to identify American commuting areas at different scales (see Morrill, Cromartie, & Hart, 1999). Our approach differs in that our LCA cores are based on employment density versus population counts/density. 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.

[3] These are constructed based on adjacent unit postcodes and designed to aggregate postcodes that have similar population sizes and are as socially homogeneous 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.

We started from the core question: where are the largest build-ups of employment activity in Britain? Employment centres are useful levels of analysis as local agglomerations with their own fundamentals (Agarwal et al., 2012). 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).[4] The medium density measure represents LSOAs that are in the region of, or slightly above, the mean GB employment density figure of 127 jobs/km^2. After applying some exclusion thresholds[5] in order to identify the largest aggregations, we found 162 medium density cores (MDCs) and 433 high density cores (HDCs) in England. The higher density measure (HDCs) captures denser employment zones that typically, but do 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, but we think capture the most relevant areas of economic activity. Note that many of these encompass parts of several different political jurisdictions.

Some important questions flow from these conceptualisations. First, is there any evidence of micro agglomeration, such as a relationship between LSOA density and productivity? What is the relationship between HDC, MDC, and non-MDC productivity and how does that correlate with size? Might there be a wider regional bias to productivity outcomes? To what extent does this seem to be a proximity to London effect? Research for DfT by Brown and Fingleton (2019) used dynamic spatial panel analysis to identify a causal link between effective economic density, once transport linkages were included, and both labour and total factor productivity for both a number of individual sectors and at the economy-wide level. As you might expect, effective economic density was strongly influenced by proximity to central London. Finally, how might we expect these impacts to play out differently in different local economic geometries?

Geometries of economic activity

As we discussed above, where economic activity takes place within any given scale of aggregation - such as an urban area - can affect the effectiveness of agglomeration effects. To explore this idea, we devised a spatial typology that separates areas by the relative concentrations or dispersion of their economic activity. We measure this by looking at the percentage of employment concentrated in HDCs located in the MDC. That is, how much of the employment within MDCs is concentrated in a large HDC versus spread across several significant subcentres of economic activity.

Dispersed areas are those where fewer than 60%[6] of MDCZ jobs are located in central HDCs (HDCs within the MDC), meaning that there is a meaningful amount of employment in

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[4] 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 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.

[5] 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.

[6] We selected 60% as the threshold between centralised and decentralised places in order to effectively capture places where a significant preponderance of economic activity occurs in the medium density core.

fringe high density cores distributed outside of the central MDC (which sometimes happens) or that employment simply tends to be distributed across LSOAs with lower employment densities. There are 76 dispersed areas, such as Sheffield, Norwich, Cambridge, Blackpool, and York.

All places that were not *dispersed* were categorised as *centralised*. Crucially, however, we identified two distinct types of centralised places:

Monocentric areas are those where HDCs in the MDC represent over 60% of the total jobs in the broader commuting region (MDCZ) and the largest HDC has over 70%[7] of all jobs in HDCs in the MDC. In other words, these are areas where a large proportion of jobs are concentrated in the medium density core and, of those, most are located in a single large high density employment area. In monocentric areas, we would expect to find the greatest evidence of agglomeration effects. We identified 77 monocentric areas including London, Bristol, Derby, and Oxford.

Polycentric areas are those where HDCs in the MDC represent over 60% of the total jobs in the broader commuting region (MDCZ) but the largest HDC accounts for less than 70% of high-density employment in the MDC. In this case, the broader area is still relatively centralised, but high-density employment is distributed across two or more high density employment centres. Agglomeration effects might still be significant in polycentric places, but we hypothesise that these will be weaker than in monocentric places. We found 38 polycentric areas, which included Manchester, Nottingham, Leeds, and Leicester.

The different patterns of economic activities are interesting in and of itself and worthy of greater discussion than practical in this paper. However, it is notable that there is a great deal of polarization amongst UK places. We found almost the same number of dispersed - relatively decentralized - places as monocentric - highly concentrated - places, with about half as many polycentric places in between. Interestingly, there are some correlations between geometry and size. For instance, monocentric places tend to be smaller, with the exception of London. Most large MDCs in the UK are polycentric. Dispersed places are also likely to be smaller, with the exception of Sheffield. As such, England exhibits an interesting pattern of its largest places being either polycentric or dispersed (aside from monocentric London). We suspect that these patterns have impacts on productivity performance. Why these patterns have developed is beyond the scope of this paper, but might be important to explore given the findings we present below. In any case, we use these types as lenses to better understand economic dynamics and find them to be relatively useful in hypothesising productivity outcomes.

Measuring spatial productivity

In order to align with ONS analysis and data, the measure we use is the ratio of annual sectoral GVA (in £) to sectoral employment (measured in jobs), in each of our geographies. This is probably the most widely used metric to represent labour productivity. Sometimes GVA/hour worked is preferred, however data on hours worked was not available.

For this we used the Business Structure Database (BSD), which contains a snapshot of firm-level data for all firms in the UK over the VAT threshold. The BSD does not explicitly contain data on GVA, but rather firm turnover, which after some processing to allow for a proportional distribution of turnover across multiple local units for multi-site firms, can be

[7] We selected the 70% threshold for monocentric areas to ensure that the places we were capturing in this category really were dominated by a single large high-density core. At this threshold, at best the second largest HDC would account for less than half of the largest core's employment. Below that threshold, either the second largest core may account for a more significant amount of high-density employment and can credibly be considered a rival centre or employment is fragmented across several smaller cores.

aggregated to local sectoral turnover. A conversion must be therefore performed to estimate the local sectoral GVA. This conversion was done using detailed national-level input-output tables, which provide data on total turnover and total GVA at a detailed sectoral level. Relying on the assumption that on aggregate, firms within a sector will share a similar turnover/GVA ratio, that we believe to be a reasonable one, we apply this conversion ratio to local sectoral turnover in order to estimate local sectoral GVA. Local sectoral employment can be measured directly (for the same cohort of firms).

Findings

Our analysis proceeds through three phases. First, we investigate patterns of productivity at the micro scale to get a finer grained picture of where the highest productivity places are. These results add interesting nuance to the discussion of spaces of productivity. Second, we turn to our aggregate geographies - MDCs and HDCs - to explore how their productivity performance is related to employment density and economic geometries. This analysis reveals interesting patterns that support arguments that agglomeration effects may only be significant at specific scales - in this case, they are most powerful at the MDC level of aggregation. Finally, we consider these results in combination with data on sectoral structures and sectoral productivity. Through this we make the case that *what* is productive matters as well as *where* it is located.

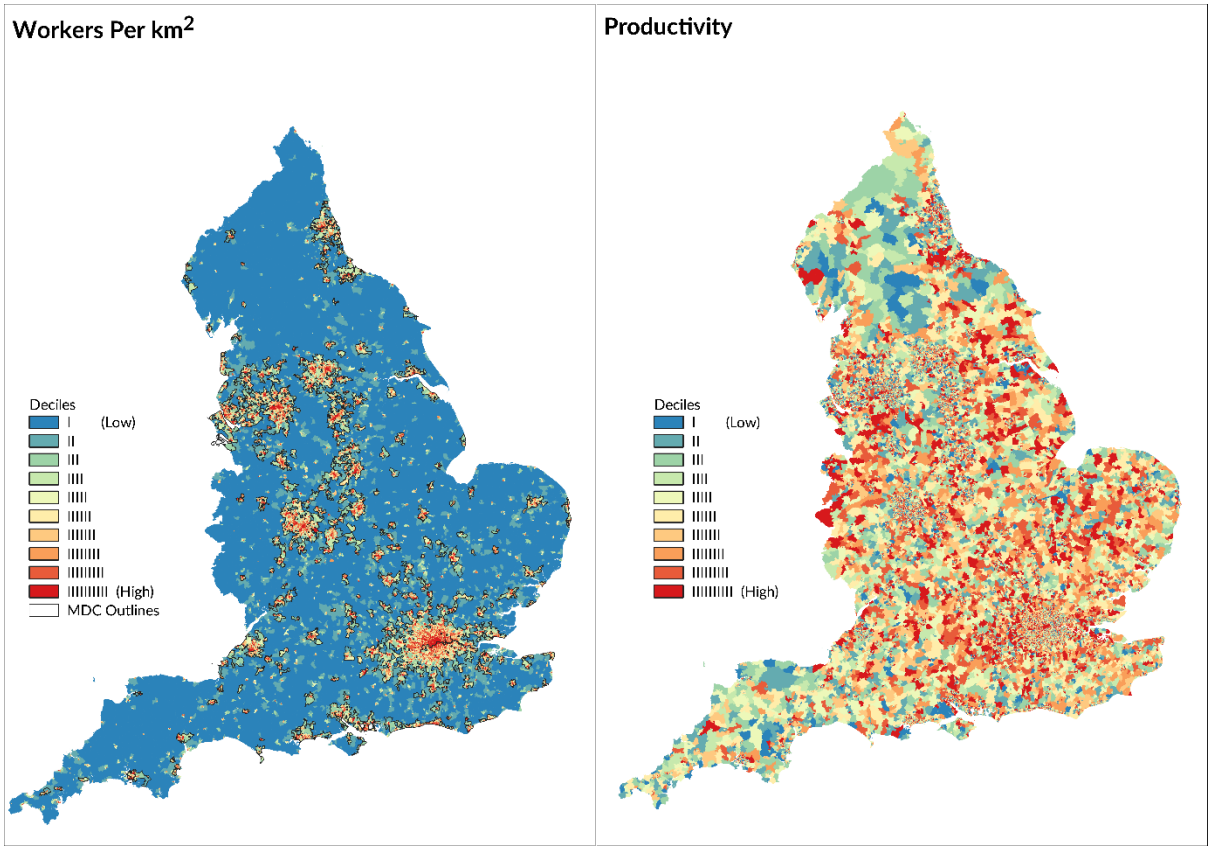
Overall Pattern of Productivity in England

Examining economic patterns at the LSOA scale without reference to regional or urban boundaries can provide a deeper understanding about where economic activity actually takes place in those spaces and, therefore, can generate a more informed understanding of the role of space. These provide a new vantage from which to challenge underlying assumptions. Our analysis begins with some basic visualisations of economic activity (see Figure 1) of (a) workers/km^2 and (b) productivity (GVA/worker).

The first map shows where economic activity is concentrated as measured by employment density (workers/km^2). As expected, this map shows the highest concentration of employment density at and around urban and town centres with density diminishing in more or less concentric rings. In some places, it is possible to pick out multiple higher density areas. In places like Birmingham, Leeds, and Manchester distinctive blooms of high-density employment are clearly separated by areas of lower density activity. The reason the map appears dominated by blue, is of course because lower density LSOAs tend to be geographically larger.

The second map visualises the geography of productivity by LSOA (GVA/worker). As can be seen, the spatial correlation between productivity and employment density does not appear to be a strong one, with areas of top decline productivity, shown in red, dispersed across both high and low employment density LSOAs. While the LSOAs are physically smaller in denser urban areas, aggregations of higher productivity are evident. However, it is immediately apparent that high productivity is by no means confined to urban areas, with large swathes of high-productivity activity visible across lower-density LSOAs outside of urban areas. This fact clearly challenges the currently fashionable urban-focused narrative of high-productivity cities “supporting” their surrounding regions.

Figure 1: Workers per km2 and productivity (GVA/worker) by LSOA



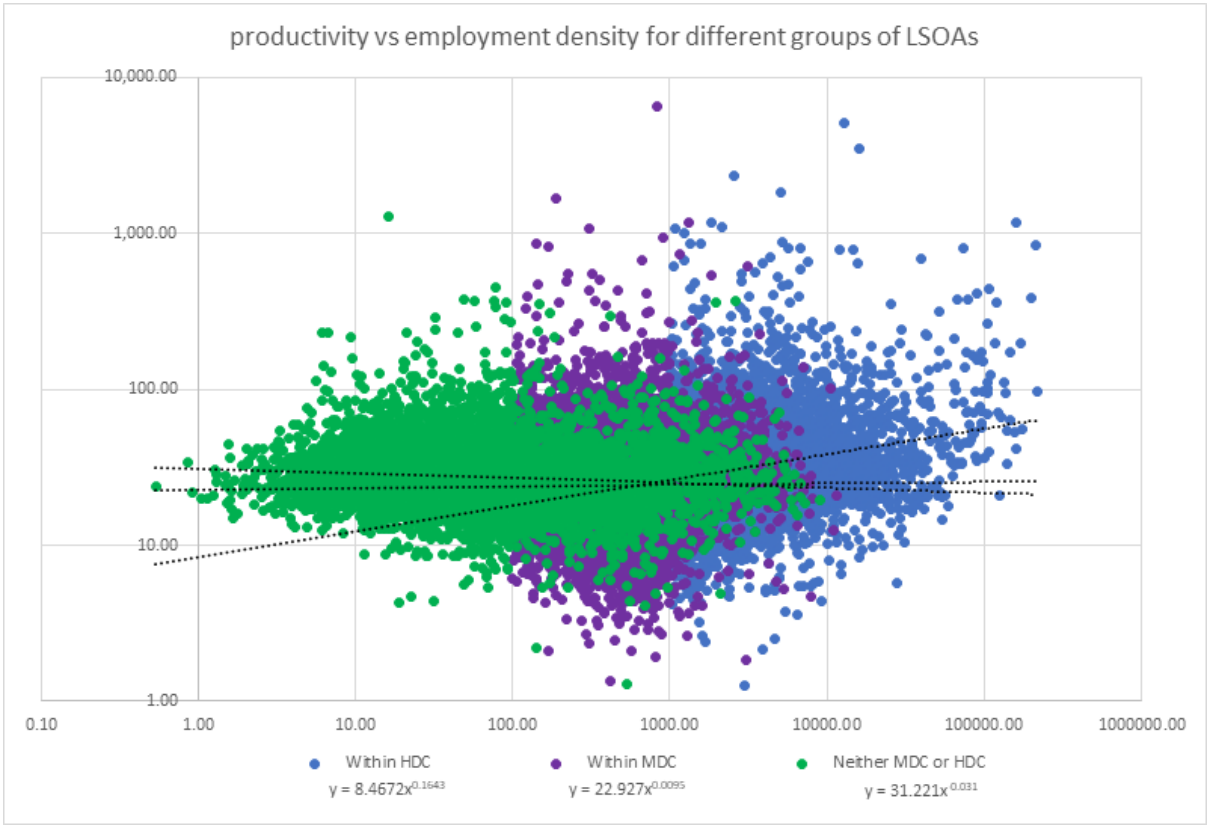
In order to explore this phenomenon further, we analysed the relationship between employment density and productivity through the lens of specific geographies of economic activity. For instance, is there a stronger relationship between employment density and productivity in areas of agglomeration? And if so, at what scale might these effects come into play?

When we focus on our geographic categories – MDCs, HDCs, and areas outside of these places – we find some interesting differences in average productivity. Namely, HDCs tend to be, on average, more productive than MDCs. In turn, MDCs have higher average productivity than the areas outside of them.[8] Figure 2 charts the relationship between LSOA employment density and GVA/worker. It suggests that there's a weak link between employment density and productivity at the LSOA level, but it is strongest *within* HDCs, and weakest outside of them. This suggests that while agglomeration effects, at least based on employment, have some effect, they are most powerful in the areas with the highest density employment. Outside of either MDCs or HDCs, the relationship is actually negative. This also supports the contention that there are productivity benefits to being located in denser urban areas, potentially due to agglomeration effects.

These findings enable us to refine our hypotheses about what we might find in analysing economic geometries. Theory suggests that centralised places - e.g., mono- and polycentric - will have greater productivity advantages over more decentralised (dispersed) places. However, our findings suggest that monocentric places will deliver greater productivity benefits of the two subtypes.

[8] Mean productivity by geography: In HDCs = 78.16; In MDCs = 42.29; Outside of HDCs and MDCs = 36.51

Figure 2: Productivity (y axis, £000 per worker) of LSOAs by employment density (x axis, workers/sqkm) categorised by geographical location - within HDC, within MDC, or neither MDC or HDC.



Geographies and geometries of productivity

An analysis of productivity outcomes with economic geometries largely supports these conclusions. However, before exploring the relationship between size, geometries, and productivity it is worth discussing how our alternative spatial definitions change our understanding of the map of productivity.

Figure 3 depicts GVA/worker for (a) MDCs and (b) HDCs coloured by decile. The MDC map shows London as a large agglomeration in the highest decile of productivity with other larger cities ranking, for the most part, in the top half of the scale. While larger MDCs do appear to be more highly productive than smaller ones it is notable that London is the only big, diversified economy in the top decile. The rest are places that, further inspection reveals, specialise in particular industries. These include places like Milton Keynes, Coventry, Bournemouth and Norwich, as well as Grimsby, Aylesbury, and Newmarket. While there are some overlaps with official measures based on city regions and NUTS 3, there is some interesting divergence in our list.

The HDC map is even more interesting on a number of levels. Most notably, while there is some correlation between the places with the highest productivity MDCs and the highest productivity HDCs (London, Milton Keynes, Bournemouth, Coventry), some of the highest productivity MDCs have lower productivity HDCs. Grimsby and Norwich both stand out here. Again, that London is the only large, diversified economy in the top decile is notable. The other top decile HDCs tend to be smaller edge city or exurban sites specialising in a single industry.

This disconnect between the productivity of high- and medium-density cores hint that there are spatial and sectoral dynamics at play in these geographies that require further investigation and suggest a further challenge to the link between agglomeration and productivity. At the very least, the Grimsby and Norwich cases add nuance to our finding above about the more powerful link between employment density and productivity in HDCs. In these places, that link is much weaker and productivity performance is driven by activities in medium density areas.

Figure 3: MDC (left) and HDC (right) productivity (GVA/worker), by decile

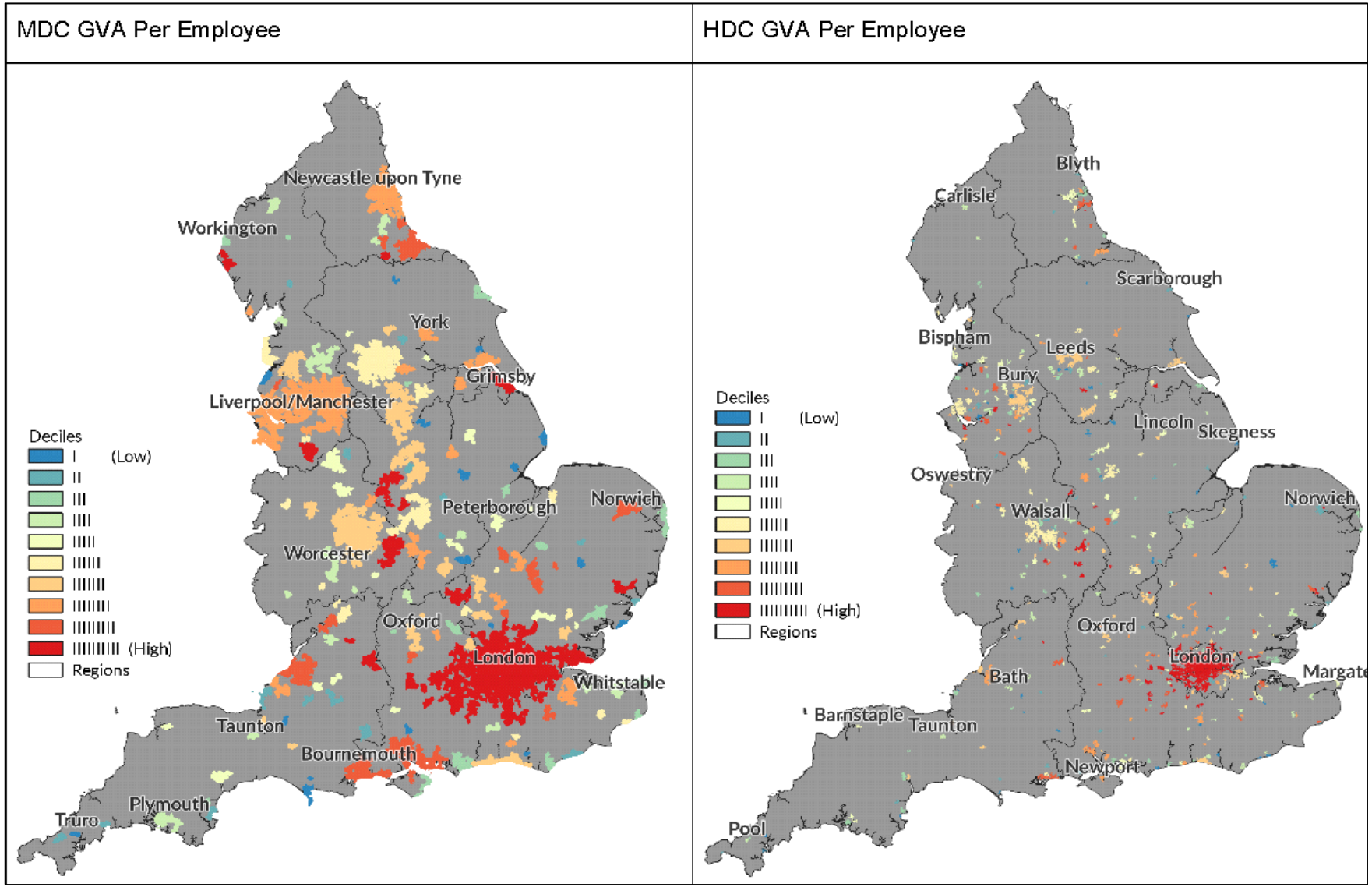
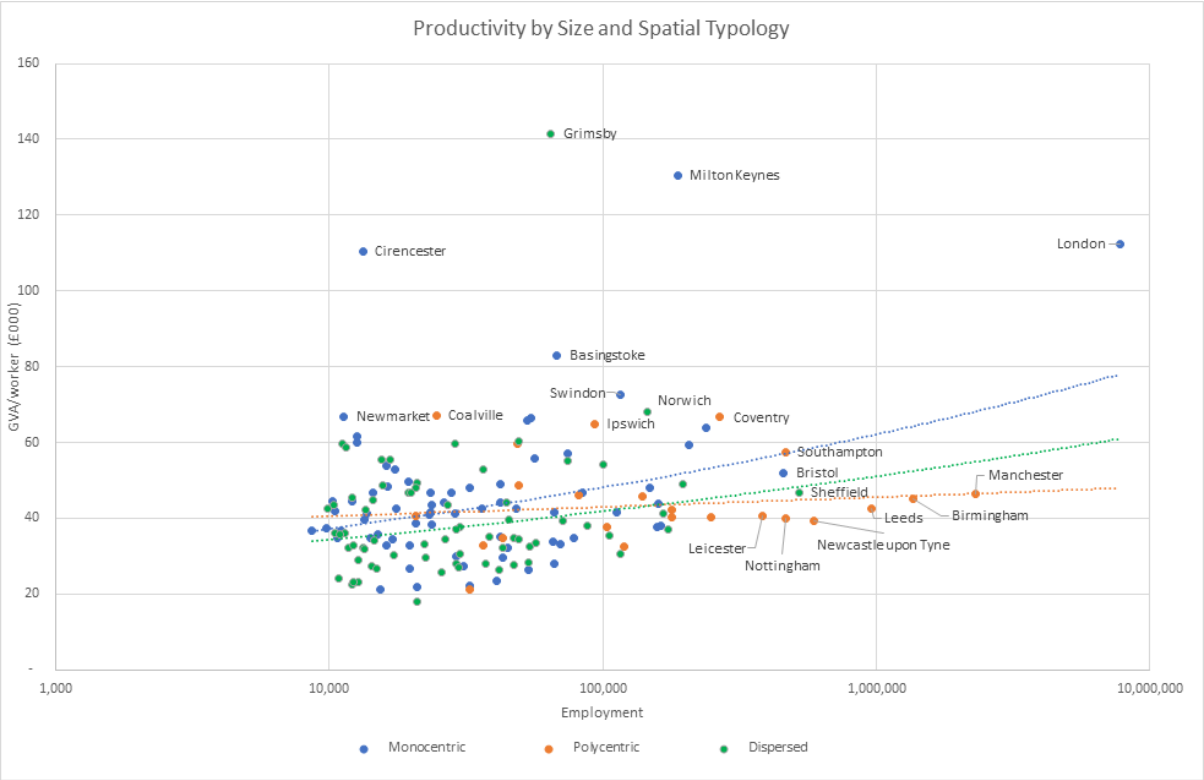


Figure 4 shows productivity by MDC and geometries. Bearing in mind previous caveats about the importance of effective density rather than city size per se, we found a (relatively weak) positive relationship between size and productivity across all types. Interestingly, this relationship was strongest for monocentric places, and weakest for polycentric places. This suggests that the feedback loops that drive agglomeration benefits over time appear to function more strongly in places where economic activity is concentrated in one central area of employment density. Places where economic activity is distributed across several high-density employment centres (HDCs) don't appear to benefit from these mechanisms to the same extent as places with a single, dominant core. It is notable that outside of London, many of the UK's largest MDCs tend to be polycentric, for a variety of historical and infrastructural reasons. The highest performing MDCs in the country are mostly monocentric and spread across a range of sizes (see Milton Keynes, Cirencester, Basingstoke, Swindon, Newmarket). Grimsby and Norwich are high performing dispersed geographies, whereas Coalville, Ipswich, Coventry and Southampton are better performing polycentric geographies. We investigate the causes for some of these in further detail in the case studies section.

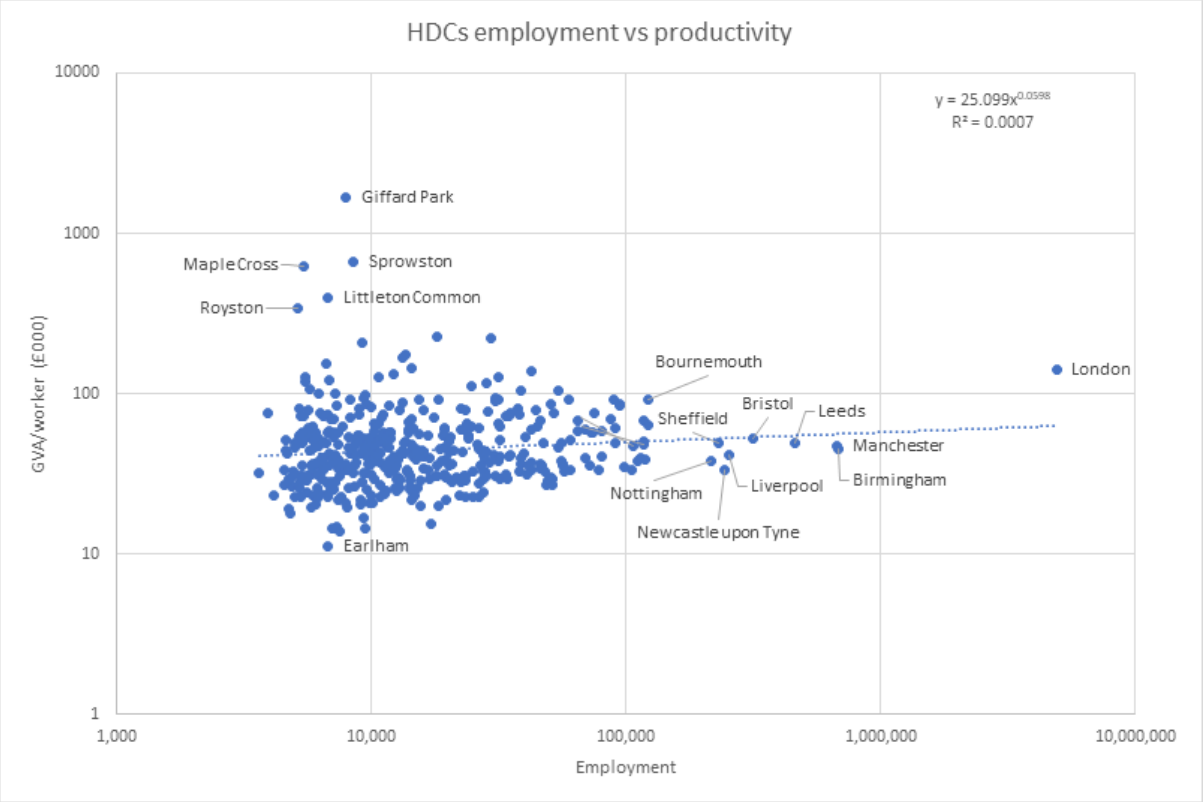
Figure 4: The relationship between MDC productivity (GVA/worker), size (employment), and economic geometry



While there is still a weak positive correlation between size of HDC and productivity the effect is not as pronounced for HDCs as for MDCs (see Figure 5). This sideways V pattern in the data is due to the inverse relationship between sample size and variance from mean. This is to be expected from data of this nature. Again, outside of London, larger HDCs, representing the inner cores of Nottingham, Leeds, Newcastle, etc. appear to underperform relative to their size. This is another area where findings diverged from our expectations. As described above, there are reasons to expect that agglomeration effects may be more pronounced at greater densities, such as HDCs. However, this relationship, though positive, is relatively weak. Some of the most productive HDCs, such as Giffard Park, Maple Cross, Sprowston, Littleton Common, may offer some insights. These HDCs tend to be relatively small, and these results

are likely connected to sample size issues where higher productivity may be due to the distorting effects of a single highly productive employer.

Figure 5: The relationship between HDC productivity (GVA/worker) and size (employment)



**Note that this is a log-log plot due to the higher diversity of productivities in HDCs*

Sectoral structures

To gain a better understanding of why we're seeing these productivity patterns at the MDC and HDC scales, we explore the role of sectoral structures. It is likely that localised sectoral structures and degrees of specialisation are influencing overall productivity performance and causing distortions that are difficult to see in aggregate measures. In our analysis, we explored productivity across 9 different broad sectoral groups (primary, manufacturing, construction, transport & logistics, consumer services, public services, technical services, professional services, and support services).

Figure 6: The relationship between the number of sectors in which MDCs have productivity above the national average in that sector and productivity (GVA/worker)

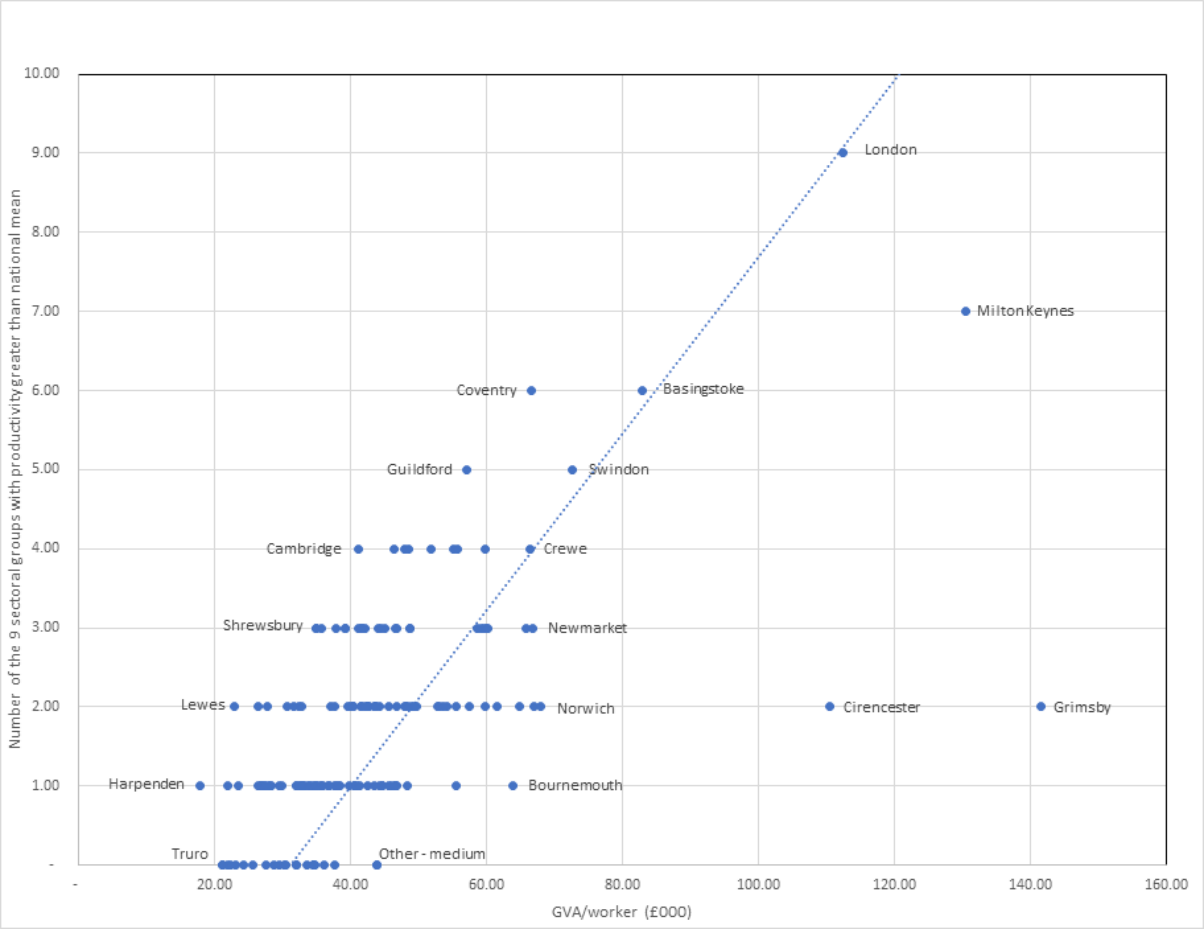


Figure 6 shows the relationship between overall productivity in MDCs and *the number of sectoral groups in which it has higher productivity than the national mean productivity in that sectoral group*. Non-MDC LSOAs are also included in the analysis as three additional data points, grouped by local employment density as (other-high, other-medium and other-low). The results demonstrate the utility of taking this comparative approach. It is worth noticing that due to the positively skewed nature of sectoral productivity distributions, the majority of MDCs inevitably have more sectoral groups *below* the national average than above. Indeed, 18 geographies underperform the national average for all sectoral groups. Unsurprisingly, these areas tend to also score lower on total productivity. At the other end of the scale, London is the only MDC that performs above the national mean for all nine sectoral groups.

However, it is the places that diverge from the trend line that offer interesting insights into how differently sectoral specialisation (or lack thereof) can play out. Grimsby is only above the mean in two sectors, but those sectors are so unusually productive relative to the rest of the country that Grimsby's overall productivity is the highest of all MDCs. Cirencester and Milton Keynes also perform well as a result of specialisation. MDCs to the left of the trend line exhibit lower levels of overall productivity than might be expected, perhaps due to a lack of an equivalent dominant specialisation.

The lessons here are interesting. While increasing the productivity of all sectors in an MDC could be an effective strategy to improve overall performance, very few places have managed to leverage that diversity to generate higher productivity. London and Milton Keynes stand out as places with a diverse portfolio of above-average performing sectors but, other than that,

everywhere with four or more of these tends to have lower than expected productivity. Cirencester and Grimsby stand out as places with extremely high productivity relative to expectations, but highly dependent upon just one or two key sectors for this level of performance. However, a great number of places such as Newmarket, Norwich, and Bournemouth, outperform expectations given their share of higher productivity sectors. This suggests that improving the performance of key sectors rather than focusing on generalised gains may have a greater impact.

The presence of high productivity sectors can positively impact others

Closer analysis of productivity performance by sector and place offers some clues as to which to focus on. Figure 7, shows sectoral employment versus sectoral productivity in MDCs. These graphs show that tradable sectors (primary, manufacturing, technical and professional services) have a positive relationship between specialisation and productivity. By contrast, non-tradable sectors such as consumer and support services exhibit a negative relationship between specialisation and productivity. Public sector and construction also show positive relationships while transport & logistics is more ambiguous.

Interpreting these patterns and their significance requires returning to the interplay between urbanisation and localisation economies. We suspect that local productivity advantages in tradable sectors lead to increased competitiveness, sector growth, and cluster formation. These create a positive reinforcing feedback loop between specialisation and productivity. Conversely, local productivity advantages in lower value services sectors with fixed output demand simply lead to lower employment demand and hence a negative correlation between specialisation and productivity. In other words, consumer and support services do not benefit from localisation economies and probably do not experience as strong a positive feedback loop. On reflection, this makes sense. Growth in these sectors relies on direct spending from tradeable firms and from consumers. Therefore, their productivity will likely be more impacted by proximity to productive tradable sectors and the higher wage jobs that they generate, which will tend to augment commercial and consumer spending. Through this mechanism, localisation economies in other sectors increase urbanisation economies to the benefit of non-tradables. As a result, we would expect places with specialisation in non-tradables to exhibit higher productivity in those sectors the greater the share of high-productivity tradables are present in the MDC.

Figure 7: The relationship between sectoral employment and sectoral productivity (GVA/worker) in MDCs

Case studies

One of the most compelling findings from our analysis is that the primary explanations for spatial productivity patterns vary by context. For instance, London and Grimsby both have high productivity and wildly different geographies and geometries and sectoral analysis reveals that the sources of their productivity advantages are very different. While we have identified some general trends, we can only understand outcomes through the specific lenses of local economic geographies, geometries, and sectoral composition.

In this section, we dive into six case studies to demonstrate the impact of different spatial and sectoral dynamics. We focus primarily on showing the productivity performance at the LSOA scale (the first map in each case), employment density (the second map in each case), and the geographies and geometries of economic activity (the third map). These enable us to add context to our discussions of the relationship between density, degree of fragmentation of economic activity, and productivity outcomes. The cobweb graphs focus show relative productivity of the sector (orange dots and lines) and sectoral location quotient (blue dots and lines). Where the blue dots appear in the outer two rings, the place has a specialisation in those sectors. Where the orange dots appear in the outer two rings, the place has higher productivity. By examining the location of these dots in relation to one another, we can identify sectors that are productivity niches (significantly outperform LQ) or drags (significantly underperform LQ). In the latter case, there may be unexploited opportunities to increase productivity performance.

During the analysis we use the following terms:

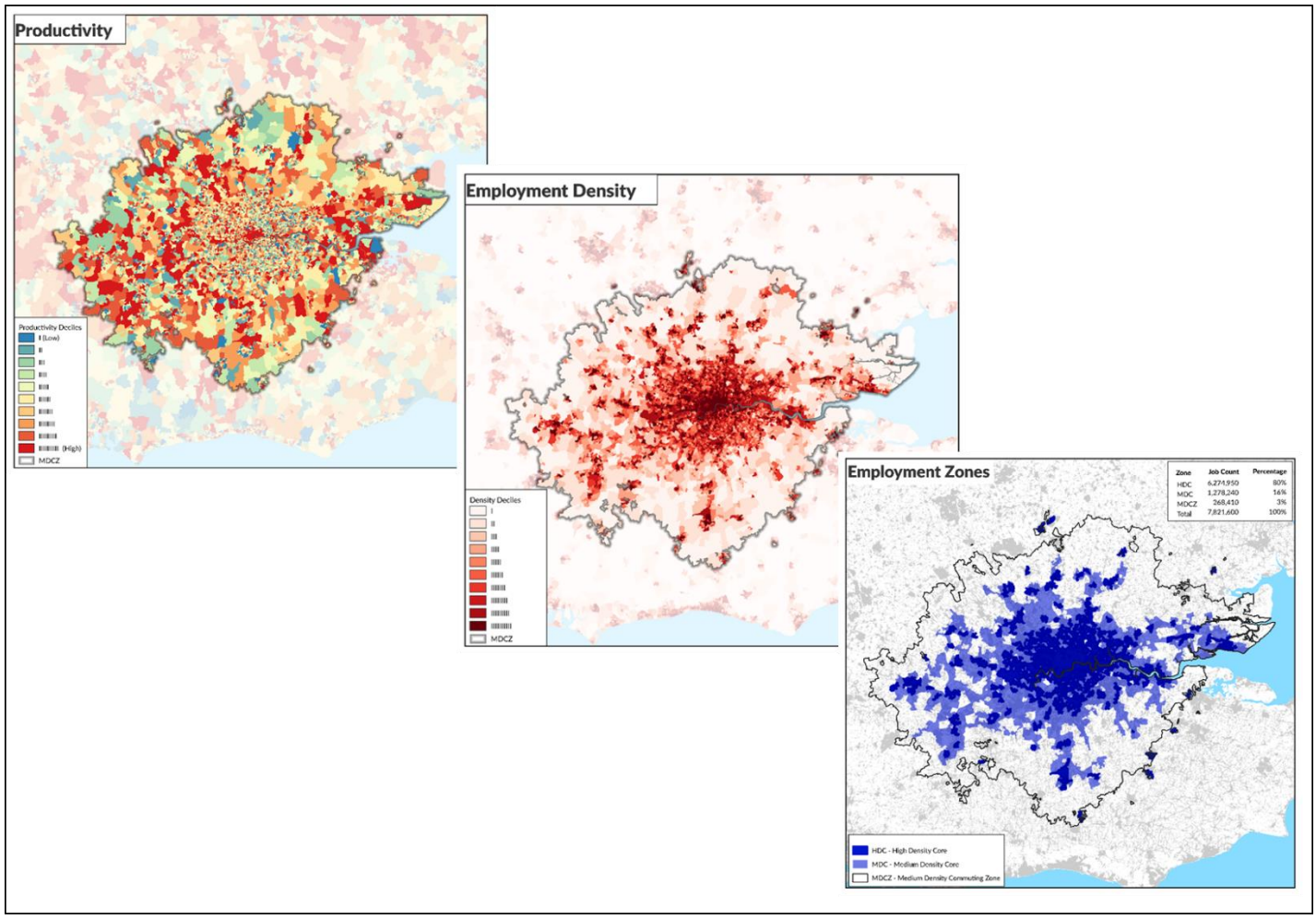
- Specialisation: both relative productivity and location quotient greater than one;
- Primary specialisation: particular large and noteworthy specialisation;
- Secondary specialisation: more marginal specialisation;
- Productive niche: relative productivity greater than one, but location quotient less than one

London

No report on productivity can ignore the singular case of the London region. Despite its size, the London area is highly monocentric. The MDC contains 96% and inner HDCs account for 80% of all employment in the MDCZ. The largest HDC accounts for 73% of high-density employment in the MDC, representing a considerable centralisation of employment despite the presence of several other (sometimes far flung) high-density centres.

Both the HDCs and MDC of the London area score in the 10th (top) percentile on GVA/worker. However, neither is the most productive. The London MDC is third, after Grimsby and Whitehaven, and the London HDC is 22nd after a variety of much smaller, more specialized locations including Bracknell, Giffard Park, Redhill, and Ellesmere Port.

The map of GVA/worker by LSOA illustrates how varied productivity is within its cores. At the centre of the map is a tight cluster of high productivity, high density LSOAs in the very centre of the inner London HDC. However, outside of this central area, the rest of the capital displays a patchwork of productivity levels, with a considerable number of LSOAs with below average productivity. These divergent productivity outcomes are likely the result of microscale geographical economic functions at the LSOA scale. We expect that some of the lower productivity LSOAs will be primarily residential areas dominated by consumer services, for example, but there may be other dynamics at play. The map also shows a ring of lower density, but high productivity LSOAs around the edges of the HDC. There also appears to be a small East-West productivity bias in the wider MDCZ, with LSOAs in the western suburbs more likely to be in the top productivity decile.



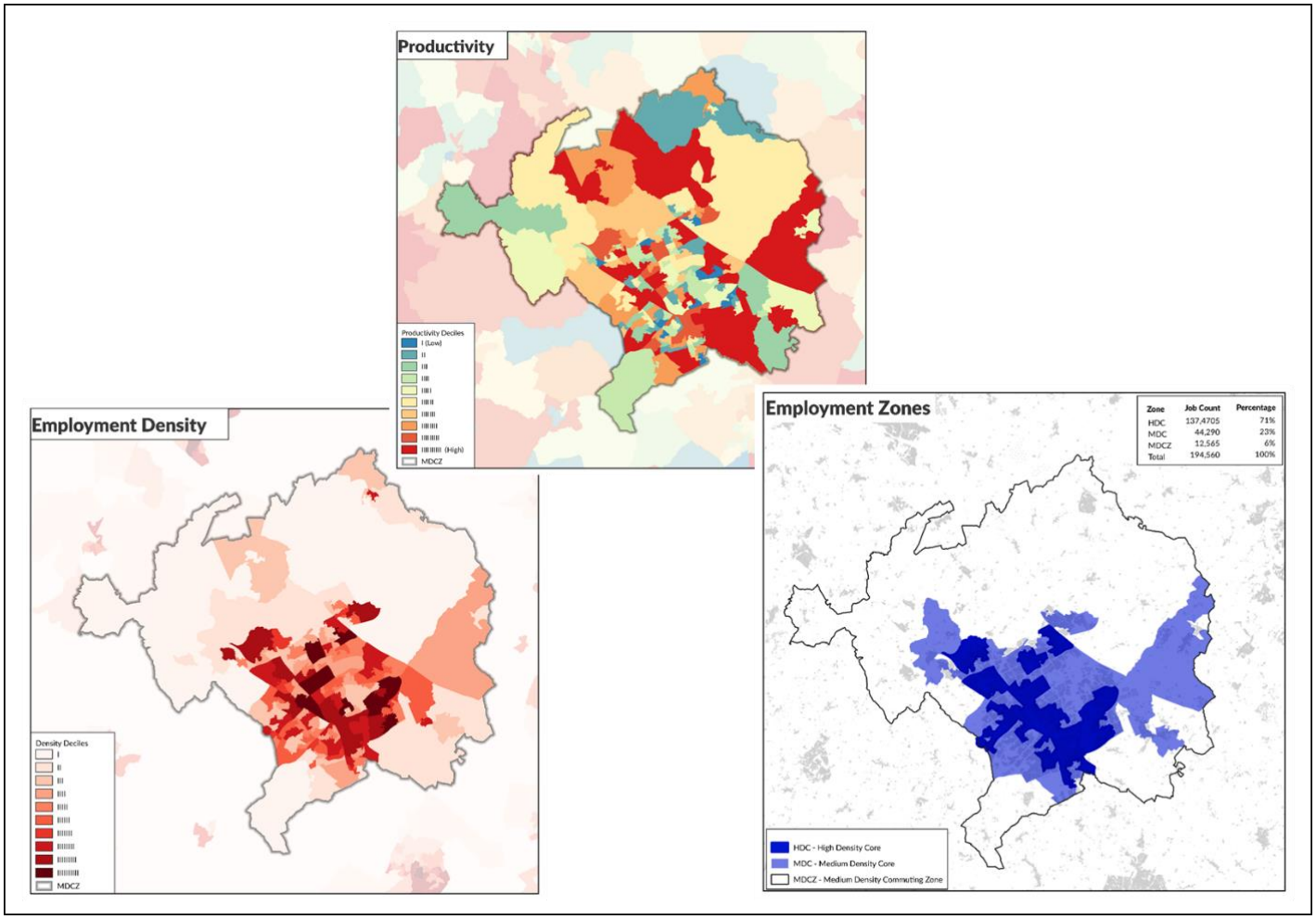
London is a very diverse economy and is among the only large, diverse economies near the top of both HDC and MDC productivity rankings. Sectoral analysis shows that London has primary specialisms in professional and technical services, sectors that we know are particularly susceptible to positive agglomeration benefits, as do its secondary specialisms in consumer and support services. The presence of such significant agglomeration externalities is only possible with London's comprehensive transport network. These connections make synergies possible within and between sectors, and accounts for its monocentricity despite its large size, in ways that are not as possible in less fully integrated economic geographies.

Milton Keynes

Like London, Milton Keynes is also a monocentric and highly productive MDC. A much smaller area, its economic geometry is different to London's, with no obvious equivalent cluster of high-density, high-productivity LSOAs at its centre. Instead, we see a patchwork of high- and low- productivity LSOAs throughout the HDC and MDC, reflecting the more dispersed, zonal nature of the Milton Keynes layout

Milton Keynes scores in the top decile on productivity performance for MDC, ranking just behind London on GVA/worker. The HDC, however, ranks in the 7th decile, suggesting that the reason for the area's success is due to high levels of productivity in less economically dense areas.

The map of productivity deciles shows a familiar patchwork pattern. Very high productivity LSOAs are interspersed with, and sometimes right next to, very low productivity LSOAs, reflecting the differing economic roles of different areas of the geography. The location of some strong pockets of high productivity on the edges of the MDCZ (particularly to the east), combined with the presence of such low productivity areas in the centre, are one reason why the MDC so significantly outperforms the HDC. Some large high-productivity LSOAs are not captured by the MDC, such as the largest red areas north of Newport Pagnell and east of Bletchley. These represent areas of lower employment density but still significant productivity performance. Finally, there are significant areas of high-productivity right on the outer boundaries of the MDCZ, most likely connected to the areas strengths in logistics.

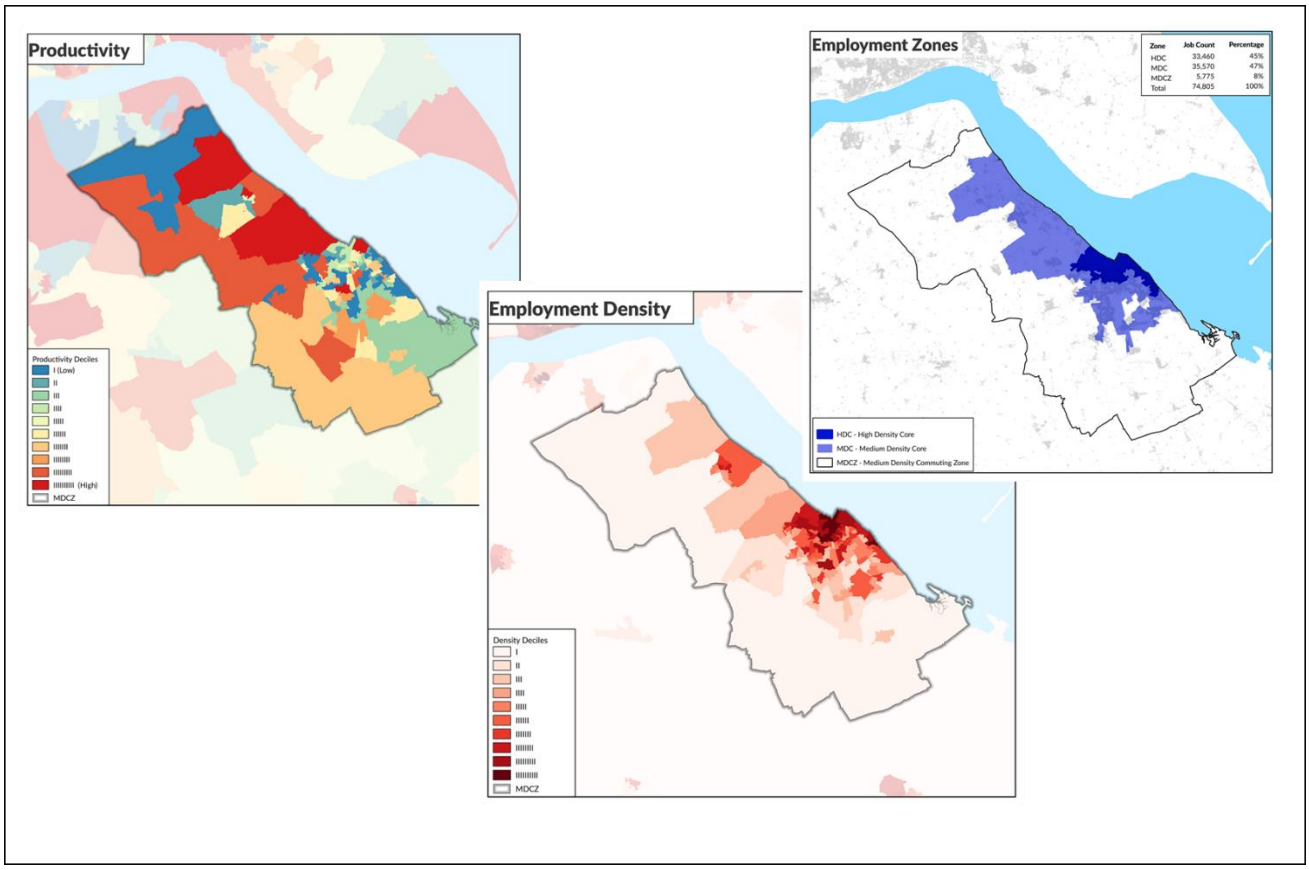


Like London, its productivity performance is the product of relatively high productivity across a variety of sectors. Milton Keynes has above average productivity in 7 of 9 sectors although both public services and technical services are below average. Its specialisms include professional services, transport and logistics, and it has a secondary specialism in consumer and support services. Productive niches include the primary sector, manufacturing, and construction. These specialisms in things like transport and logistics may explain why higher-productivity areas tend to be concentrated on the edges of the MDC. These may also be lower-density office parks housing professional and support services.

Grimsby

According to the data we analysed, Grimsby, a medium-sized coastal city in the Northeast, is actually the most productive MDC in the country. We classify it as a dispersed place given that less than half of MDC employment is located in HDCs. Its relatively low employment density makes sense in the context of its specialisms in primary and manufacturing, which tend to favour medium and lower density locations.

The productivity performance of the HDC relative to the MDC confirms this hypothesis. Although Grimsby tops the ranking for MDCs on GVA/worker, its HDC ranks only in the 3rd decile (and 316th overall). Again, this is related to the sectors of the economy where it is high performing. Notably, only two of these perform above the national average for their sectors but those two outperform by a significant margin. The cobweb reveals the magnitude of Grimsby's productivity in primary sector and manufacturing, which have such high relative productivity as to be off the chart. All sectors aside from primary and manufacturing have relatively low productivity, so it's likely that the HDC's relative weakness stems from its lack of specialisation in these sectors, compared to the wider MDCZ area. The GVA/worker decile map confirms this narrative. The highest performing LSOAs are along the coast to the north of the densest part of the MDCZ (visible from the smaller sizes of the LSOAs).


Productivity
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Percentage
HDC
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45%
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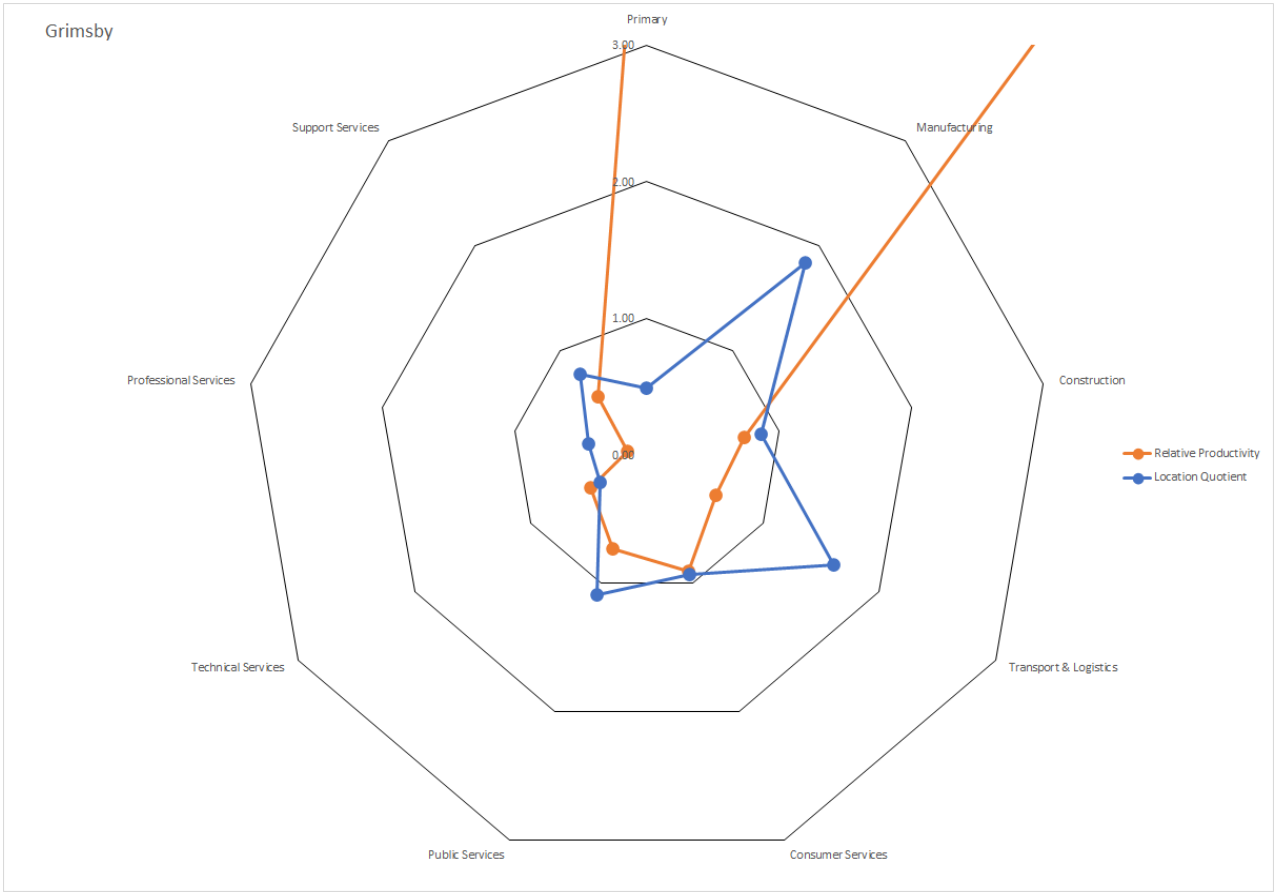
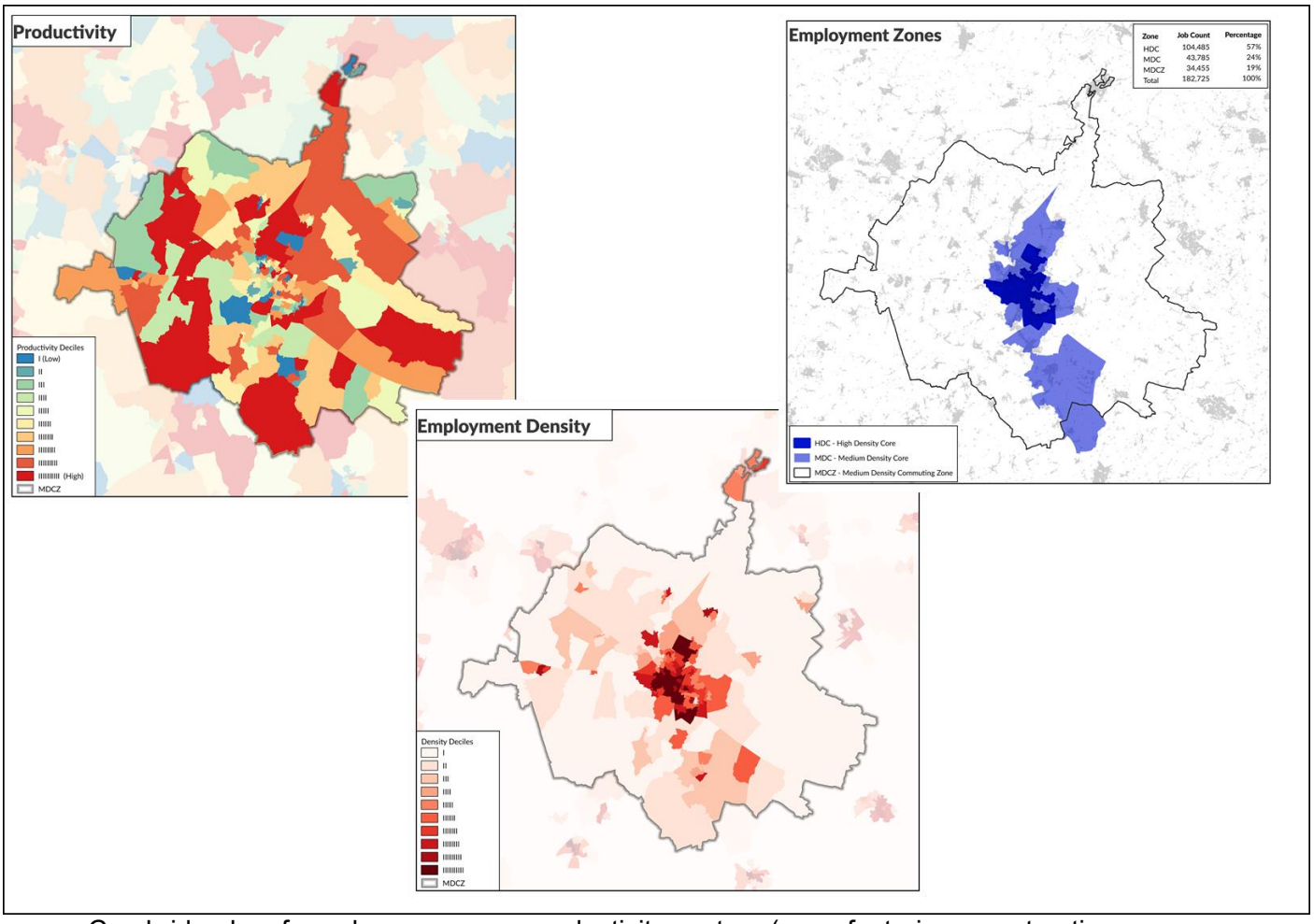

Grimsby
Primary
3.00
2.00
1.00
0.00
Manufacturing
Construction
Transport & Logistics
Consumer Services
Public Services
Technical Services
Professional Services
Support Services
Relative Productivity
Location Quotient

Cambridge

Cambridge is also a mid-sized, dispersed and relatively high-productivity place. The largest HDC has just under 60% of total employment in the MDC making it one of the most centralised places in the dispersed category. The Cambridge MDC ranks in the 9th decile (28th overall) on GVA/worker. Its HDC ranks in the 7th decile on the same measure (along with Milton Keynes) and 155th overall. Elsewhere, we have characterised Cambridge as an inside out place. Because its centre is dominated by the university, it does not concentrate as much of its knowledge intensive economic activity in its higher-density core. The HDC itself is relatively small and covers only a small swathe of the map, while the MDC is oddly shaped around a central corridor (roughly around the M11 and A10). The city is surrounded by highly productive LSOAs of lower employment density, representing Cambridge's ring of research campuses, science parks and advanced manufacturing sites.



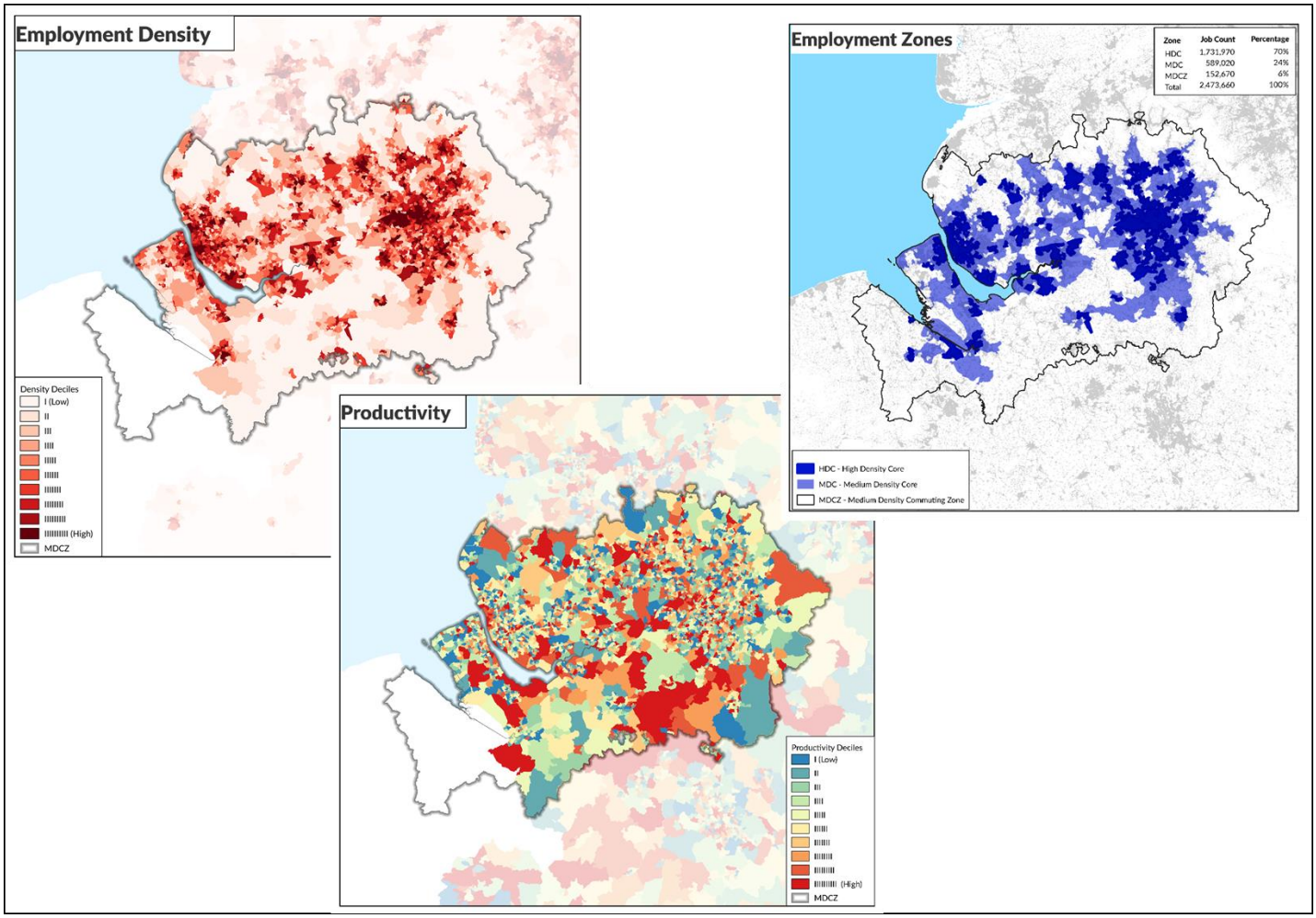
Cambridge has four above-average productivity sectors (manufacturing, construction, transportation and logistics, and technical services). The cobweb diagram confirms that Cambridge has a particularly strong specialism and high levels of productivity in technical services; however this does not appear to translate into more widespread economic productivity. Interestingly, it has higher relative productivity (niches) in manufacturing, construction, transport and logistics but doesn't have very high LQs in those areas and its relative productivity performance is quite weak in all other areas. Despite a highly visible tourist industry, Cambridge is not a specialist provider of consumer services.

The lack of apparent strong spillover effects from its globally significant and highly productive tech cluster to the wider local economy may explain why Cambridge is often identified as the most unequal city in the UK.

Manchester & Liverpool

Manchester and Liverpool occupy a single MDC in our spatial definition. As such, it is a classic polycentric urban area and the largest one in the country. In this area, economic activity is centred on two larger urban poles - Manchester and Liverpool - with significant density in and around Warrington, Chester, and several peripheral areas. The economic fragmentation is evident in both the employment density and geographies maps. Manchester's HDC concentrates 38% of high-density employment in the MDC. The second-largest, Liverpool, has 15%. That the two largest HDCs only concentrate 53% of total high-density employment in the MDC demonstrates just how fragmented economic activity is in the area.

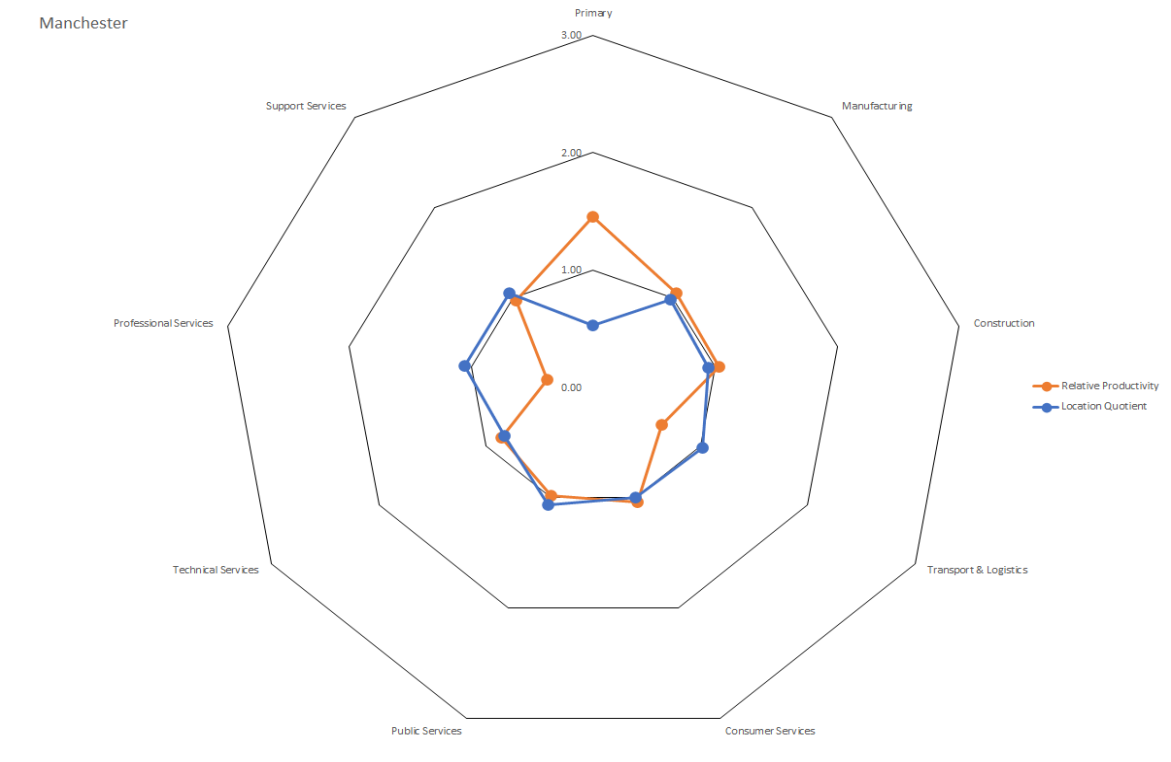
Although this area is the second largest by employment after London, its productivity performance is quite different. Its MDC is in the 8th decile (45th overall). Its HDC is in the 7th decile (152nd overall). These lower-than-expected results make sense given our finding that polycentric areas tend to have lower correlation between size and productivity than monocentric and dispersed places.



Because of the relatively high density of the urban area, the GVA/worker map is made up of much smaller, and harder to see, LSOAs. A visual comparison of the maps shows little relationship between areas of high productivity and high employment density. Almost every HDC has some areas of higher productivity but these do not create obvious aggregations and they are also interspersed with lower-productivity LSOAs. Revealingly, there is no cluster of high-productivity, high-density LSOAs as was visible in inner London.

The cobweb diagram reveals a very “average” conurbation, with both location quotient and relative productivity staying close to the value of one, across the range of sectors. The area has above average productivity in four sectors – primary sector, manufacturing, construction, and consumer services. According to the cobweb diagram, it has slight productivity niches in all of these aside from consumer services. The sectors the conurbation tends to do marginally better at, are also the things it tends to do slightly less of, and vice versa.

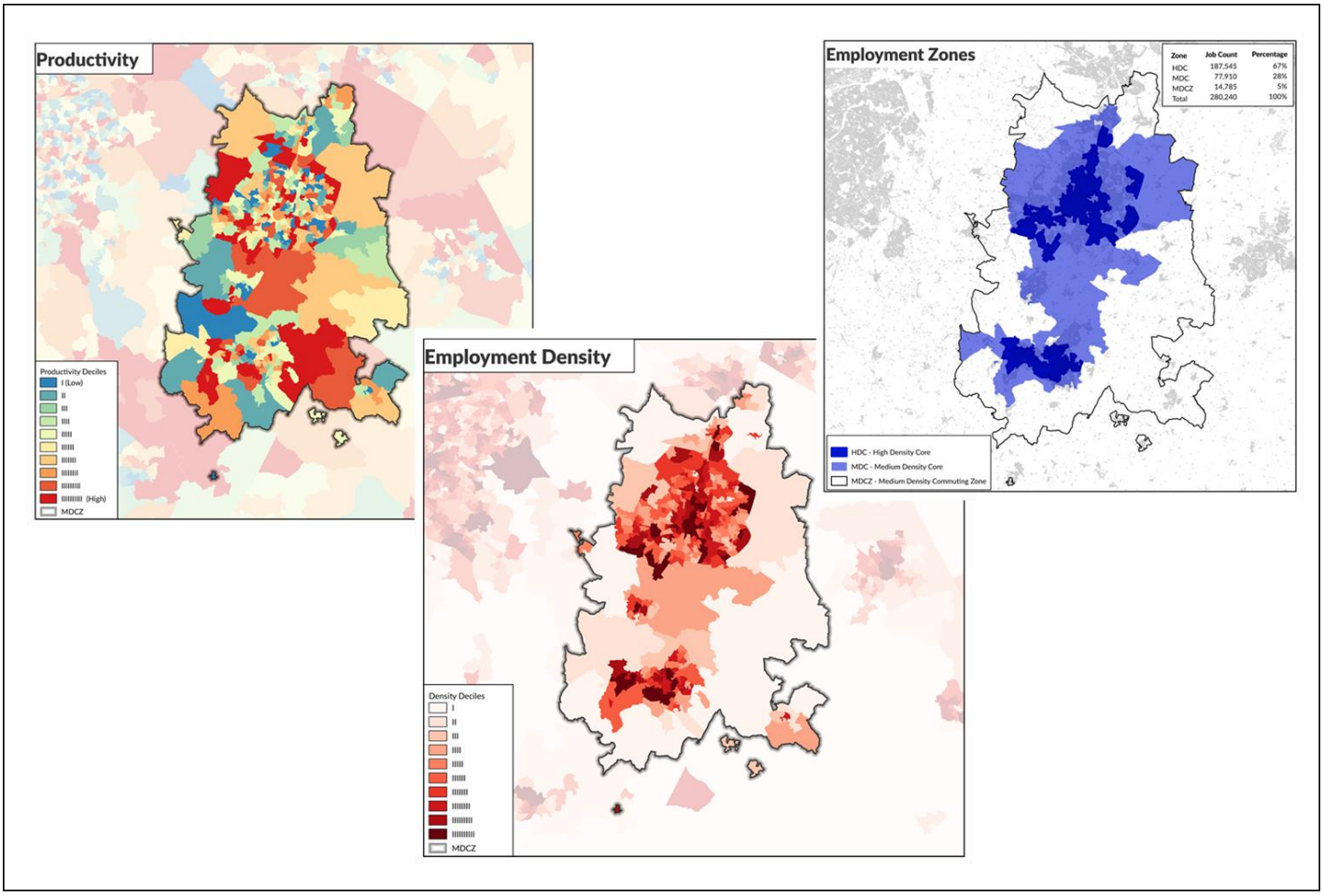
In this case, we think that the area’s geometry may help explain lower than expected productivity performance relative to its size. Fragmentation may be hindering the development and influence of urbanisation economies, whilst a lack of any truly significant specialisation inhibits the development of strong localisation effects. While polycentric places can be quite productive (see the case of Coventry, below) much depends on how well-connected areas of activity are to one another and how synergies have developed between them.



Coventry

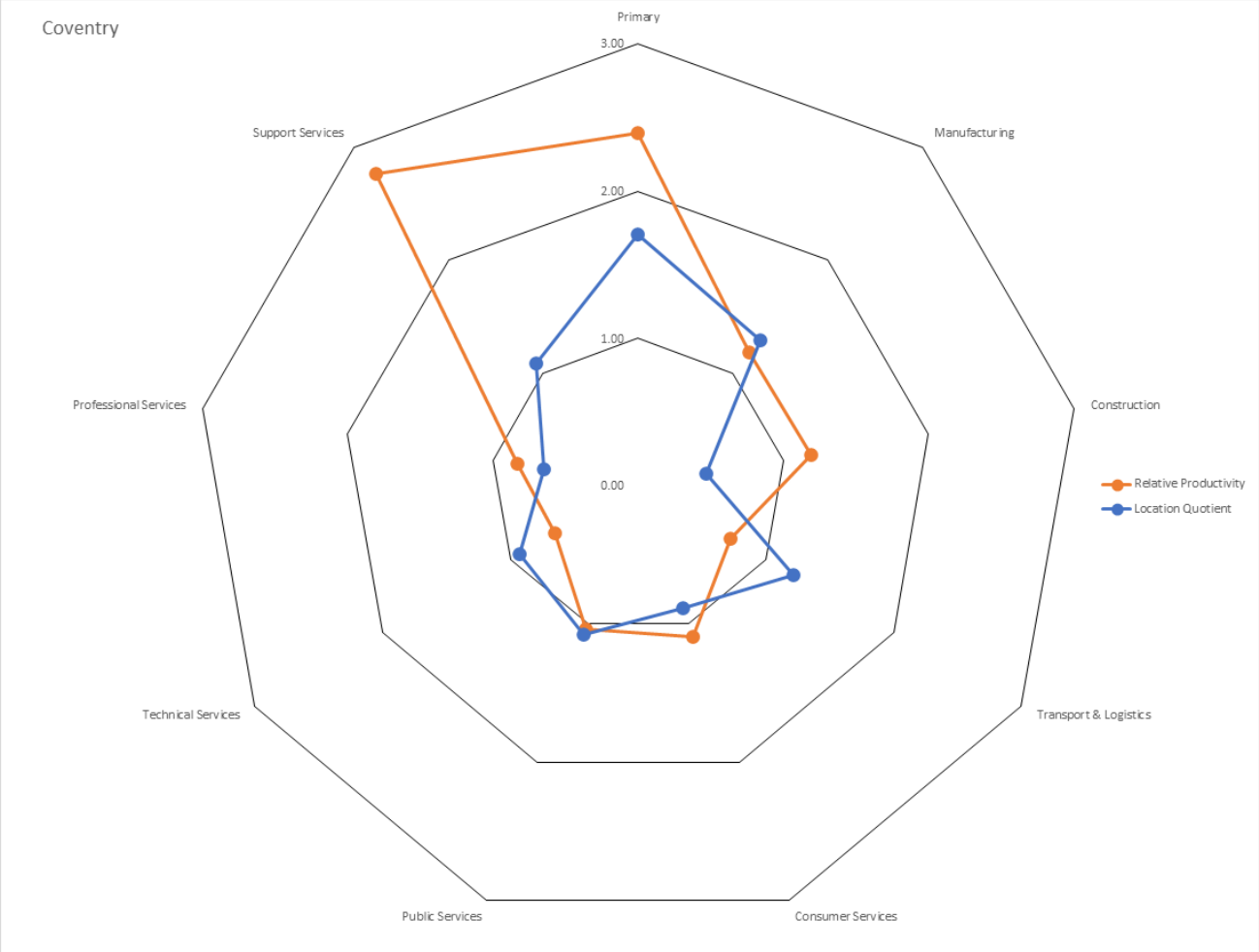
The Coventry MDC is a highly productive medium-sized polycentric urban area that consists of concentrations of economic activity around Coventry, Warwick and the University of Warwick. The largest HDC, hosts just over 51% of all high-density employment in the area. The second largest, consists of 28%. While this area is not as fragmented as Manchester, economic activity is clearly divided between physically separated subareas.

The Coventry MDC scores in the 10th decile, ranking 8th overall (four places behind Milton Keynes). Its HDC is also highly productive and ranks in the 10th decile (36th overall). These results are particularly notable as we have found that polycentric places do not experience urbanisation economies in the same way as monocentric places do, as they get bigger. It is likely that relative success is due to how synergetic and clustered they are and, as a result, we think that Coventry is successful for that reason despite its polycentricity.



The GVA/worker map shows that many of the highest decile LSOAs are on the edges of the densest parts of the area in both Coventry and Warwick. While many of these are captured within the two largest HDCs, a few to the east of Coventry anchor smaller secondary HDCs. As in other cases, there are high-productivity LSOAs outside of the HDCs, but these are mostly captured by the Coventry MDC with the exception of a few large LSOAs to the east of Warwick. The Coventry MDCZ is also surrounded by relatively large high-productivity areas to the northeast and southwest.

Coventry has six sectors with relative productivity greater than one – primary sector, manufacturing, construction, consumer services, public services, and support services. Its primary specialisms are clearly in the primary sector, manufacturing and support services sectors, with a more marginal specialism in public services. Its most significant productivity niches are in construction and consumer services. It is likely that these more significant levels of relative specialisation help explain why despite its polycentric geography, Coventry still appears to experience some non-negligible agglomeration effects.



Conclusion

While there has always been a strong urban bias in narratives about productivity and spatial inequalities, our analysis based on micro data (LSOAs) shows a much more complex picture. High productivity does not seem to be as restricted to urban areas, and nor is the performance of a city region entirely determined by the strength of its central business district alone. The link between density and productivity is less directly deterministic than often characterised – effective density matters more than physical density, and the possibility of synergy implied by economic density does not guarantee the realisation of that synergy – other factors must also fall into place.

A lot of high productivity activities are land-intensive (e.g., manufacturing and logistics) and so select away from high land-cost areas (Lowe et al 2012). This challenges the contention that productivity is solely or even essentially driven by urbanisation and density. Rather, the relationship between city cores, edge developments, and wider hinterland is one of interdependence, and the extent to which this relationship is synergetic defines the success of the region (see Burger et al 2015, Volgmann and Rusche 2020). These dynamics are more easily observed using boundaries defined by economic activities and based on microscale building blocks rather than by political jurisdictions and less granular units. This also presents a strong argument to explore the geometries of urban economies as well as to expand research on productivity beyond urban boundaries.

Where agglomeration economies appear to be strongest is within high density cores themselves. This is interesting but intuitively makes sense – HDCs tend to correspond with high density specialised cores of city centres, such as those areas populated by the most agglomeration-sensitive firms. Here, denser often does mean more productive. But outside of these cores, high productivity is probably just as likely to be on a lower density trade park or farm than in a medium density town centre.

These findings suggest that exploring economic geometries will help explain the nature of agglomeration effects and to understand where, and at what scales, they might have a significant influence. Our results support the theory that urbanisation economies were likely to be strongest in the cores of monocentric urban areas, and that dispersed or polycentric areas are more likely to be reliant on localisation economies and specialised sectoral clusters to support the highest productivity activities.

A key insight here is that our non-London cities are *about as productive as you'd expect, given their polycentric geometries and lack of dominant specialisations*. London is different not just because it is bigger but because it is monocentric in a way the majority of other large urban areas simply are not. Polycentric places do not experience urbanisation economies in the same way as they get bigger, and hence relative success is down to how synergetic and clustered they are (e.g., we think that Coventry is successful for that reason despite being polycentric). One of many questions that we cannot answer in the context of this report is about why some of the largest urban areas in the country remain polycentric, whereas others, most notably London, have developed around a single monocentric core. We suspect that this is partly a result of historic governance structures, cultural attitudes and even local rivalries; and partly a product of infrastructure and land use planning, a connection that we hope to explore in more detail in subsequent research.

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