Industrial Strategy & Industry 4.0: structure, people and place

Cecilia Wong, Wei Zheng, Andreas Schulze Baing, Caglar Koksal & Mark Baker

Spatial Policy & Analysis Lab, Manchester Urban Institute, University of Manchester

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Foreword

The persistent social and economic inequalities across the UK need to be challenged. This need is heightened by the political and economic uncertainties brought about by Brexit and the global challenges of technological and climate change. This report by the Manchester Urban Institute, University of Manchester, titled '' Industrial Strategy & Industry 4.0: structure, people and place 'is therefore very timely.

Cities and regions are increasingly taking ownership of their futures through the devolution agenda, yet deeper structural inequalities cannot be tackled by local action alone. National frameworks are needed, not least, given the lack of one for England and, more generally, because of the sectoral approach which is taken to policy.

In October 2018 I therefore launched the UK2070 Commission, an independent inquiry into city and regional inequalities in the UK. The UK2070 Commission not only aims to Illuminate the nature of these inequalities but also Illustrate the potential value of national spatial frameworks, and to identify the range of policy interventions needed to address them, including governance and fiscal instruments. The UK2070 Commission will report its findings in November 2019.

This report by the Urban Institute highlights the importance of facing up to the radical changes in the shape of the economy. As the report states, the current industrial revolution (Industry 4.0) is driven by the adoption of smart digital and cyber technologies. This requires a national spatial economic strategy if we are to harness the power economic change to the benefit of all communities.

This report has been submitted as a response to the UK2070 Commission's call for evidence. It has informed the considerations of the UK2070 Commission, especially in the drafting of its First Report, May 2019. I am delighted to see it now published as a Policy Report by the Manchester Urban Institute.

Lord Bob Kerslake

Chair of the UK2070 Commission

Because digital technology knows no borders, there are many questions that come to mind when considering the geographic impact of technology and the impact of geography on technology. What will define the roles that countries, regions and cities play in the fourth industrial revolution?

(Klaus Schwab, 2016: 71)

UK's Industrial Strategy and Industry 4.0

While UK's industrial output increased by over 40% between 1970 and 2007, its share of Gross Value Added (GVA) declined from over 32% to 12%[1]. With industrial production in continuous 'relative' decline over the last five decades, the government's publication of the 2017 Industrial Strategy (UKIS) is long-overdue. According to the GMB, the total number of manufacturing jobs has significantly reduced by 600,000 to 2.9 million since the economic downturn in 2007, which was a drop from 12% to 9.2% of total employment[2]. The revived political interest in manufacturing is a necessity as global economic leaders are preoccupied with the '4th industrial revolution' and the Germany's Federal Ministry of Education and Research even coined it as 'Industry 4.0'. Unlike the previous industrial transformation, Industry 4.0 requires a more comprehensive and holistic approach to manufacturing by focusing on machine-to-business connectivity and the partnership between manufacturing industry and service platforms.

As highlighted by the Executive Chairman of the World Economic Forum[3], the past industrial revolutions achieved major economic change by steam and water power, electricity and assembly lines, and electronic computerisation, but the latest change is about the adoption of smart digital and cyber technologies (Figure 1).

> *The changes are so profound that, from the perspective of human history, there has never been a time of greater promise or potential peril. My concern, however, is that decision-makers are too often caught in traditional, linear (and non-disruptive) thinking or too absorbed by immediate concerns to think strategically about the forces of disruption and innovation shaping our future.*

[1] PWC (2009) *The Future of UK Manufacturing*, PWC, UK. (www.pwc.co.uk/assets/pdf/ukmanufacturing-300309.pdf)
[2] www.theguardian.com/business/2018/jun/04/uk-manufacturing-has-lost-600000-jobs-in-a-decade-says-union
[3] Schwab, K. (2016) *The Fourth Industrial Revolution*, Cologny/Geneva: World Economic Forum.

(Schwab, 2016: 8)

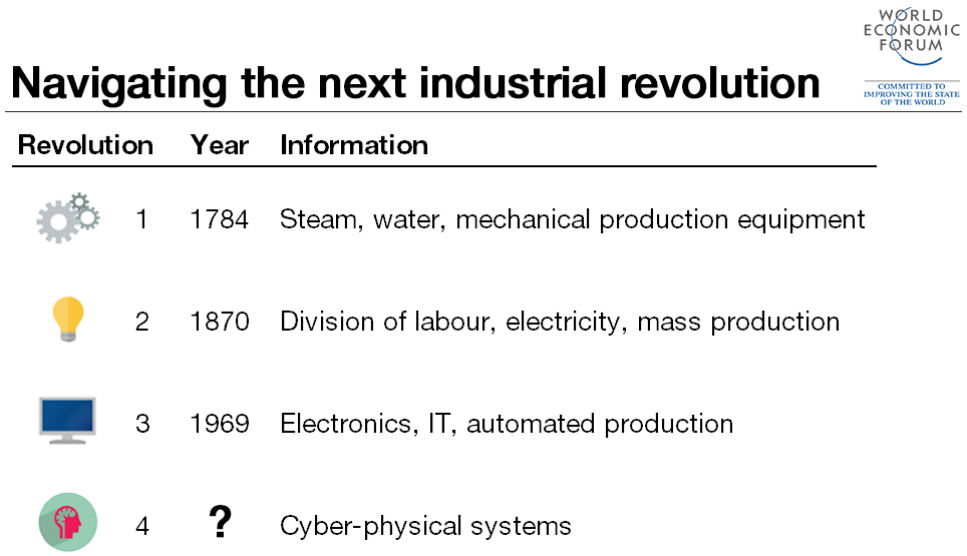

Figure 1 Drivers of the four industrial revolutions
Source: World Economic Forum[4]

The UKIS clearly focuses national attention to play a part in the global economic race by heightening the country's competitiveness, but is more ambiguous about how the strategy could reduce the severe spatial disparities that have such negative consequences for the overall economy. A more geographical balanced approach in transport and infrastructure investment is mentioned as the government's approach to the entrenched spatially imbalanced economy[5]. The successful delivery of such a national strategy would require a more joined-up approach involving a range of government departments and the public and private sector, as well as more consistency between some of the current policies that are being espoused. More importantly, there is a need to have greater sensitivity to the implication of the spatial pattern of local economic strengths and weaknesses across the country.

[4] www.weforum.org/agenda/2015/09/navigating-the-next-industrial-revolution2/
[5] HM Government (2017) Industrial Strategy: building a Britain fit for the future, London: HM Government, pp.128-129.

Only less than 10% of UK's GVA comes from traditional manufacturing. As Figure 2 shows, the GVA share of manufacturing is very much concentrated in locations outside London and the South East, whereas the total GVA share in Figure 3 exhibits the opposite pattern. Many towns and cities in northern England, being the cradle of the first industrial revolution, have experienced long term economic decline as the manufacturing industries on which their prosperity was based collapsed in the face of cheaper international competition. Eventually the provincial cities 'reinvented' themselves as high level services centres in their own right and are seen as engines of growth. Nevertheless, many former industrial towns remain the loci of concentrations of unemployment and low incomes as measured by the Index of Multiple Deprivation.

Artificial intelligence, data science and clean technology are at the forefront of the UKIS, but these sectors could be a strategy for any aspiring cities across the globe. The crux is to establish the geography of the growth of certain industrial sectors and the geography of local development potential. Locational factors[6], underpinning the exploitation of development potential, are found to be important to local economic development and improving local residents' quality of life. This report adopts a *spatial* perspective[7] to highlight the uneven geographical patterns of the required economic contexts, labour markets, skills and associated infrastructure, through mapping analysis[8], to inform the debates around the delivery of the UKIS and the UK's prospects of taking part in the fourth industrial revolution.

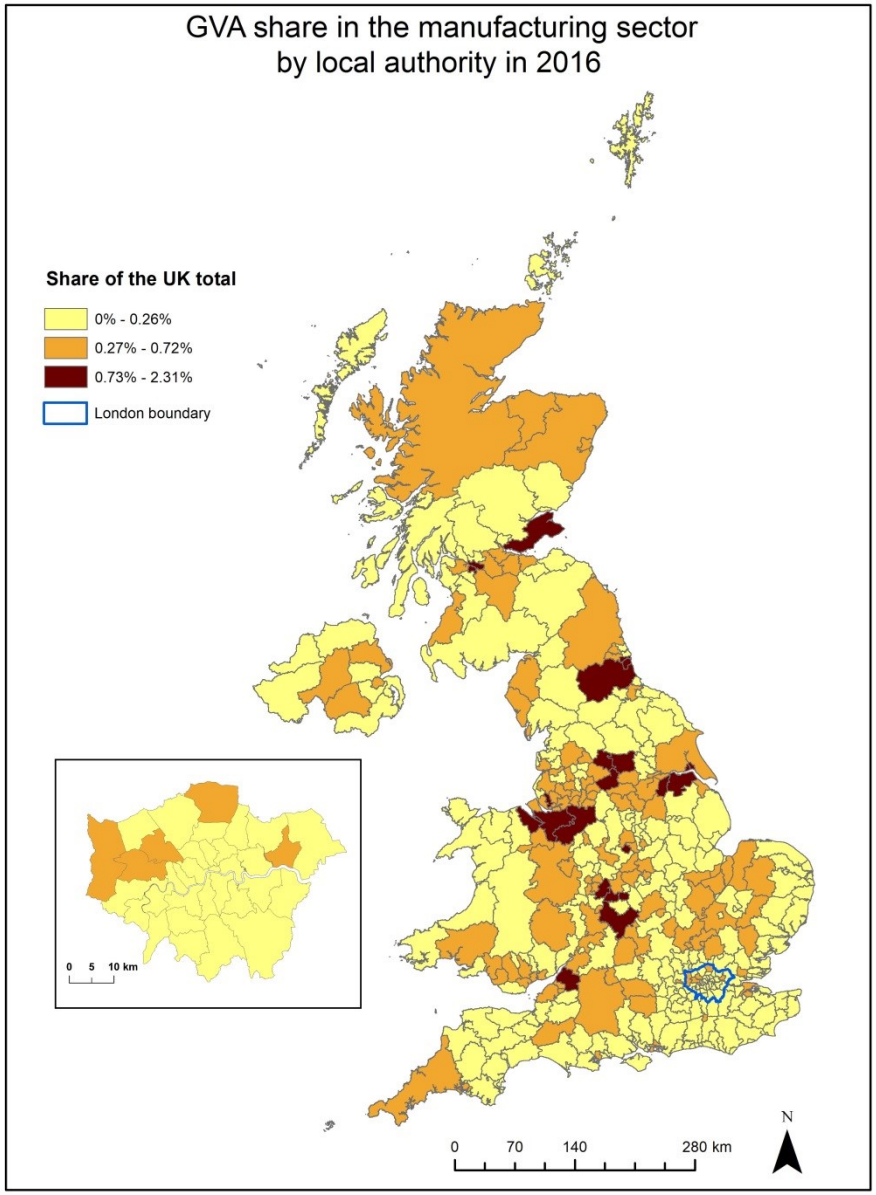

Figure 2 UK GVA share, manufacturing (£177 billion), 2016

[6] Wong, C. (2002) 'Developing indicators to inform local economic development in England', *Urban Studies*, 39 (10), 1833-1863; and Wong, C. (2001) 'The relationship between quality of life and local economic development: an empirical study of local authority areas in England', *Cities*, 18, 25-32.

[7] Due to the lack of robust small area data, the mapping analysis uses local authority district (LAD) as the basic unit to illustrate the broad spatial patterns. This means their value may be distorted by the way the administrative boundaries were drawn and thus the interpretation should take this into account and focus on the broad distribution patterns.

[8] The thematic maps were created with the use of ArcGIS software. For each variable, descriptive statistics, including mean, median and standard deviation, as well as data distribution (via histograms) were first examined. The statistical distribution analysis was then used to inform the break values of the legend categories of each map. This avoids the more mechanical mapping approach of simply adopted quartile/quintile classifications. For the commuting maps, QGIS was used to map the origin-destination flow matrix of the compiled spatial database.

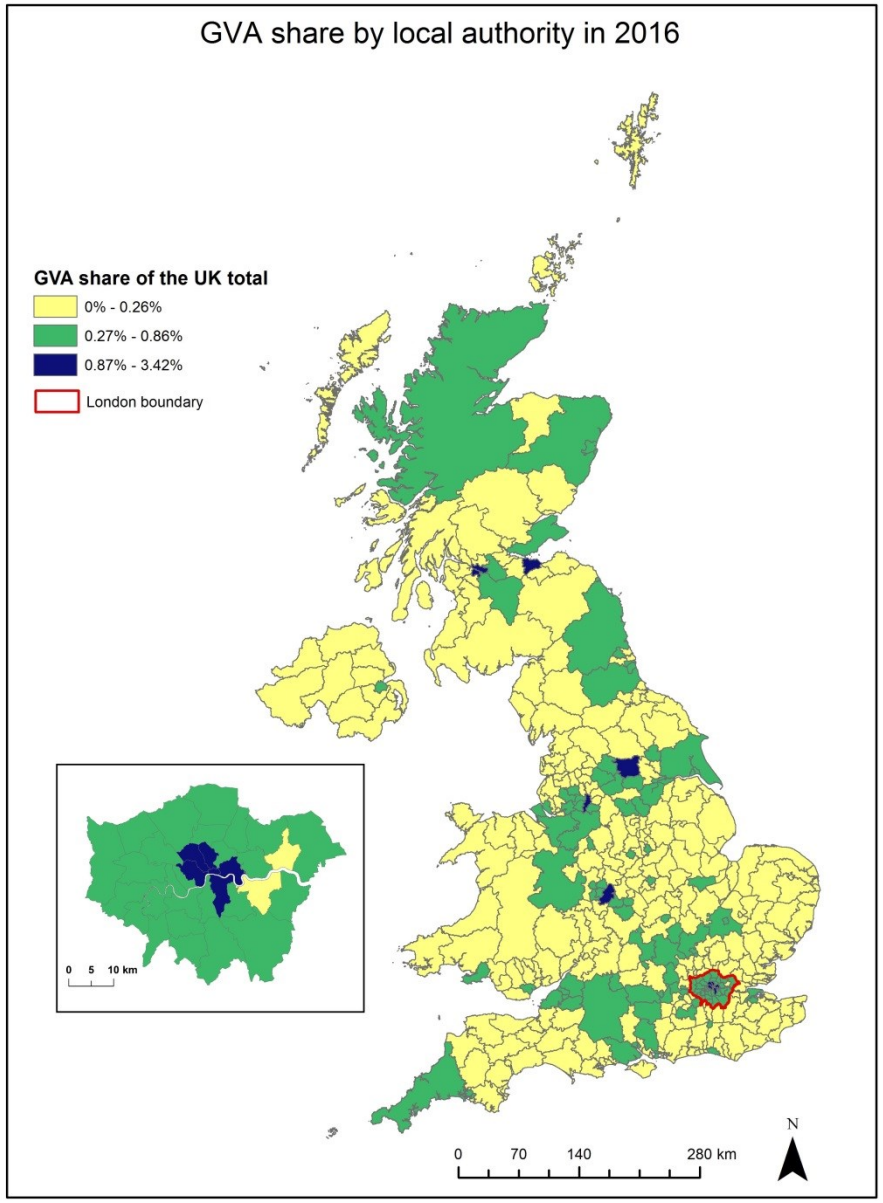

Figure 3 UK GVA share (£1,729 billion), 2016

The geography of growth

Economic development literature has highlighted the path dependency of economic development and the lock-in effects that hinder transformative changes[9]. The lock-in effects apply to market behaviour as much as to the political system. The shape of our economic growth and structure is examined via the analysis of business concentration, employment structure and GVA distribution.

Business concentration: number vs density

The high concentration of businesses in central London, both in absolute and density terms, is of a different magnitude from the rest of the country: about 37.4% of UK's businesses (5,415 per 10,000 economic active population) are found in City of Westminster, City of London, Camden and Kensington & Chelsea; whilst 10.5% (24.7 per 10,000 economic active) of UK's large businesses are found in 6 central London boroughs. Figure 4 shows the number of businesses of all sizes and that London and the core cities such as Birmingham, Leeds and Manchester are doing very well, as are some rural localities such as Cornwall and Scottish Highlands.

When examining their density patterns in Figure 5, the picture is rather different. Those areas that perform above the UK level[10] are either in the South East region, especially in central London; or in the less urban and shire areas such as Cheshire East, North Yorkshire, Devon, shire Midlands, mid Wales, the Highlands, and west Ulster. Also, none of the core cities perform above the national level, which suggests a less dynamic entrepreneurial culture. However, the spatial distribution of large businesses with 250+ employees[11] is rather different: with a clear high density belt running from central London to Swindon along the M4 corridor and a smaller concentration in Manchester-Trafford-Warrington along the M62 corridor. It is also clear that the two capital cities of Edinburgh and Belfast are homes of larger businesses, but no areas in Wales perform about the UK average. The other high performing areas are individual towns such as Peterborough, Milton Keynes, Warwick, Tewkesbury, Telford and Wrekin; as well

[9] Pike, A., Birch, K., Cumbers, A., MacKinnon, D. and McMaster, R. (2009) A geographical political economy of evolution in economic geography, *Economic Geography*, 85 (2): 175-182.
[10] UK average is 1700 businesses per 10,000 economic active population
[11] UK average of 8 per 10,000 economic active

as shire areas such as East Staffordshire, Northwest Leicestershire, North Warwickshire, and Aberdeen.

Employment structure

The concept of manufacturing is changing, with some new technical industries exhibiting a closer overlap between manufacturing and service sectors. Since Industry 4.0 is about partnership between manufacturing industry and service platforms, Figures 6-8 map the employment data (employed and self-employed) of the manufacturing, information & communication (IC), and professional, scientific & technical (PST) sectors from the Business Register and Employment Survey. Figures 9-10 provide a mapping overlay to identify areas with the largest share of employment in all three sectors (employed and self-employed).

The total number of persons employed in manufacturing was over 2.51 million in 2017, which was lower than the employment in the PST sector's 2.63 million, but higher than the 1.31 million jobs in the IC sector. The data distribution suggests that manufacturing in the UK is widely dispersed over different local authorities and even the largest share was about 1.55% in Birmingham, which was closely followed by Leeds, Bradford, Derby, County Durham, and Kirklees (over 1% share); as well as Cheshire East, Leicester, Sheffield, Sunderland, Kingston upon Hull, Sandwell, Flintshire, Coventry, Glasgow, East Riding of Yorkshire, and Wiltshire (all over 0.7% share).

The distribution of the IC and PST sectors has a cliff edge around central London; with Westminster and the City of London taking 8.7% of the UK share of IC jobs and 9.6% of all PST employment. Other strong performing areas in the IC sector include Camden, Islington, Tower Hamlets, Southwark, Hounslow, Leeds, Hammersmith & Fulham, Glasgow, Manchester, Edinburgh, Bristol, Kensington & Chelsea, Hackney, Wokingham, Birmingham, and Reading (over 1%); and Cardiff, West Berkshire, Belfast, Lambeth, Milton Keynes, Bracknell Forest, Nottingham, and Salford (over 0.7%). Areas with high shares of PST employment are Camden, Southwark, Leeds, Birmingham, Islington, Manchester, Tower Hamlets, Glasgow, Edinburgh, Bristol, and Aberdeen (1% and above); and Cheshire East, Sheffield, Warrington, Hackney, Trafford, South Cambridgeshire, Watford, Wiltshire, Cheshire West & Chester (0.7%).

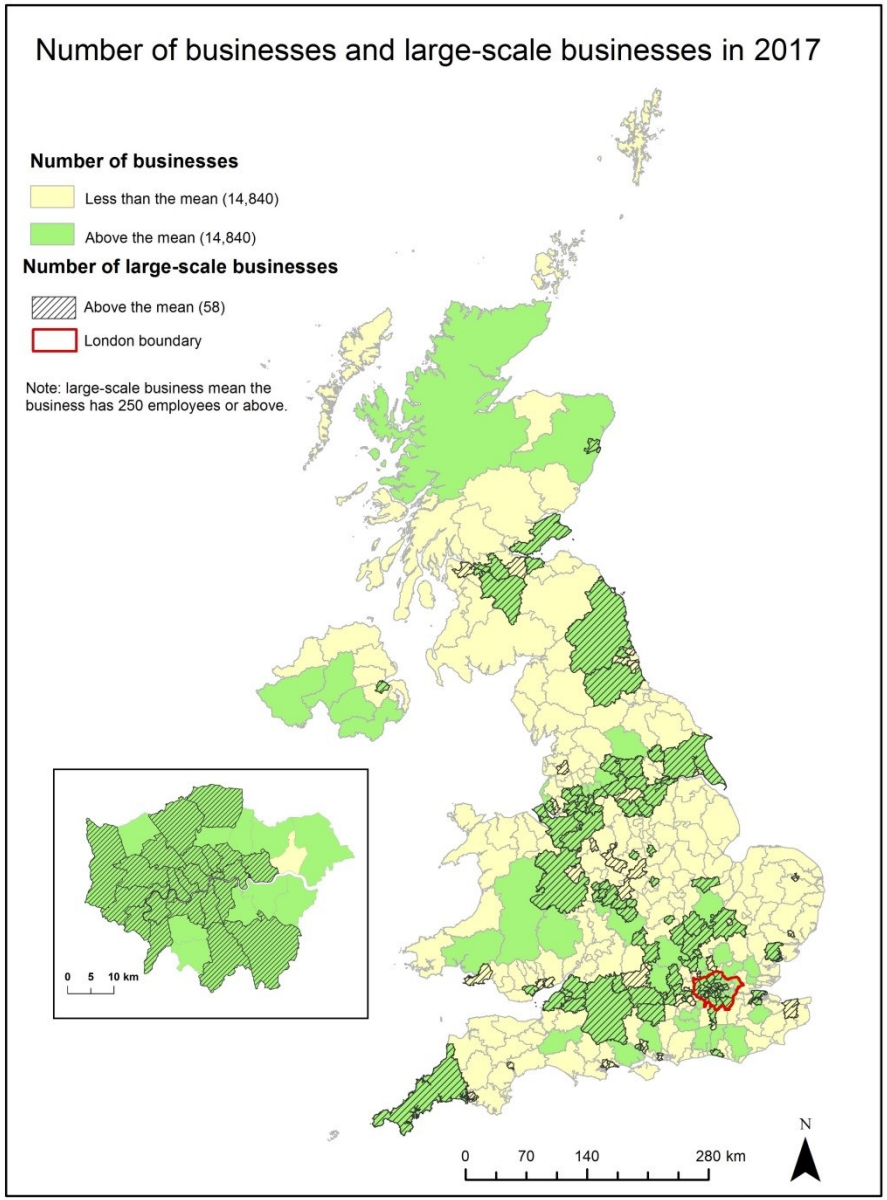

Figure 4 Number of businesses in the UK, 2017

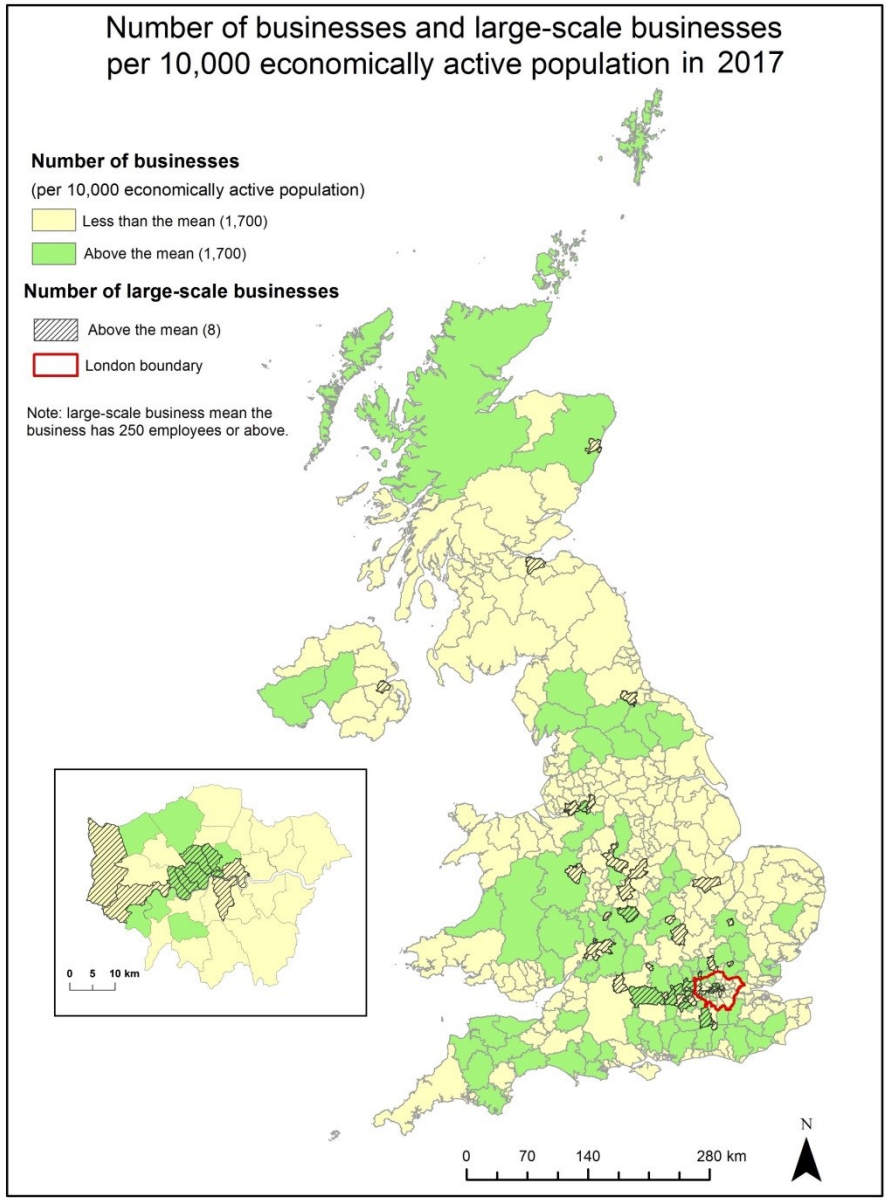

Figure 5 Density of businesses in the UK, 2017

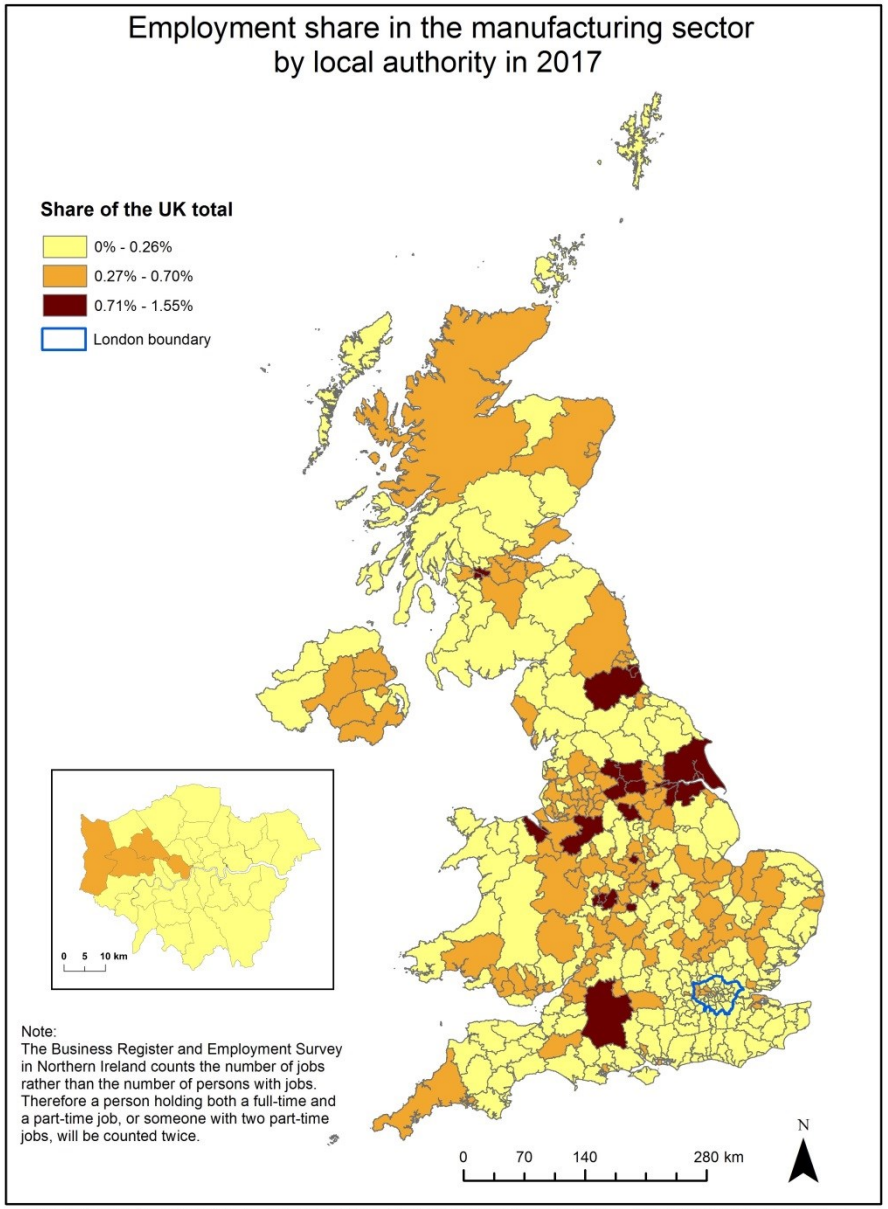

Figure 6 UK manufacturing employment share, 2017

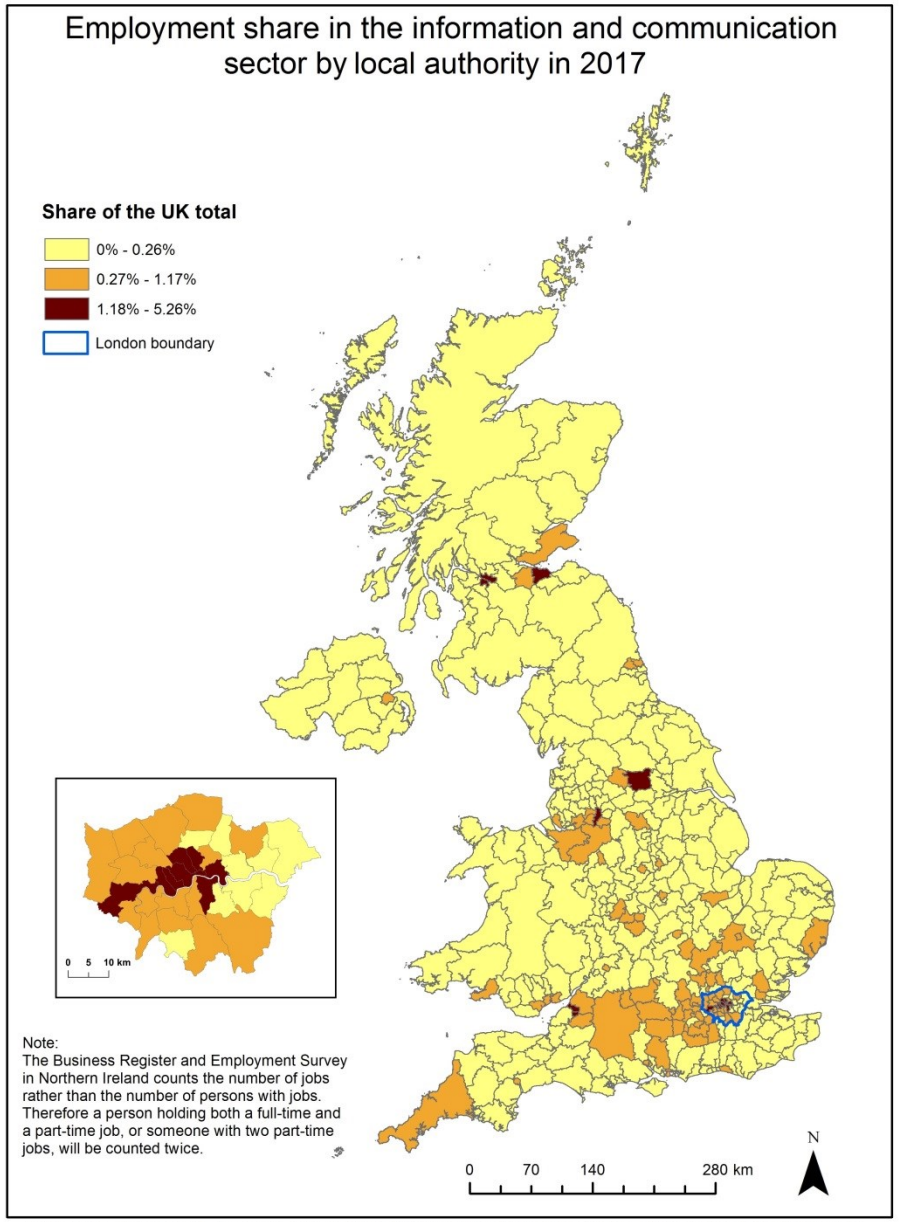

Figure 7 UK information & communication employment share, 2017

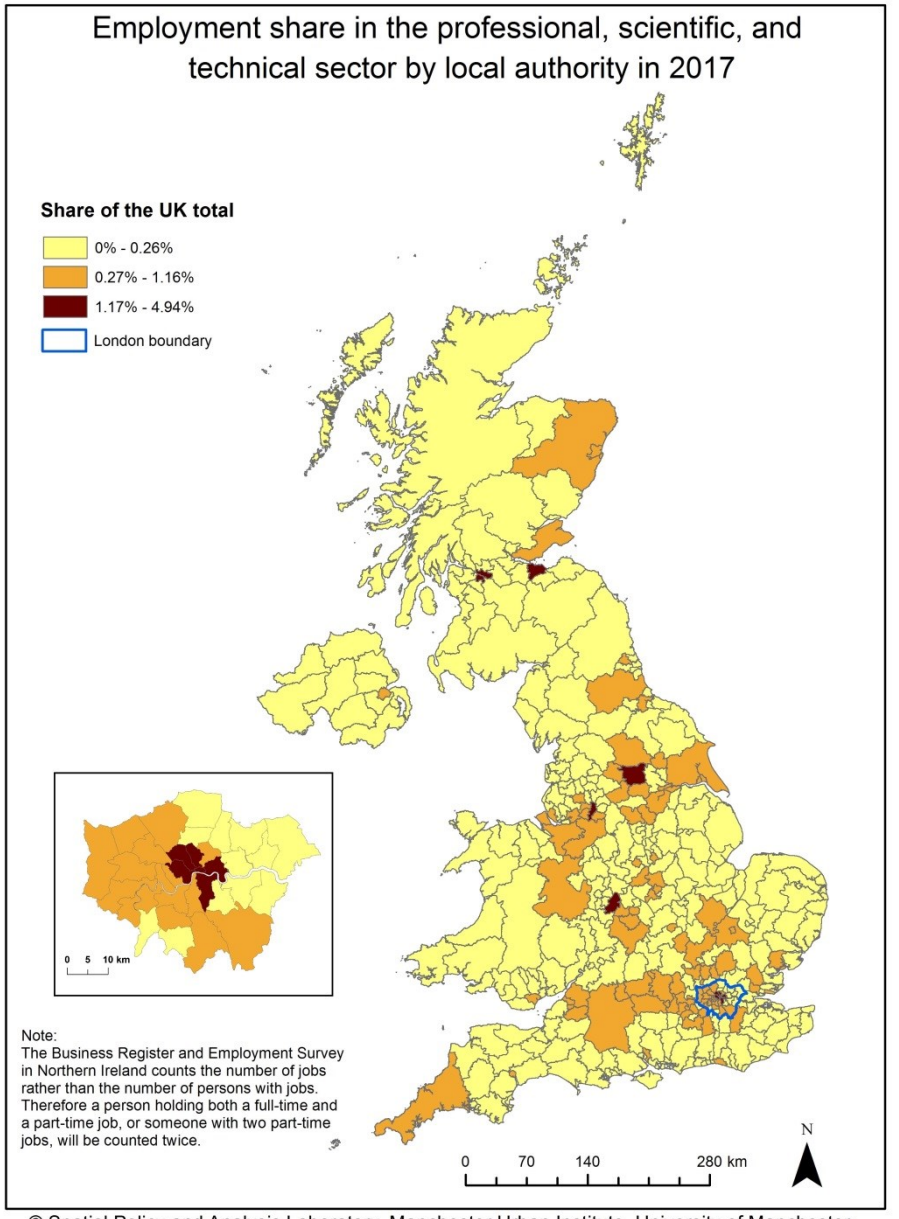

Figure 8 UK professional, scientific & technical sector employment share, 2017

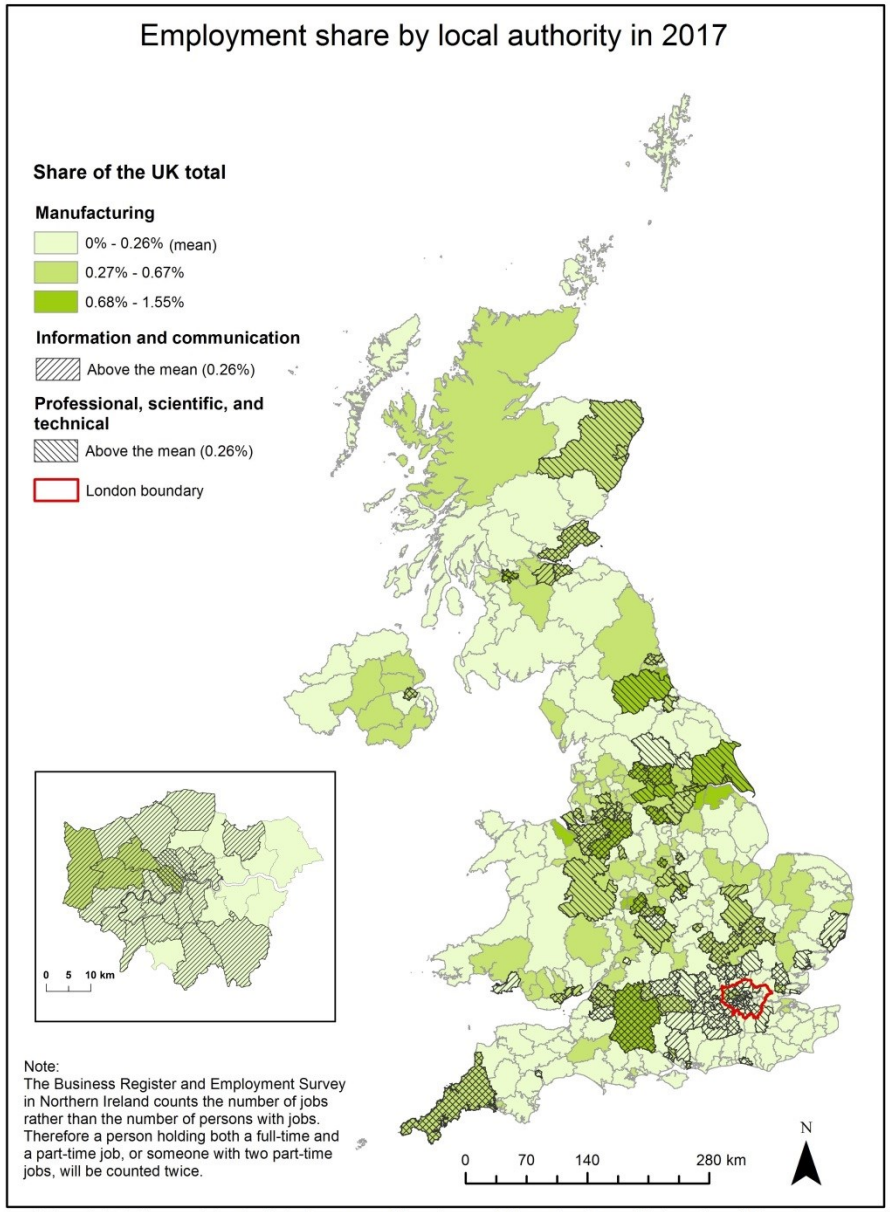

Figure 9 Above average UK employment share of manufacturing, IC and PST sectors

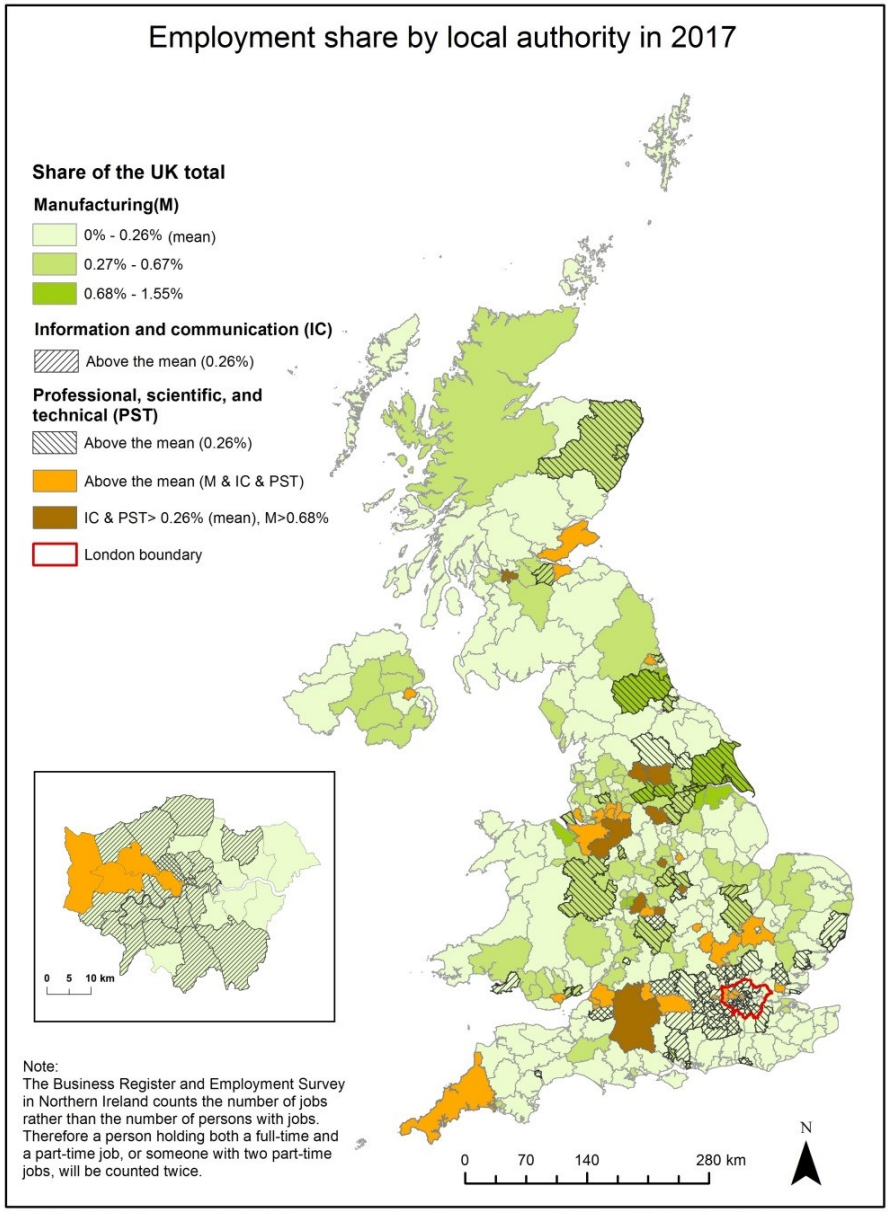

Figure 10 High share of manufacturing and above average IC and PST sectors

Areas that have larger shares of manufacturing employment (top 5% LADs) and have above average employment levels in the IC and PST sectors are: Leeds, Birmingham, Glasgow, Cheshire East, Wiltshire, Sheffield, Bradford, Coventry, Leicester and Derby. It is, however, important to note that most of London and the South East region has a high concentration of IC and PST sectors; but has a below average share of manufacturing employment. By focusing on areas with above average shares of employment in all three sectors, a number of spatial clusters emerge in Figure 10: the Central Belt in Scotland; the West Yorkshire cluster; the Mersey Belt and Cheshire; and the M4 corridor.

An extra dimension is added by examining the broad spatial distribution of life sciences companies in the UK[12]. It is clear that there is the so-called golden triangle with over 2,000 firms clustering London, Cambridge and Oxford (see Figure 11). There is a major cluster in coastal areas of south Wales running from Cardiff to Swansea; followed by a cluster around Cheshire-Runcorn-Liverpool-Manchester; a cluster around the Scottish central belt; and another one around Nottingham-Coventry-Loughborough-Leicester area.

Figure 12 maps the UK share of life science companies at the LAD level, the dominance of the southeast England around the golden triangle and the M4 corridor is clearly evident. There are four highly concentrated cluster hubs: the City of Westminster/City of London (10.2%), Cambridge/South Cambridgeshire (8.6%), Oxford/Vale of White Horse (6.5%); and Cardiff (2.7%). Another key feature that emerges from Figure 12 is the importance of cities for the location of life sciences companies: Edinburgh (1.5%), Manchester (1.4%), Nottingham (1.3%), Belfast (1.2%), Birmingham (1.1%) and Glasgow (1%). It is important to note that some shire areas are also performing very well such as Cheshire (Cheshire East & Chester and Cheshire West, 1.2%), mid Wales (Ceredigion and Powys, 0.7%), and Dumfries & Galloway (0.7%).

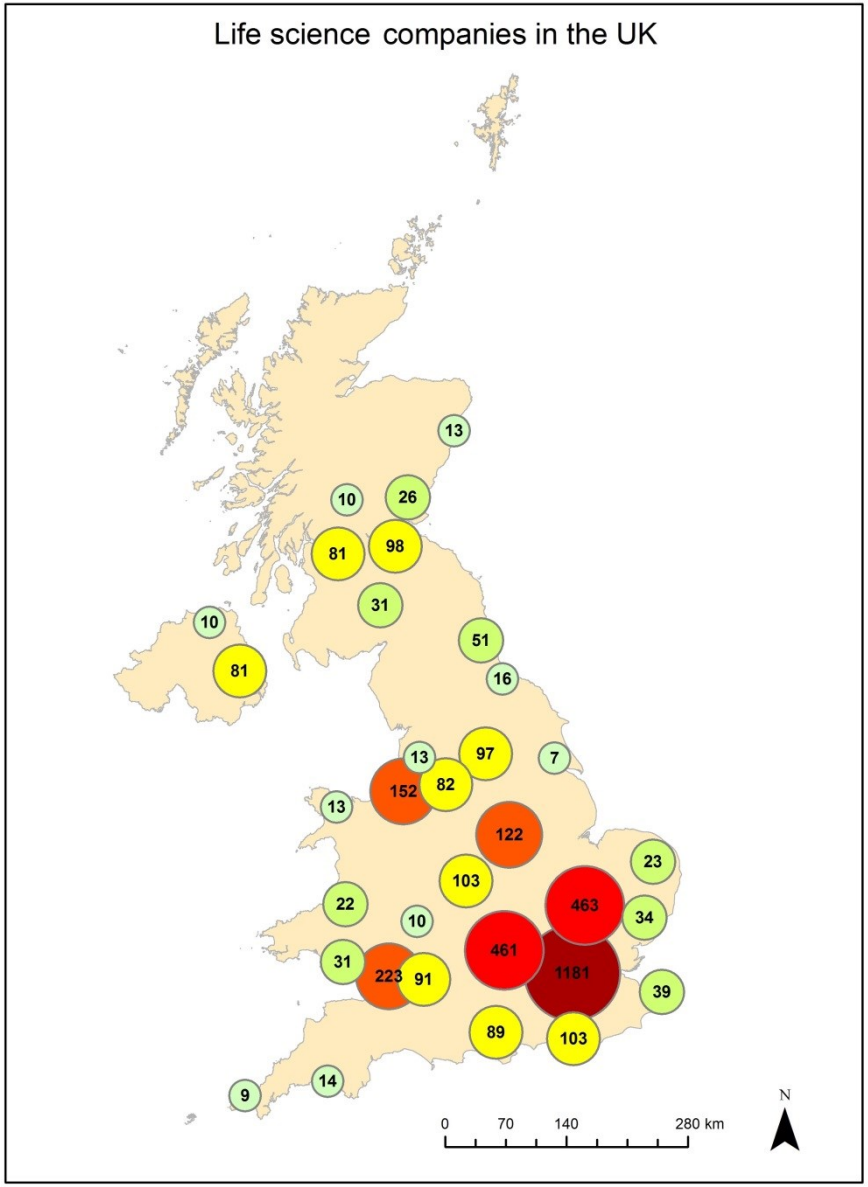

Figure 11 Number of life science companies in the UK

[12] UK Biotech Database: www.ukbiotech.com/uk/portal/index.php

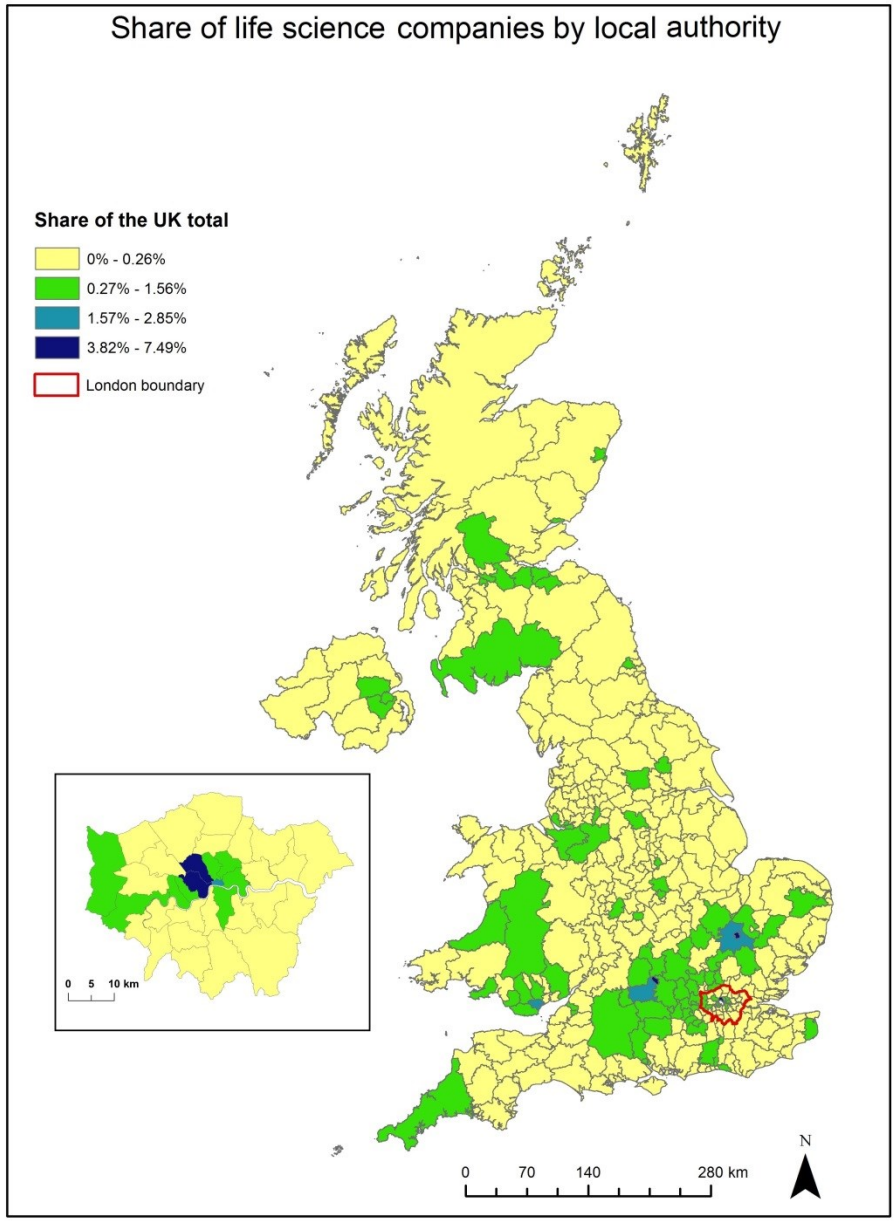

Figure 12 Share of UK life science companies

Labour market conditions

Different labour market conditions will shape the trajectories of economic growth in the era of industry 4.0. Areas with a rapidly growing workforce can reap the demographic dividend if the market is buoyant; whereas economic growth in areas with an ageing or shrinking workforce has to be derived from productivity increase. With the advance of digital and automation technology, there is a rising concern of major job losses. As highlighted by a McKinsey Global Institute report[13], about 14% of the global workforce may be displaced by automation and need to be reemployed.

> *In advanced economies, occupations that currently require only a secondary education or less see a net decline from automation, while those occupations requiring college degrees and higher grow.*
>
> *The skills and capabilities required will also shift, requiring more social and emotional skills and more advanced cognitive capabilities, such as logical reasoning and creativity.*
>
> *(McKinsey Global Institute, 2018: 5)*

It is, therefore, critical to embrace the changes and undergo the transition by having an educated and adaptable workforce that is ready to acquire new skills involving emotional intelligence and cognitive flexibility. During the transition, it is important to have a dynamic labour market with good labour mobility to avoid skills mismatch.

Job density, pay and economic activities

Figure 13 shows the job density across different parts of the UK, with 1.0 indicating a balance between the number of jobs and the number of resident population of economically active age (16-64). Only 58 out of 391 local authorities have more jobs than their economic active aged population: nearly half of them are in London and the South East regions along the M4 corridor; and the rest are scattering around the country including some large cities outside the South East (e.g. Manchester, Nottingham, Glasgow, Newcastle, Edinburgh and Bristol) as well as some shire areas (e.g. North Warwickshire, West Dorset, North Devon and Shetland Islands).

[13] McKinsey Global Institute (2017) Jobs lost, jobs gained: what the future of work will mean for jobs, skills, and wages - https://www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-mean-for-jobs-skills-and-wages#part5

The City of London, the primary central business district of London, stands out from the rest of the country as there are over 125 jobs per population capita. There are also major variations in the average pay levels across the UK: of the ten local authorities with average pay levels over £40K per annum, all but one (Copeland) are inner London boroughs (Figure 14). The average pay levels are higher in London and the South East authorities, followed by those in the Central Belt of Scotland, Harrogate and West Yorkshire; the Mersey Belt and Cheshire; and the West Midlands and Warwickshire.

Labour market dynamics is examined by mapping the economic activity rate and unemployment rate. Of the 20 local authorities with economic activity rates over 69% (Figure 15), eleven are London boroughs, three are in the South East (Brighton & Hove, Cambridge, and Oxford), and only five are outside London and the South East (Manchester, Glasgow, Nottingham, Edinburgh, and Aberdeen). The unemployment rate of the UK in February 2019 stands at 2.3%, but this masks a wide range across different local authorities from 0.5% (Hart) to 6.9% (Hartlepool).

Besides some London boroughs and some coastal areas, the general picture in Figure 16 shows that the northern regions tend to have higher unemployment rates. Local authorities with unemployment rates of 4% and over are clustered in the North East (Hartlepool, South Tyneside, Middlesbrough, Newcastle upon Tyne, Sunderland, Gateshead, and Darling); Scotland (North Ayrshire, East Ayrshire, Inverclyde, Dundee City, and Clackmannanshire); the North West (Burnley, Blackpool, Blackburn with Darwen, Oldham, Knowsley, Halton, Hyndburn, Manchester, and Rochdale); and the West Midlands (Birmingham, Wolverhampton, and Dudley).

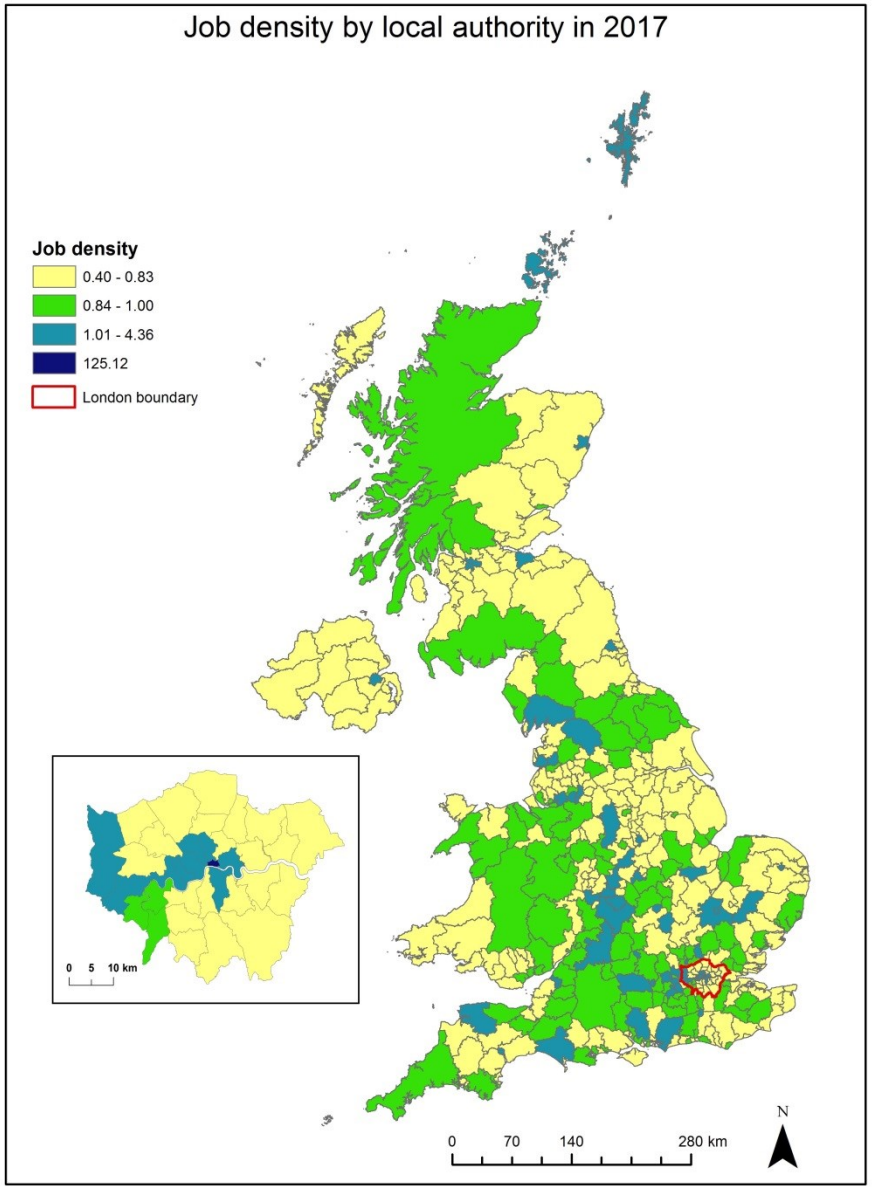

Figure 13 Job density: jobs to 16-64 population, 2017

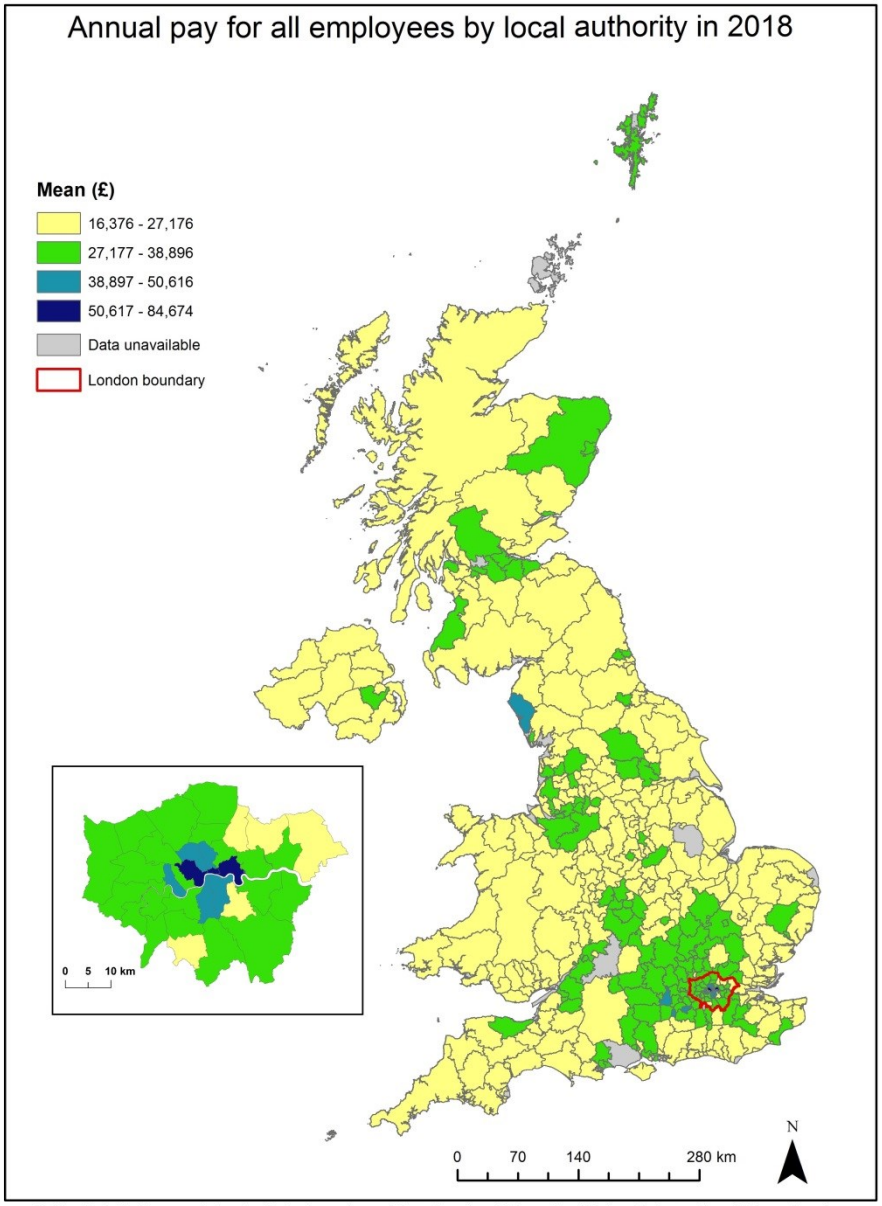

Figure 14 Average annual pay to employees, 2018

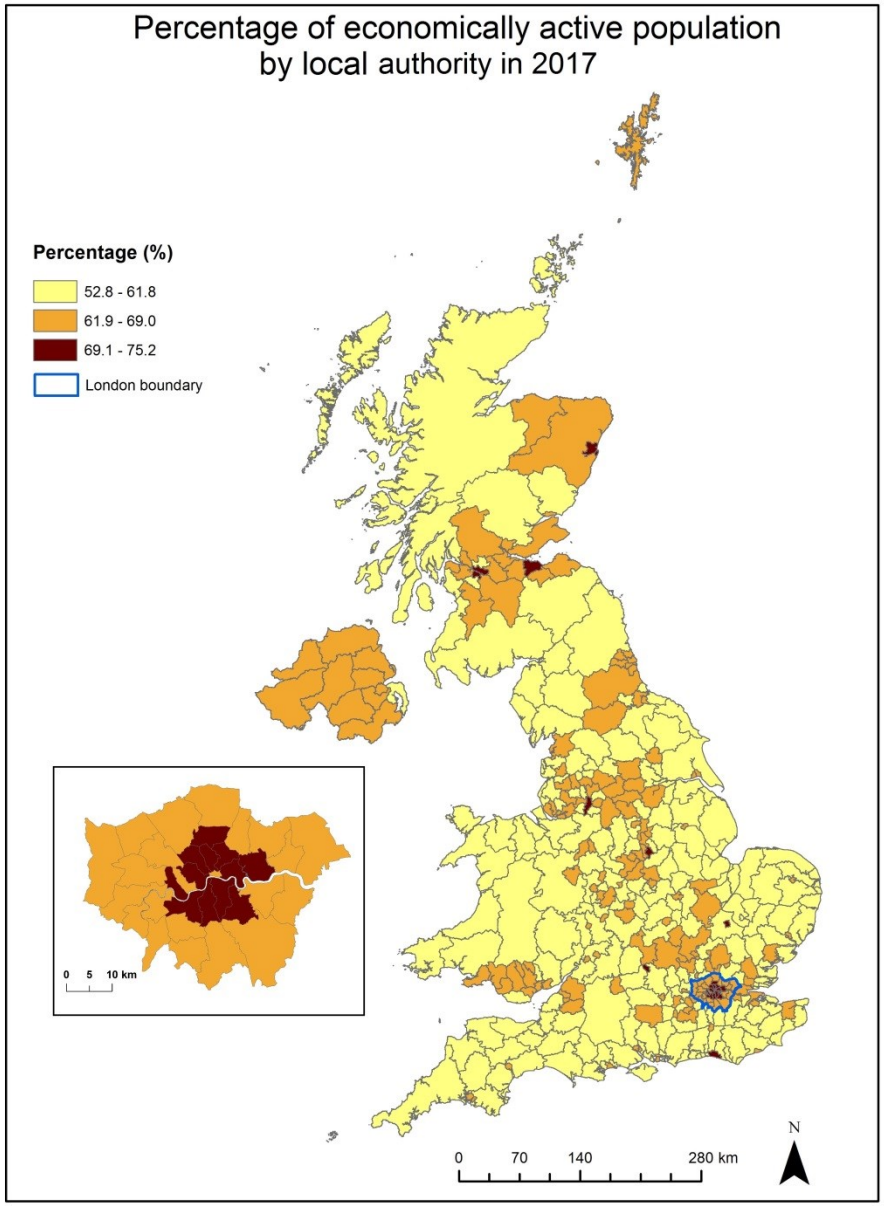

Figure 15 Percentage of economically active population, 2017

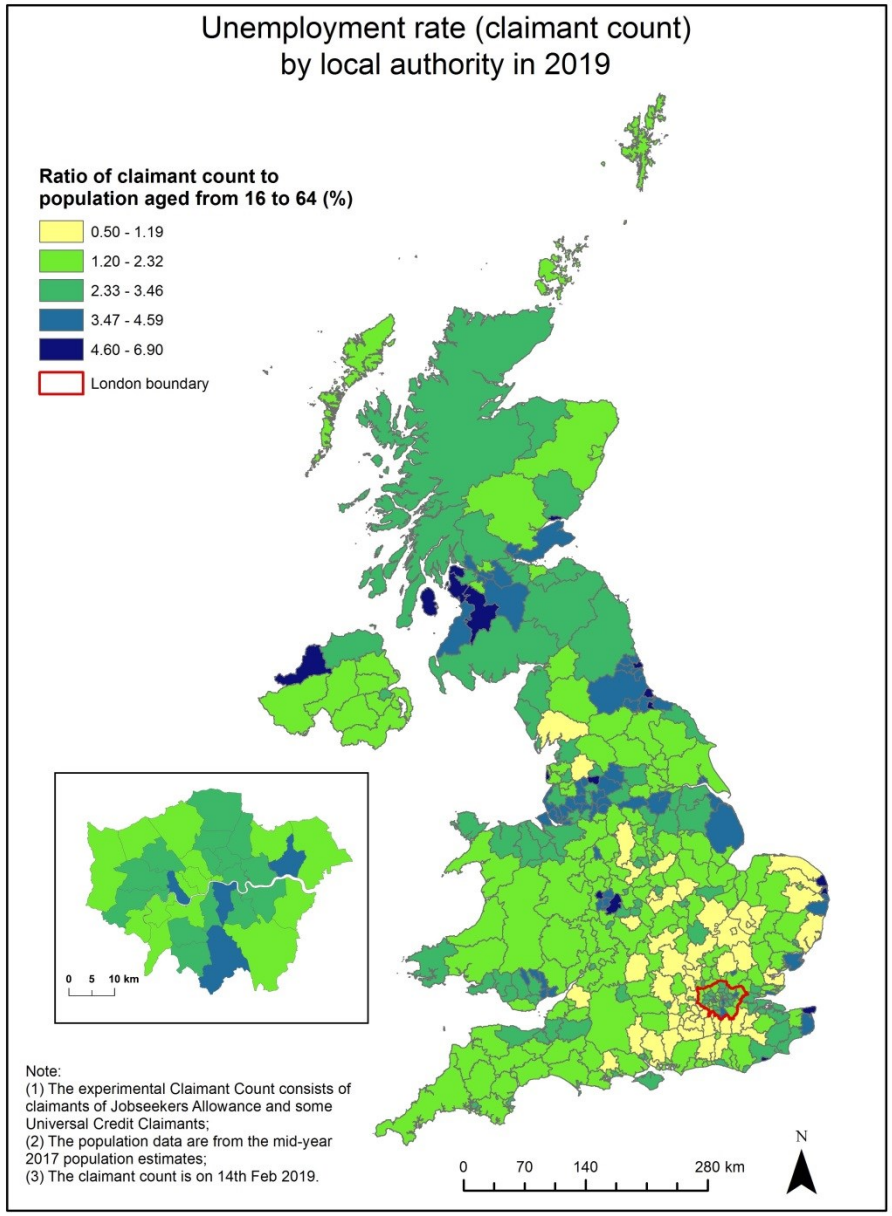

Figure 16 Unemployment rate, February 2019

Labour supply: quantity and quality

With the advance of digital technology and the move towards automation, a dynamic labour market is not just about quantity but also about quality for a well-adapted workforce. Figure 17 maps projected population change figures between 2014 and 2039 and shows that there is a broad Severn-Trent divide with areas to the south of the line having high projected population growth, especially in London and the South East. Across the UK, there is a projected growth of 11% over the 25-year period, but with wide variations ranging from 40% projected growth in Tower Hamlets to a 20% decline in the City of London.

The picture of workforce quality shows similar, but more diverse, patterns. Nationally, only 41.5% of workforce aged 16-64 has achieved at least level 4 of National Vocational Qualification (NVQ)[14] and only 72 out of 391 local authorities exceeded the 50% threshold. The City of London has the largest proportion of qualified workforce (91%), followed by ten other London boroughs (all with over 70%). As shown in Figure 18, local authorities in London and the South East tend to have a larger proportion of the workforce with NVQ4+. Outside London, local authorities in Scotland and core cities tend to have higher than the UK average level of qualified workforce. Local authorities in Cheshire, North Yorkshire, Warwickshire, Northamptonshire and coastal areas in Dorset and Devon are also performing above the national average level.

Home-work relationship: commuting patterns

Commuting patterns capture very complex socio-economic relationships between home-work locations which are manifested in spatial flows[15]. The geographical mobility of labour does not simply entail the movement of individuals between two locations but is dependent on the willingness of the entire household to relocate[16]. There has been a shift in the labour market towards 'flexible' practices, which is coupled by a parallel trend of a 'roots' effect in which households choose a fixed residential base and cope with job changes by commuting.

[14] NVQs are awarded at six different levels based on practical skills; with level 6 equivalent to a Bachelor's degree, while level 4 equates to the first of a Bachelor's degree.

[15] Hincks, S. and Wong, C. (2010) The spatial interaction of housing and labour markets: commuting flow analysis of North West England, *Urban Studies*, 47 (3), 629-649.

[16] Breheny, M. (1999) Introduction, in: M. Breheny (Ed.) *The People: Where Will They Work?* Town and Country Planning Association, London, pp.1-8.

Figure 19 shows the broad commuting flows of the four countries in the UK, though it is important to point out that the commuting flows are based on different datasets and definitions[17] and do not show cross-country flows. For more detailed analysis, the complex commuting flow patterns across different parts of England and Wales are mapped in Figure 20a. It highlights the continuous dominance of the super-London functional labour market area, stretching over 60km from central London to the surrounding South East, which was coined as the 'London eye' effect in the 2006 RTPI report[18]. This map also identifies the spatial connections across different localities, especially around core cities and major towns.

Researchers at Manchester University[19] have classified commuting flows by different socio-economic traits of workers. More qualified workers, engaged in higher level employment, tend to commute further afield as shown by the different commuting patterns of those with 'blue collar traits' and the 'high flyers' in Figures 20b and 20c. However, the commuting flows of the 'tech and city type' (in Figure 20d) exhibit the extreme long commuting journeys and the very interesting patterns radiating mainly from London, Birmingham, Manchester and Leeds, which reminds us the route of the proposed HS2 rail line which will further strengthen the spatial connectivity of these main centres.

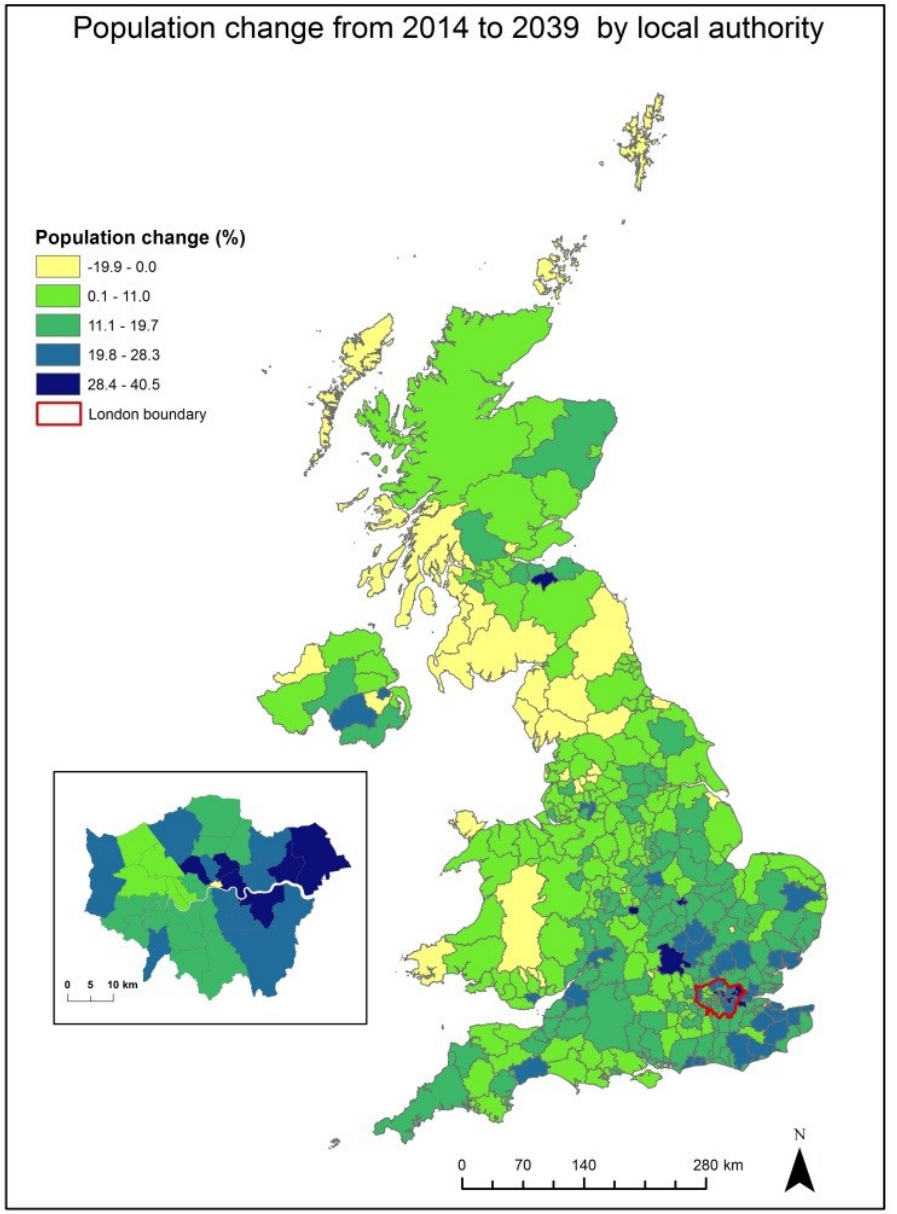

Figure 17 Projected population change, 2014-2039

[17] Since flows in Scotland and Northern Ireland are at the local authority district level, so the locational accuracy is rather low because some rural district is rather large in area and its centroid is used to plot the flows; which differ from flows in England and Wales that based on very localised Super Output Areas.

[18] Wong, C., Schulze Baing, A. and Rae, A. (2006) *Uniting Britain: the evidence base—spatial structure and key drivers,* Royal Town Planning Institute, London.

[19] See the interactive portal: http://www.commute-flow.net/ and Hincks, S., Kingston, R., Webb, B. and Wong, C. (2017) A new geodemographic classification of commuting flows for England and Wales, *International Journal of Geographical Information Science*, 32, 663–84.

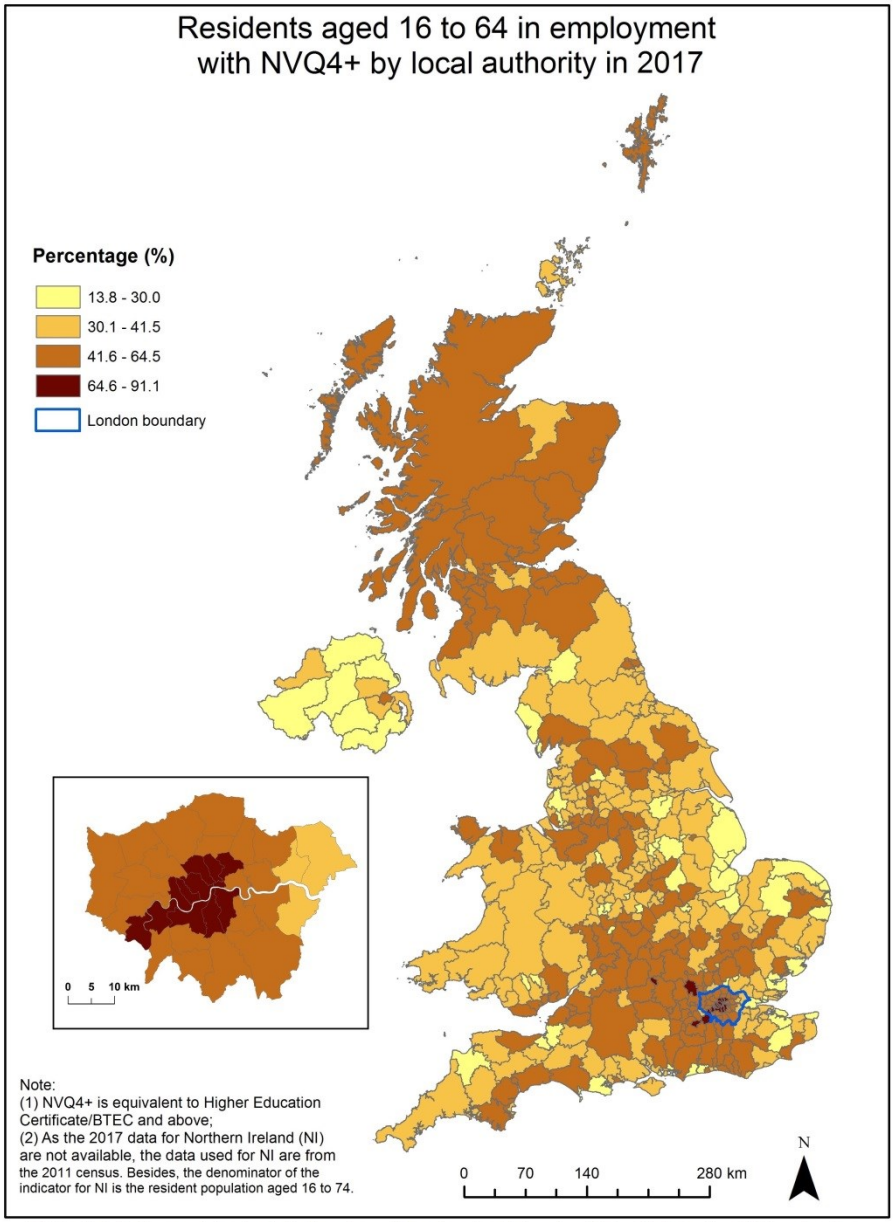

Figure 18 Qualifications of workforce aged 16-64, 2017

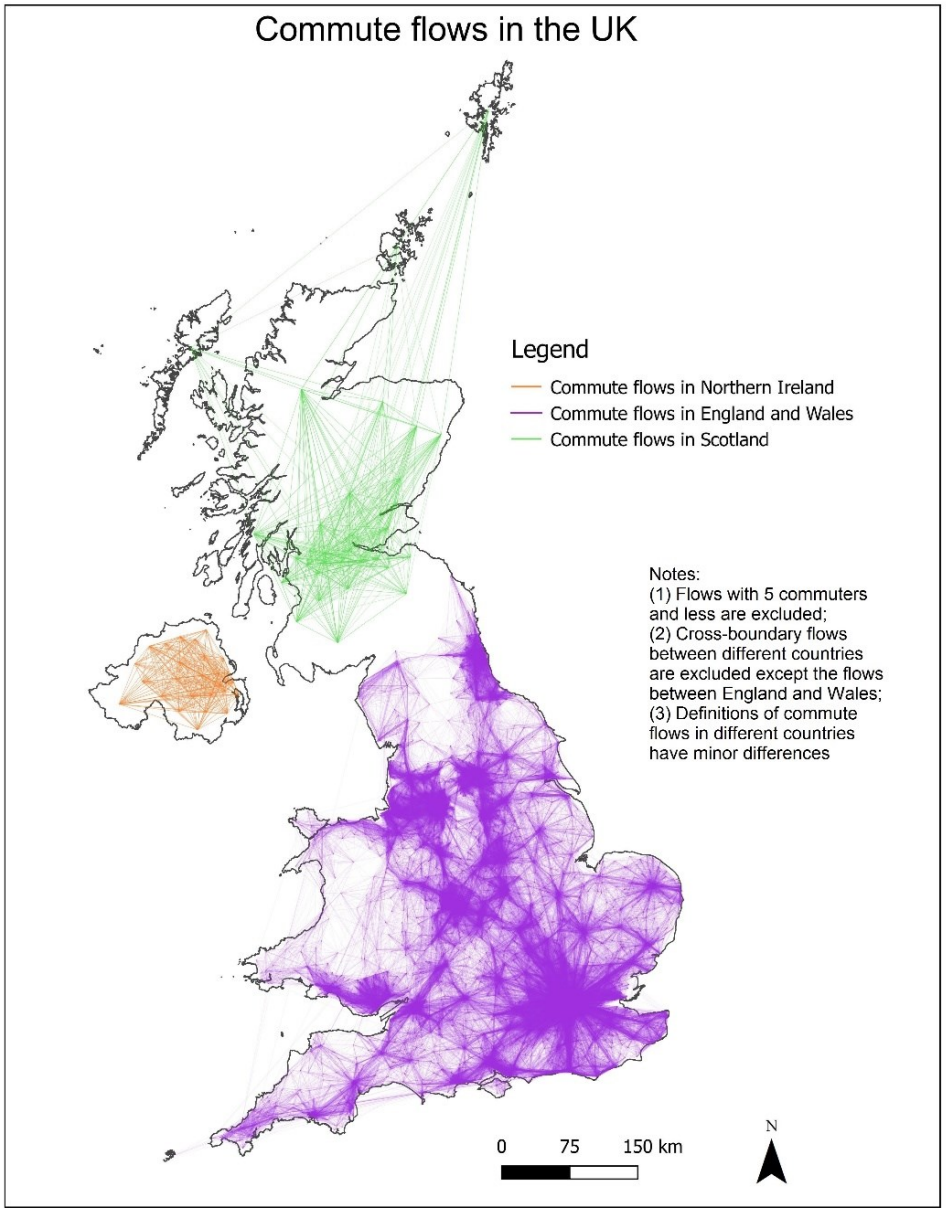

Figure 19 Commuting flows in the UK, 2011

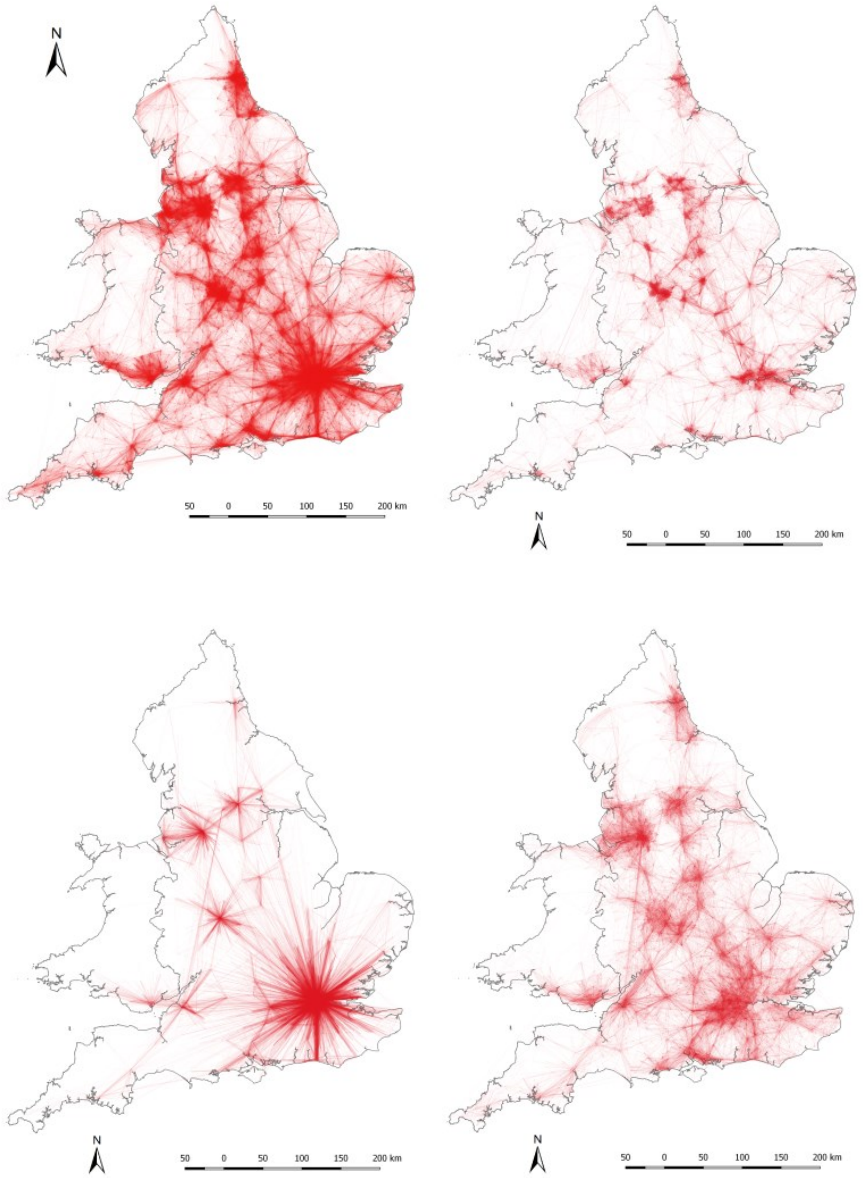

Figure 20 Commuting flows: (a) all; (b) Blue Collar Traits; (c) High Flyers; (d) Tech and City Type (clockwise from top left hand corner)

Drivers of economic productivity

The stagnation of UK's productivity since the 2008 economic downturn has attracted different assessments and explanations. The uneven distribution of workforce skills and the highly centralised economy with differential regional economic performance are identified as the key factors that play a part in the productivity puzzle that *'the gap between the least and most productive areas is larger than at any point since 2004'*[20]. Andy Haldane, the Bank of England's chief economist, pointed to the unusually long tail of 'unproductive' companies with poor management practices that are slow to adopt new technology[21]. This links to the widely held argument that a chronic lack of R&D expenditure has resulted in UK's low R&D intensity and slow productivity growth[22].

R&D expenditure and research capacity

As measured by gross expenditure on research and development (GERD), UK spent £34.8 billion on R&D in 2017 (1.69% of GDP). UK's 1.69% was below the European Union's 2.07%[23]. The UK's performance is 15 years behind the EU-28's 1.79% in 2002 and is struggling to achieve the EU's 2020 target of reaching at least 3.0%. As pointed out by Eurostat (see Figure 21), 'the EU's R&D intensity is still lagging behind other advanced economies, such as the United States, Japan and South Korea, with only the best performing Member States surpassing the United States'[24].

Within the UK, there are major variations in R&D expenditure across the four countries: England spending £554, Scotland £466, Northern Ireland £371 and Wales £238 per capita in 2017[25]. As shown in Figure 22, there is a clear southeast and eastern bias in GERD: with the South East (19.34%), East of England (17.06%) and London (15.94%) accounting for over half of the UK's R&D expenditure (£18.2 billion). On the other end of the spectrum, the North East (1.81%), Northern Ireland (1.99%), and Wales (2.13%) together only spent under 6% of

[20] https://blog.ons.gov.uk/2017/12/07/our-productivity-puzzle/
[21] https://www.ft.com/content/f5e074ae-9734-11e8-b67b-b8205561c3fe
[22] https://www.businessinsider.com/uks-productivity-puzzle-and-the-lack-of-rd-spending-2016-12?r=US&IR=T
[23] https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/ukgrossdomesticexpenditureonresearchanddevelopment/2017
[24] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Europe_2020_indicators_-_R%26D_and_innovation#General_overview
[25] https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/ukgrossdomesticexpenditureonresearchanddevelopment/2017

the UK total. Figure 23 maps Eurostat's estimated 2016 figures for NUT2 regions for more refined spatial analysis. It is clear that the lion's share (35%) of UK's R&D expenditure was taken up by three areas: Great London (14.97%); Berkshire, Buckinghamshire & Oxfordshire (10.91%); and East Anglia (9.19%).

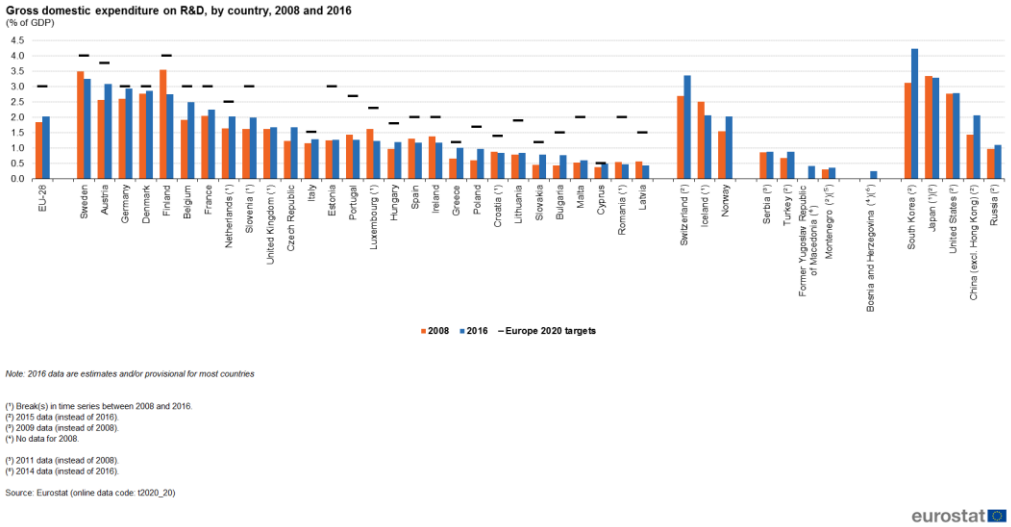

Figure 21 GERD of EU countries, 2008 and 2016

The significance of sectoral share of R&D activities nevertheless varies widely in different regions in 2017 (see Figure 22). Of the three highest spending regions, the business sector is found to dominate the East of England (78.76%) and the South East (72.21%), which contrasts sharply with the situation in London where the higher education sector (35.72%) and the government & research councils (8.06%) constitute over 43% of its total spend. The business sector is also found to be the predominant sector in the West Midlands (83.2%), East Midlands (78.48%), Northern Ireland (73.78%), North West (72.74%), and South West (70.78%). Similar to Germany and the USA, the business sector forms over two-thirds (68.05%) of UK's R&D expenditure. It is, however, interesting that London's R&D expenditure does not conform to the expected patterns.

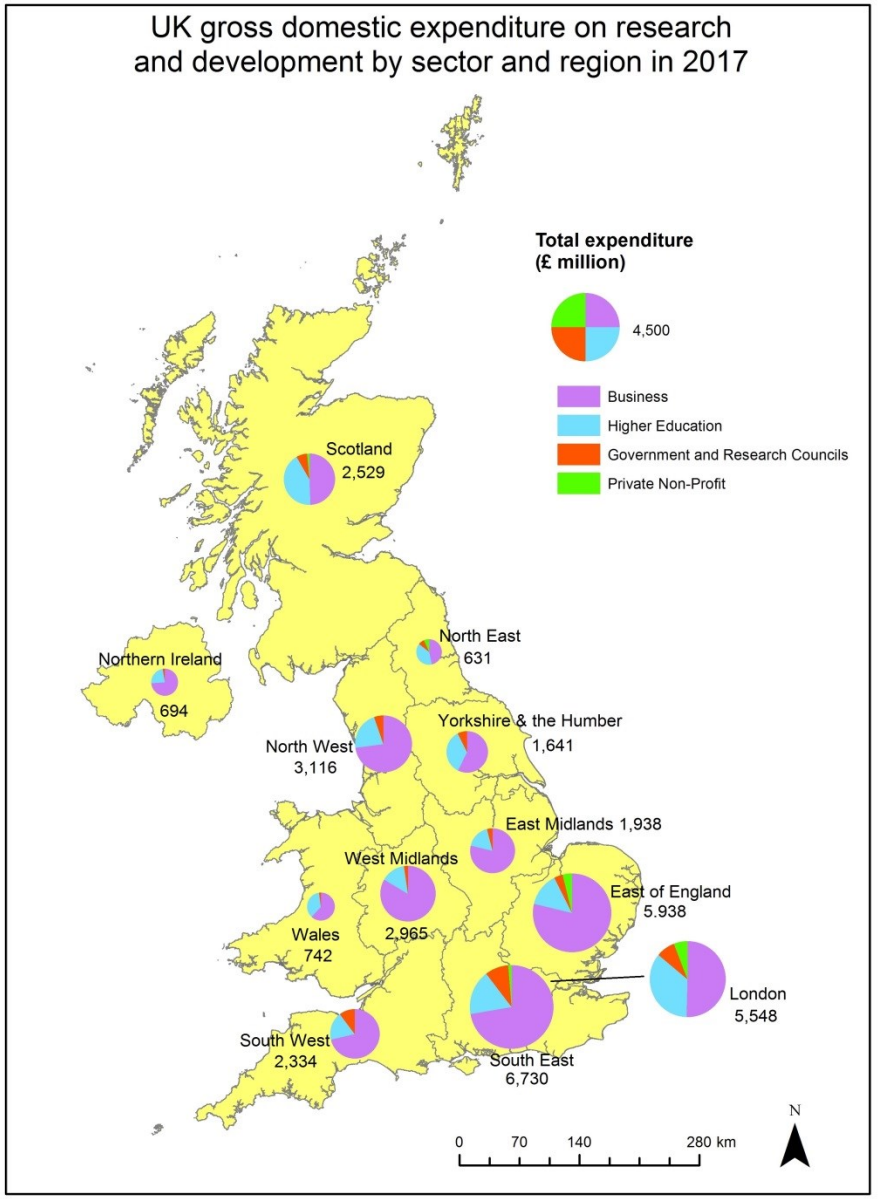

Figure 22 R&D expenditure by sector, 2017

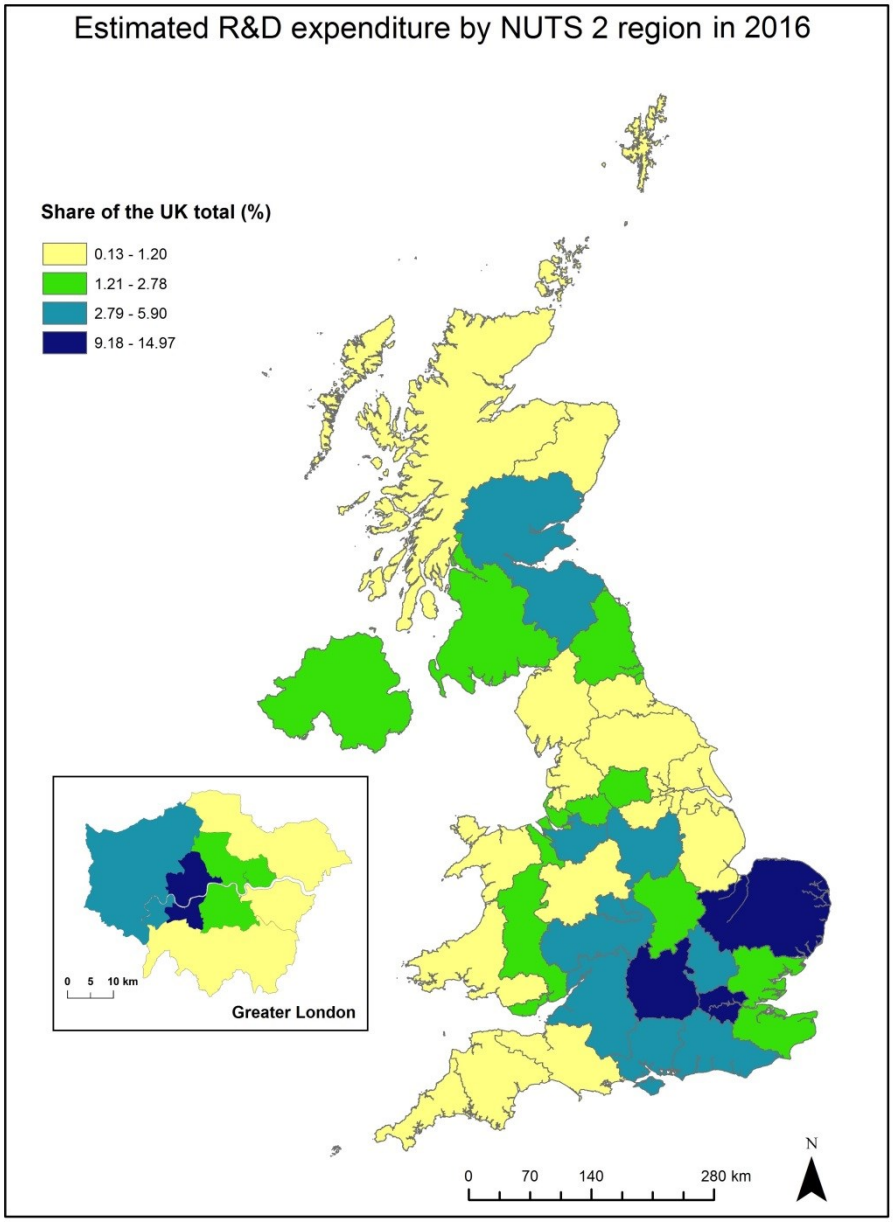

Figure 23 Estimated R&D expenditure by NUTS 2 region

The spatial distribution of government's R&D spending (Table 1) shows a strong bias in the South East and London, with a lion's share of over 48% of its total spend, which disproportionately boosts these regions' total GERD. These two regions further enjoy a large share of higher education spending, largely funded by the UK Research and Innovation, taking 38.61% of the national share. The situation of the West Midlands and the North West is a rather different story, as their GERD is largely funded by the business sector and has a relatively small UK share of expenditure from the government and the higher education sectors.

Table 1 Share of UK'S gross expenditure on R&D by sector and region, 2017

UK share (%)	Total	Government & Research Councils	Higher Education	Business	Private Non-Profit
South East	19.34	27.81	14.36	20.52	11.32
East of England	17.06	9.65	10.02	19.75	30.63
London	15.94	20.35	24.25	11.80	43.01
North West	8.95	7.64	8.32	9.57	0.14
West Midlands	8.52	3.23	5.09	10.42	1.46
Scotland	7.27	7.78	13.12	5.26	5.19
South West	6.71	11.02	5.19	6.97	2.13
East Midlands	5.57	3.37	4.17	6.42	0.27
Yorkshire & Humber	4.71	5.51	7.08	3.96	0.40
Wales	2.13	0.73	3.29	1.93	0.00
Northern Ireland	1.99	0.73	2.03	2.16	0.00
North East	1.81	2.19	3.07	1.23	5.45
UK	100	100	100	100	100

This misalignment of funding is indeed not a new trend. There was a major outcry in 2000 when the Labour government decided to base a £500m Diamond synchrotron project at the Rutherford Appleton laboratory in Oxfordshire rather than at the Daresbury Laboratory in Cheshire which was then home to Britain's synchrotron[26]. In 2008, there was another well publicised row over the funding of a new light source facility between the Daresbury scientists (from Manchester and Liverpool Universities) and the leading institutes in golden triangle[27]. These decisions have been closely related to the mind-set that research funding has to

[26] https://www.theguardian.com/politics/2000/mar/14/uk.politicalnews1
[27] https://www.theguardian.com/education/2008/may/20/highereducation.research

cluster and concentrate in the southeast for global competition. Critics like Tom Forth analysed the 2013 NUT2 region data and concluded that:

> *... regions where business invests significantly in R&D and government is almost completely absent. Cheshire (Pharmaceuticals), Hertfordshire (Biotech), and Herefordshire, Worcestershire and Warwickshire (Automotive supply chain) are examples ... places where government invests significantly despite low business investment. London stands out, but East Scotland is notable too. It is this pattern, among other factors, that explains why AstraZeneca recently left Cheshire and moved to East Anglia.*[28]

In order to validate Froth's claim, the estimated percentage of local GDP on R&D expenditure in 2016 is mapped in Figure 24. Bearing in mind that the UK only spent 1.67% of its GDP on R&D, there are five UK NUTS2 regions that surpassed the EU's 2020 target of spending at least 3.0%. These include East Anglia (4.62%); Cheshire (3.76%); Berkshire, Buckinghamshire & Oxfordshire (3.67%); Bedfordshire & Hertfordshire (3.35%); and Herefordshire, Worcestershire & Warwickshire (3.01%). Derbyshire & Nottinghamshire (2.81%) just dropped below the line. Froth's analysis of the 2013 situation still persists as evident in the 2016 local GDP share analysis and the 2017 sectoral regional expenditure data.

Besides the uneven landscape of GERD, the research capacity of UK universities is also heavily concentrated in the golden triangle (Figure 25). By taking into account the research quality profile and the staff numbers in the 2014 UK Research Excellence Framework (REF) assessment, a Research Market Share Index[29] was developed by Research Fortnight to estimate the distribution of research funding share. The institutions under the charter of the University of London (16.7%) and Imperial College (3.3%) constitute one-fifth of UK's research capacity; which is closely followed by the Universities of Oxford (6.3%) and Cambridge (5.3%). Outside the golden triangle, the best performing universities are scattering over different parts of the country: Edinburgh (3.9%); Manchester (3.4%); Nottingham (2.8%); Bristol (2.5%); Leeds (2.4%); Southampton (2.4%); Sheffield (2.2%); Glasgow (2.2%); Warwick (2.1%); and Birmingham (2.1%).

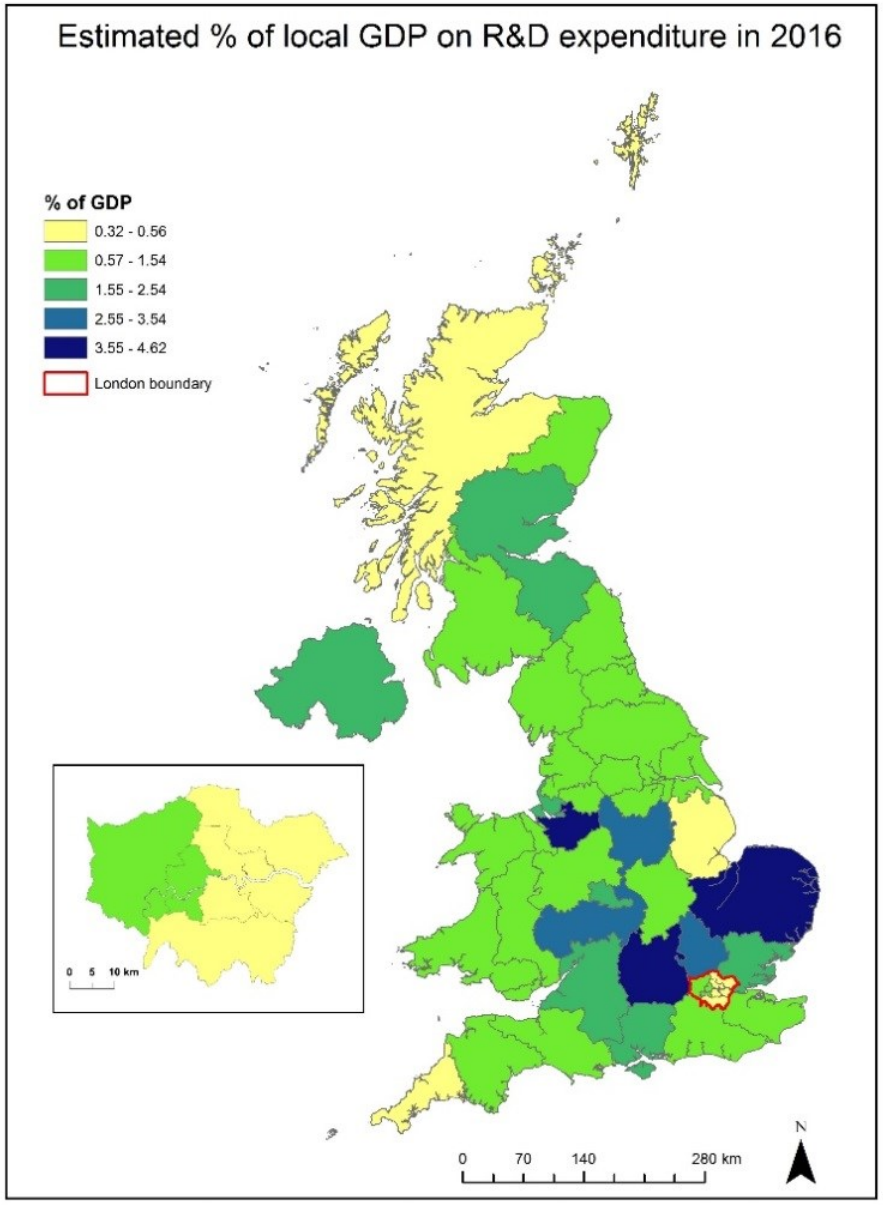

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Figure 24 Estimated local GDP on R&D expenditure, 2016

[28] https://www.tomforth.co.uk/boostingrd/

[29] Based on the results of UK Research Excellence Framework (REF) 2014, Research Fortnight's Market Share Index takes the quality profile and staff number of each academic institution into account: https://www.theguardian.com/news/datablog/ng-interactive/2014/dec/18/university-research-excellence-framework-2014-full-rankings

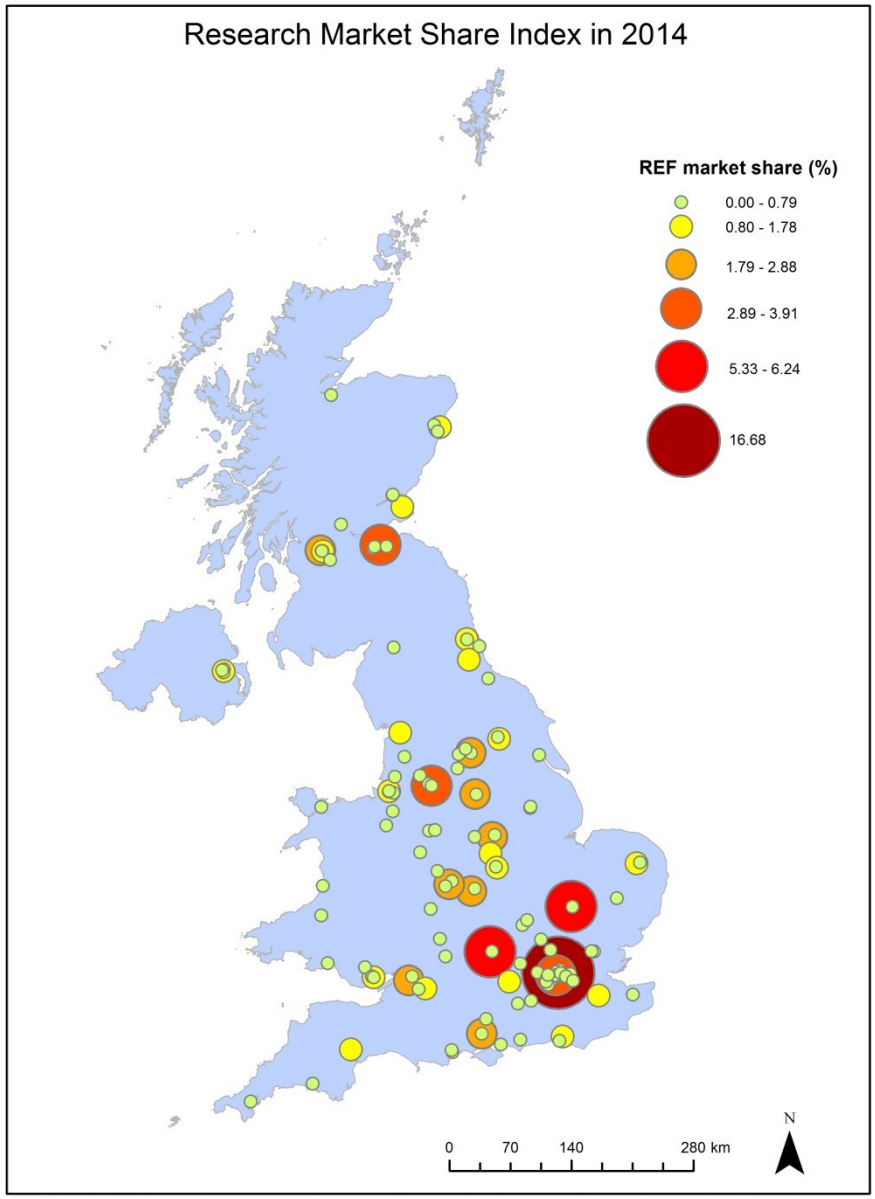

Figure 25 Research market share index, 2014

International studies show that many biotechnology companies are spin-out companies from universities and such business-university alliances are crucial for research capacity building and innovation[30]. Figure 26 maps the relationship between the location of life science companies and the Research Market Share Index. It clearly shows the dominance of the business-university alliances in the golden triangle of Oxford, Cambridge and London. Elsewhere in the country, there is another cluster around the Central Belt of Scotland and around Manchester-Liverpool-Cheshire in North West England. It is interesting to note that a regional 'Science and Innovation Audit' for Greater Manchester and Cheshire East, rather than for the wider geography of the Mersey Belt and Cheshire, was carried out in 2016 - it was one of five studies commissioned by the Department for Business, Energy & Industrial Strategy[31].

The research performance in 2014 has set train for the next six years of research funding allocation which is further reinforced by the government's GERD, as shown in Figure 27. It is noticeable that the public sector GERD's spatial impact is lessened by the private sector investment, as shown in Figure 28. As Gordon Marsden MP, a member on the innovation, universities, science and skills select committee, pointed out:

> *If you concentrate money in three or four research-intensive universities because you think these are the best, this then becomes a self-fulfilling prophecy.*[32]

[30] See for examples, George, G., Zahra, S.A. and Wood, D. R. (2002) The effects of business–university alliances on innovative output and financial performance: a study of publicly traded biotechnology companies, *Journal of Business Venturing*, 17 (6), 577-609; and Blumenthal, D., Gluck, M., Louis, K.S. and Wise, D. (1986) Industrial support of university research in biotechnology, *Science*, 231, 242-246.

[31] New Economy and University of Manchester (2016) Greater Manchester and Cheshire East: a Science and Innovation Audit Report, sponsored by the Department for Business, Energy and Industrial Strategy. http://documents.manchester.ac.uk/display.aspx?DocID=30337

[32] https://www.theguardian.com/education/2008/may/20/highereducation.research

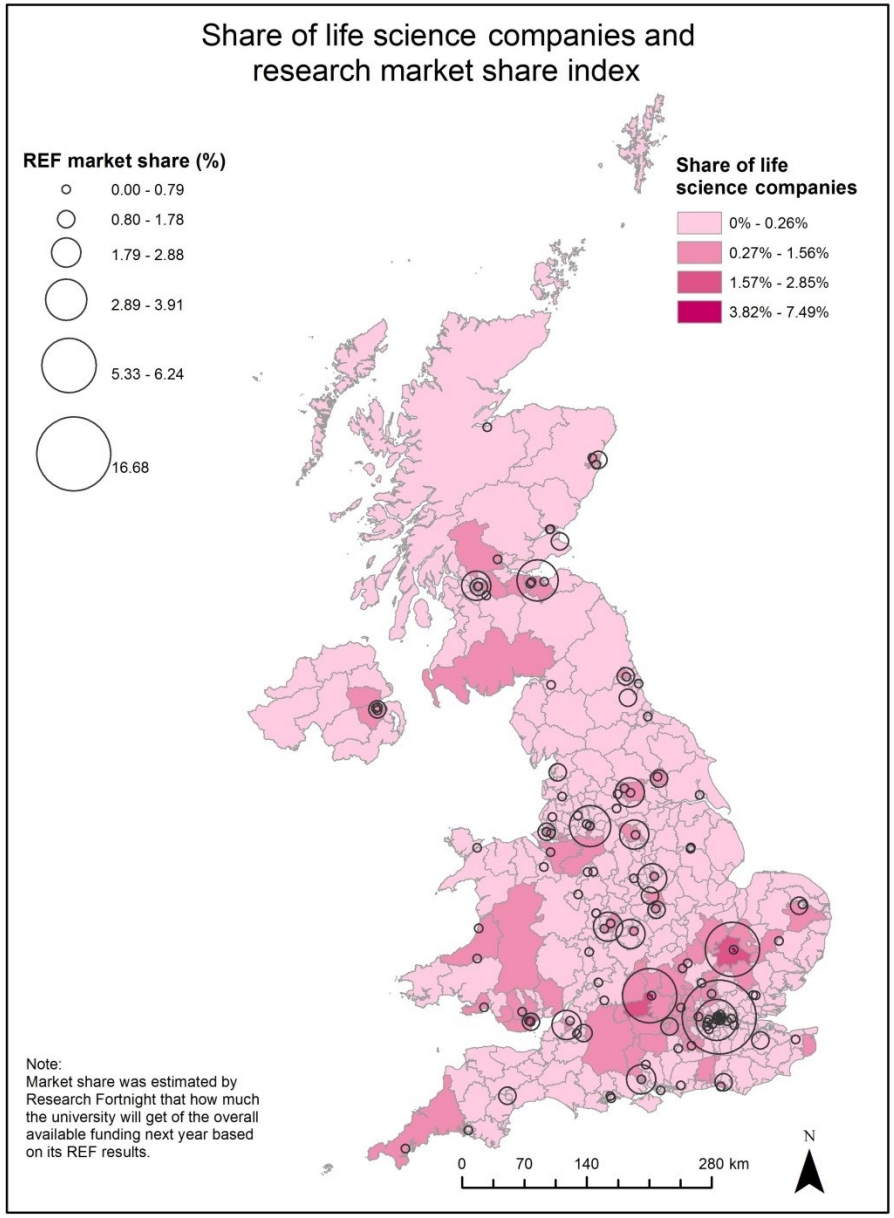

Figure 26 Life science and research market share index

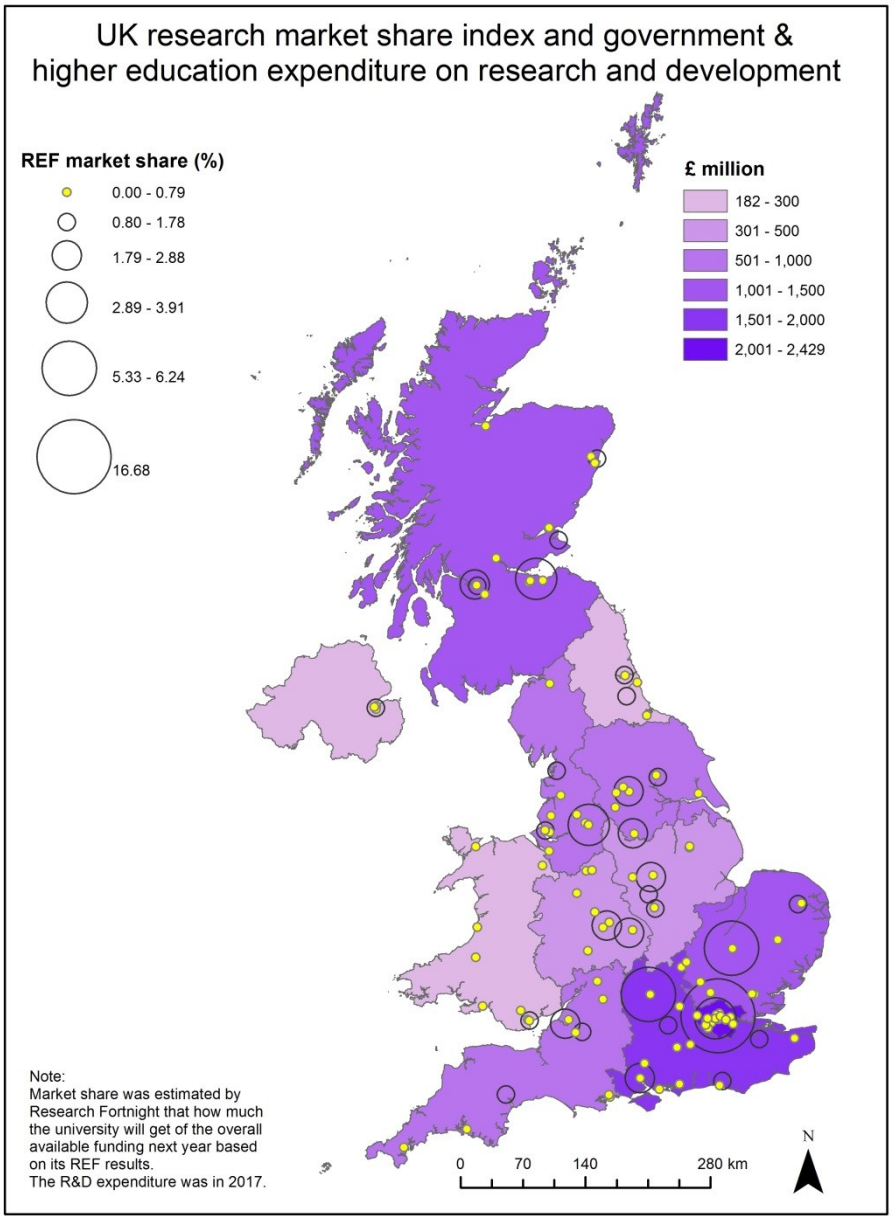

Figure 27 Research market share and government and higher education R&D expenditure

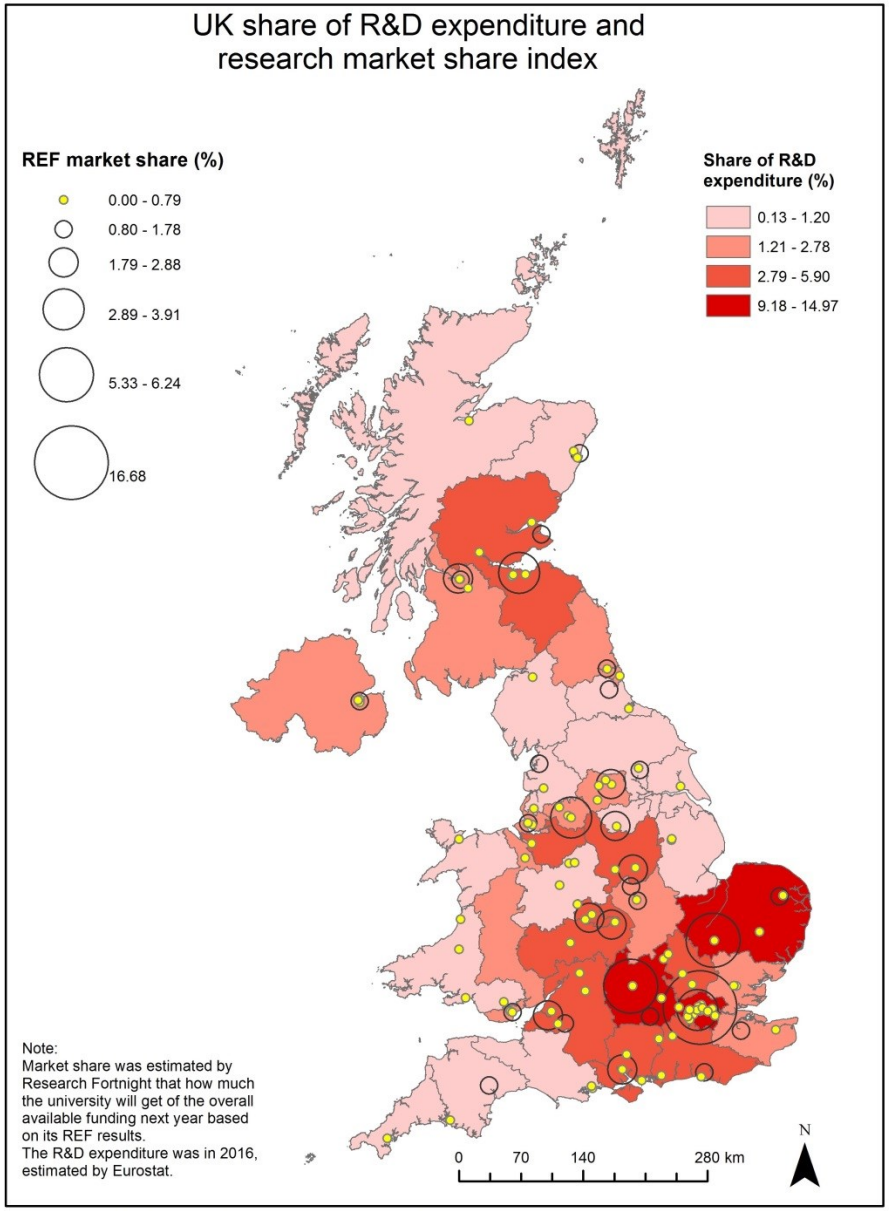

Figure 28 Research market share and total R&D expenditure

The very focus approach of R&D funding by the UK government contrasts sharply with the French approach. As stipulated in the Law, the French government has to develop a National Research Strategy *'with a multi-annual programming … to meet the scientific, technological, environmental and societal challenges while maintaining a high level of basic research … Priorities are adopted after consultation with the scientific and academic community, social and economic partners … relevant ministries and local authorities, in particular the regions'* (Bitard and Zacharewicz, 2016: 22)[33]. Languedoc-Roussillon, a poor region in need of extra boost, was the only region in France that has R&D overspending[34].

Infrastructure & locational advantage

Differential locational advantage is the result of the interplay between physical location and the dynamics of other changes, such as accessibility, communication networks and infrastructure investment. The UK Government's desire to encourage competition and a free market often conflicts with strategic spatial planning considerations that attempt to direct infrastructure investment to stimulate economic growth in lagging regions[35]. Infrastructure investment tends to reinforce the differential spatial trajectories and favour London. According to the 2013 National Infrastructure Plan, £36 billion was targeted at London, representing 40% of England's total spend on regional projects and programmes. The East Midlands and the North East, with an investment of £2 billion and £2.2 billion respectively, receive the least amount of capital funding. On a per capita basis the East Midlands continues to trail in investment with just £567 per person while the equivalent figure for London is £4,333 (see Figure 29).

The establishment of the UK National Infrastructure Commission, with the publication of the National Infrastructure Assessment, aims to inject strategic thinking on long-term infrastructure challenges and priorities. However, the Commission's *High Speed North* and *Growth Arc* reports[36] suggest that its priorities very much focus on agglomeration economic growth.

[33] Bitard, P. and Zacharewicz, T. (2016) RIO Country Report 2015: France, EU Joint Research Centre, Seville. https://rio.jrc.ec.europa.eu/sites/default/files/riowatch_country_report/FR_CR2015.pdf
[34] https://www.tomforth.co.uk/boostingrd/
[35] See for examples, Marshall, T. (2011) Reforming the process for infrastructure planning in the UK/England 1990–2010, Town Planning Review, 82, 441–67; and Wong, C. and Webb, B. (2014) Planning for Infrastructure: challenges to northern England, Town Planning Review, 85, 683-708.
[36] https://www.nic.org.uk/our-work/

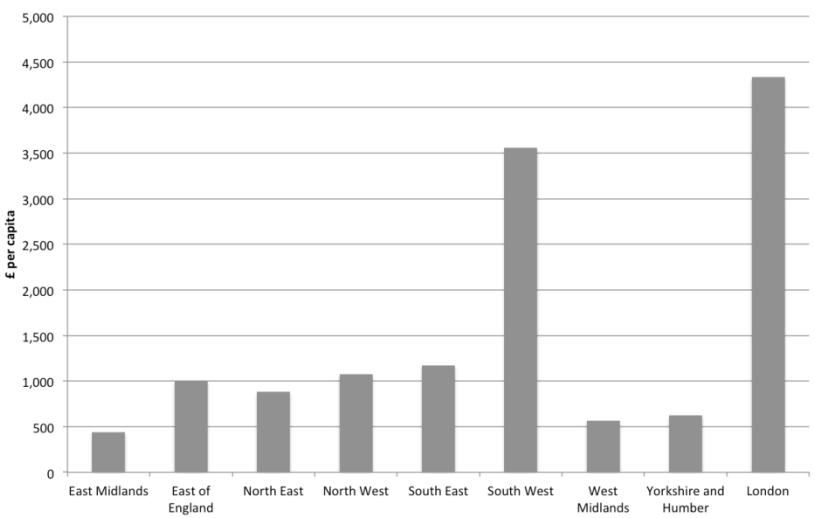

Figure 29 English regional projects and programmes in £'s per capita
Source: HM Treasury NIP data[37], recalculated by Wong and Webb (2014)[38]
Note: the South West figure OF £3,558 includes Hinkley Point C nuclear power station, excluding it, the figure is £362

The analysis here focuses on infrastructure that affects international transport and communication. There has been very lengthy and heated debate over how to accommodate UK's future aviation capacity. The existing capacity is very much dominated by the five major London airports; together they accounted for 60.3% of all passengers of UK airports in 2018. After Heathrow (27.5%) and Gatwick (15.8%) Airports in London, Manchester Airport accounted for 9.7% of all passengers, closely followed by Stansted Airport (9.6%) and Edinburgh Airport (4.9%). When only considering international scheduled flights (Figure 30), the dominance of London area airports continues. In total, they accounted for 61.7% of all UK international scheduled passengers, with Heathrow accounting for 28.7%, Gatwick for 15.5% and Stansted for 9.9% of the UK total; followed by Manchester (9.2%) and Edinburgh (5.0%).

The recent political debate has been focusing on the options of whether building a new airport in London or expanding one of the existing London airports to meet future aviation demand. There was, nonetheless, no mention of Manchester Airport as a UK international gateway in the 2011 and 2013 National Infrastructure Plans despite the proposed HS2 will connect London to Manchester Airport. Manchester Airport currently has over 28 million passengers and a catchment of 22 million people within a two hour drive, yet has spare capacity to handle as many as 55 million passengers[39]. Interestingly, even the Manchester Airports Group supported the extension of its newly acquired Stansted Airport in the 2013 Airports Commission's inquiry of the UK's future aviation capacity and connectivity need[40]. This means that passengers outside the South East will continue to travel to London or other European hubs (e.g. Amsterdam) to make international connections for most international destinations[41].

Turning to sea transport, approximately 481.8 million tonnes of tonnage, of which over 80% was international trade, passed through the ports in the UK in 2017[42]. Of the 34 main ports in the UK, 72.9%% of the tonnage (332.4 million tonnes) is concentrated in the top 10 ports. As shown in Figure 31, Grimsby & Immingham (11.9%) and London (10.9%) are the two largest ports both in total tonnage and international tonnage and they were ranked as the top 11th and 13th cargo ports in Europe[43]. Domestic traffic has been declining since the late 1990s. Figure 31 shows that a number of ports specialise in handling domestic tonnage:

[37] HM Treasury (2013) National Infrastructure Plan 2013, London, The Stationary Office.
[38] Wong, C. and Webb, B. (2014) Planning for Infrastructure: challenges to northern England, Town Planning Review, 85, 683-708.

[39] MAG (2013) Capacity for Growth: M. A. G.'s Submission to the Airports Commission (report submission), Manchester, M. A. G.
https://www.bishopsstortfordtc.gov.uk/document_library/Older%20Minutes/Agendas%20and%20Minutes%20-%20Localism%20and%20Strategy%20Committee%202013/LS130923%20Agenda%20and%20Minutes%2023%20Sep%2013/LS130923%20Appendix%207b%20Stansted%20Airport%20Consultation%20Press%20release.pdf
[40] Airports Commission (2013) Airport Commission Interim Report, Appendix 2: Assessment of Long-term Options, London.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/268620/airports-commission-interim-report-appendix-2.pdf
[41] See Forth, T. (2015) The UK's hub airport isn't London Heathrow. It's Amsterdam Schiphol
https://www.citymetric.com/transport/uks-hub-airport-isnt-london-heathrow-its-amsterdam-schiphol-1190
[42] Department for Transport (2018) UK Port Freight Statistics: 2017 Statistical Release
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762200/port-freight-statistics-2017.pdf
[43] Eurostat maritime ports freight and passenger statistics 2016 data - https://ec.europa.eu/eurostat/statistics-explained/index.php/Maritime_ports_freight_and_passenger_statistics#Slight_increase_in_seaborne_goods_and_passengers_in_EU_ports

Belfast, Larne and Warrenpoint in Northern Ireland; Aberdeen, Lock Ryan and Cairnryan in Scotland and Heysham in northwest England.

Since the late 1990s, the UK has continued to import more than export via its ports, with 243.5 million tonnes of international imports and 136.6 million tonnes of exports in 2017. This import/export imbalance has accelerated over time[44], reflecting the changing structure of the economy from manufacturing to service industries. International port traffic, a total of 275.1 million tonnes (74.4%), is heavily concentrated in 9 main ports: Grimsby & Immingham (13.4%), London (10.6%), Southampton (8.3%), Felixstowe (7.7%), Liverpool (7.5%), Milford Haven (7.4%), Dover (7.1%), Forth (6.7%), and Tees & Hartlepool (5.8%). In terms of container transport, Felixstowe (8th), Southampton (14th) and London (19th) are amongst the top 20 container ports in Europe[45]. With the transition to the fourth industrial revolution, there may be further changes in the nature and demand of sea transport. It is important to note that, besides Grimsby & Immingham, all the main UK international port capacity is heavily concentrated in the southeast and east of England.

With the advance of digital technology and the internet, high quality, reliable and good coverage of telecommunication infrastructure is critical to economic development. Speed does matter in broadband accessibility as it affects the internet search and high frequency trading, uploading and downloading speed as well as ensuring stable online access without being affected by the number of simultaneous users. Based on the Department for Digital, Culture, Media & Sport's economic impact evaluation report[46], every £1 invested brought £12.28 benefit for businesses and resulted in a £9 billion increase in business turnover as a result of having faster broadband connections.

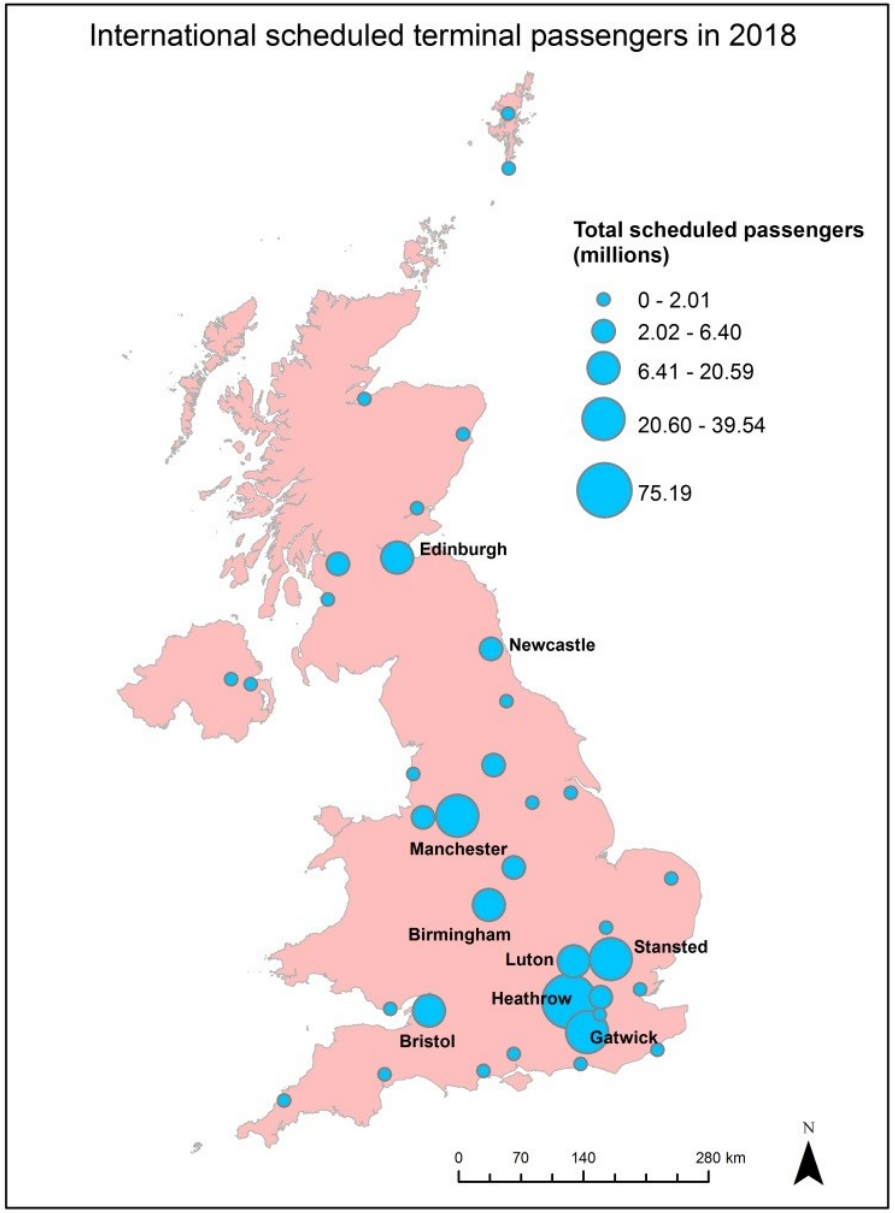

Figure 30 International scheduled flight passengers, 2018

[44] Department for Transport (2018) UK Port Freight Statistics: 2017 Statistical Release, p.2 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762200/port-freight-statistics-2017.pdf

[45] Port Economics web - https://www.porteconomics.eu/2018/05/29/portgraphic-top-20-eu-container-ports-q1-2018/

[46] Department for Digital, Culture, Media & Sport (2018) Evaluation of the Economic Impact and Public Value of the Superfast Broadband Programme Final Report, London, DCMS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734855/Superfast_Integrated_Report.pdf

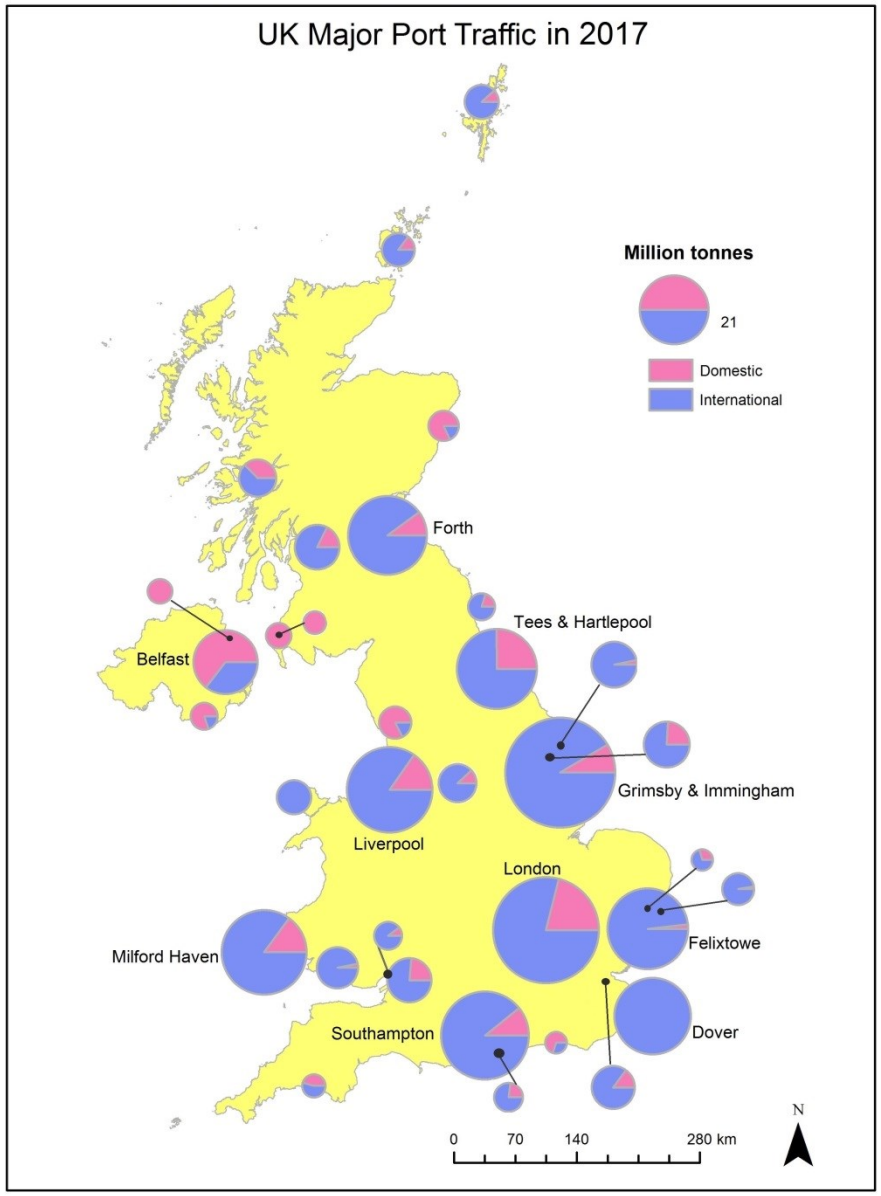

Figure 31 Major port traffic, 2017

According to Ofcom, 95% of UK premises[47] had access to superfast broadband based on the Government's own definition (24 Mbps) and this is expected to extend to 97% by 2020[48]. Ofcom, EU, Scottish and Welsh Government, however, adopt 30 Mbps as their superfast definition. Figure 32 highlights the urban/rural differentials in access to broadband infrastructure that a much higher percentage of premises in rural areas do not even have access to broadband with 30 Mbps.

Whilst the UK has good coverage of superfast broadband (93.5%), less than half of premises have access to ultrafast broadband; and indeed 3% have connectivity below the Universal Service Obligation (see Table 2). It is also clear that the coverage of the ultrafast broadband is much more varied (see Figure 33) than superfast broadband: with very high coverage in London, followed by other core urban areas; but sparsely covered in shire England and much of Wales, Scotland and Northern Ireland. It is interesting to note that Wales and Northern Ireland, with lower levels of ultrafast broadband access; but they have moved onto full fibre broadband at a slightly faster pace (see Table 2).

Table 2 Types of broadband connectivity, May 2018

	England	Scotland	Wales	Northern Ireland	UK
Superfast (>30 Mbps)	94.0%	91.5%	92.2%	88.1%	93.5%
Ultrafast (>300 Mbps)	49.9%	42.9%	27.1%	38.5%	47.9%
Full fibre (>1000 Mbps)	4.8%	2.8%	5.2%	8.3%	4.8%
Below Universal Service Obligation*	2.6%	5.0%	4.2%	6.1%	3.0%

Source: see Hutton, G. and Baker, C. (2018), page 9[49]
Note: *unable to receive 10 Mbps download speed, 1 Mbps upload speed etc.

The variation in quality broadband coverage across the four countries is probably partly related to government funding patterns. Table 3 shows funding committed to spend on broadband contracts under the superfast broadband programme. About two-thirds of total funding and three-quarters of government funding was committed to spend on England's superfast broadband infrastructure as of

[47] Gudiance on Broadband Delivery UK - https://www.gov.uk/guidance/broadband-delivery-uk
[48] Hutton, G. and Baker, C. (2018) Superfast broadband in the UK, House of Commons Library Briefing Paper, CBP06643, 13 November, p.5.
[49] ibid, p.9

contracts signed at September 2018, whereas the shares for Northern Ireland are negligible at 2.05% (total) and 1.6% (government) respectively.

When examining the government's funding leverage ratio with other additional funding, it is clear that England performs much worse than the other three countries. As pointed out in a House of Commons Briefing paper[50], SNP MPs argued that *'the UK Government targets were 'skewed towards England" and that Scotland should have received more funding due to Scotland's challenging geography'*.

Table 3 Funding spent on contracts under the superfast broadband programme, 2018

	Government funding (%)	Additional Funding (%)	Total Funding (%)	Additional/Government leverage ratio	Premises connected (%)
England	74.95	60.58	66.88	1.04	70.28
Scotland	14.09	19.97	17.40	1.82	14.22
Wales	9.36	17.05	13.68	2.34	14.15
Northern Ireland	1.60	2.39	2.05	1.92	1.35
UK	100.00 (£715.5 M)	100.00 (£917.2 M)	100.00 (£1632.7M)	1.28	100.00 (n=4,948,197)

Source: Broadband Delivery UK data on local broadband projects based on contacts signed at 24 September 2018 and adapted from Hutton and Baker (2018)[51]
Note: additional funding extra funding provided by the local body, for example from their own budgets, the EU or private investment.

With future innovations in manufacturing depending on the new 5G network, the technology has already moved onto full-fibre broadband (1000 Mbps) to forge the 5G future, which is currently only available to 4.8% premises across the UK. The government has a target of building a nationwide full-fibre network by 2033[52]. The Local Full Fibre Networks programme launched a £190m Challenge Fund in November 2017 and the first tranche of £95m was allocated in March 2018 to 13 successful projects[53]: Armagh City, Banbridge & Craigavon; Highlands; Cardiff; Manchester; Nynet (North Yorkshire); Coventry; Solihull & Warwickshire; Wolverhampton; London; Mid Sussex; Portsmouth; Cambridgeshire; Belfast; and Blackpool. The future spatial landscape of broadband coverage will no doubt significantly affect the locational advantage of different places.

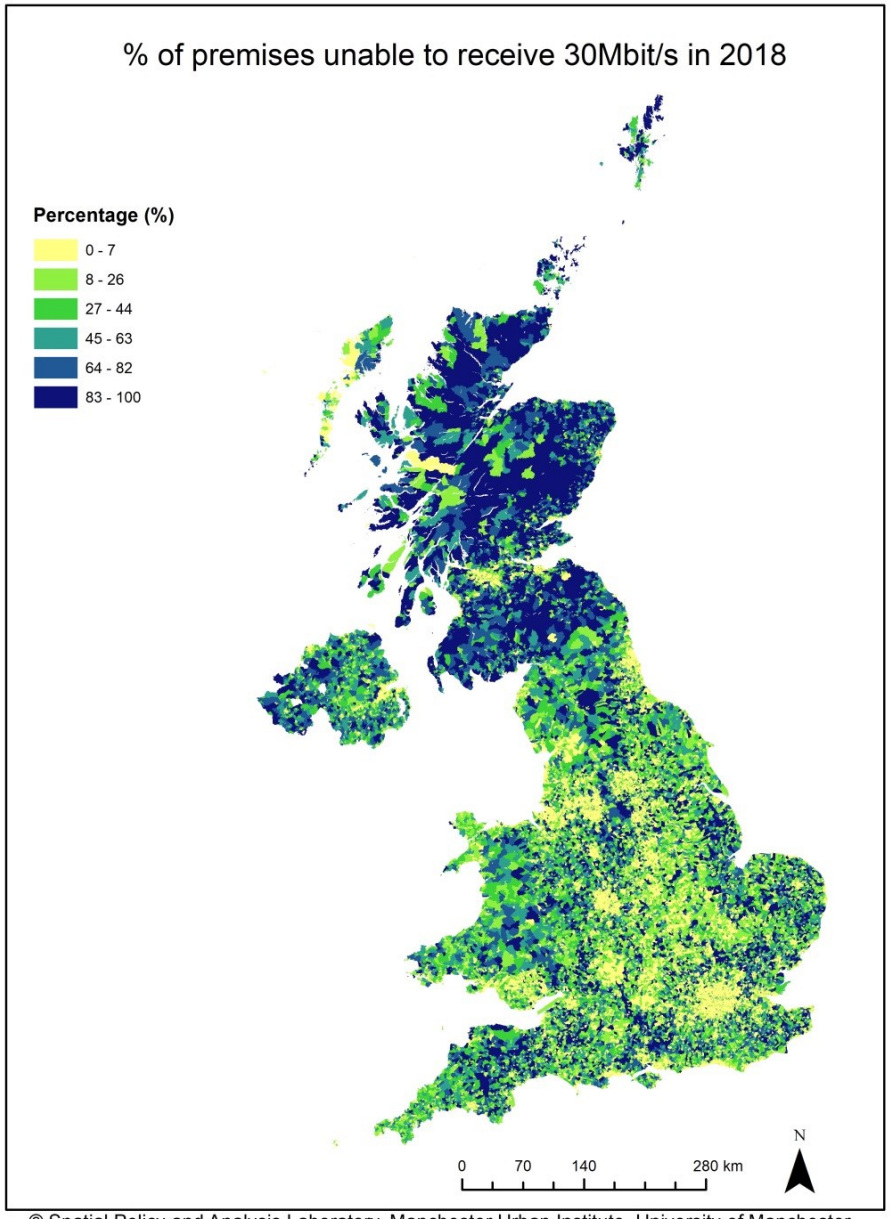

Figure 32 Lack of superfast broadband coverage, 2018

[50] ibid p.27.
[51] ibid, p.16
[52] ibid, p.7
[53] https://www.gov.uk/guidance/local-full-fibre-networks-programme

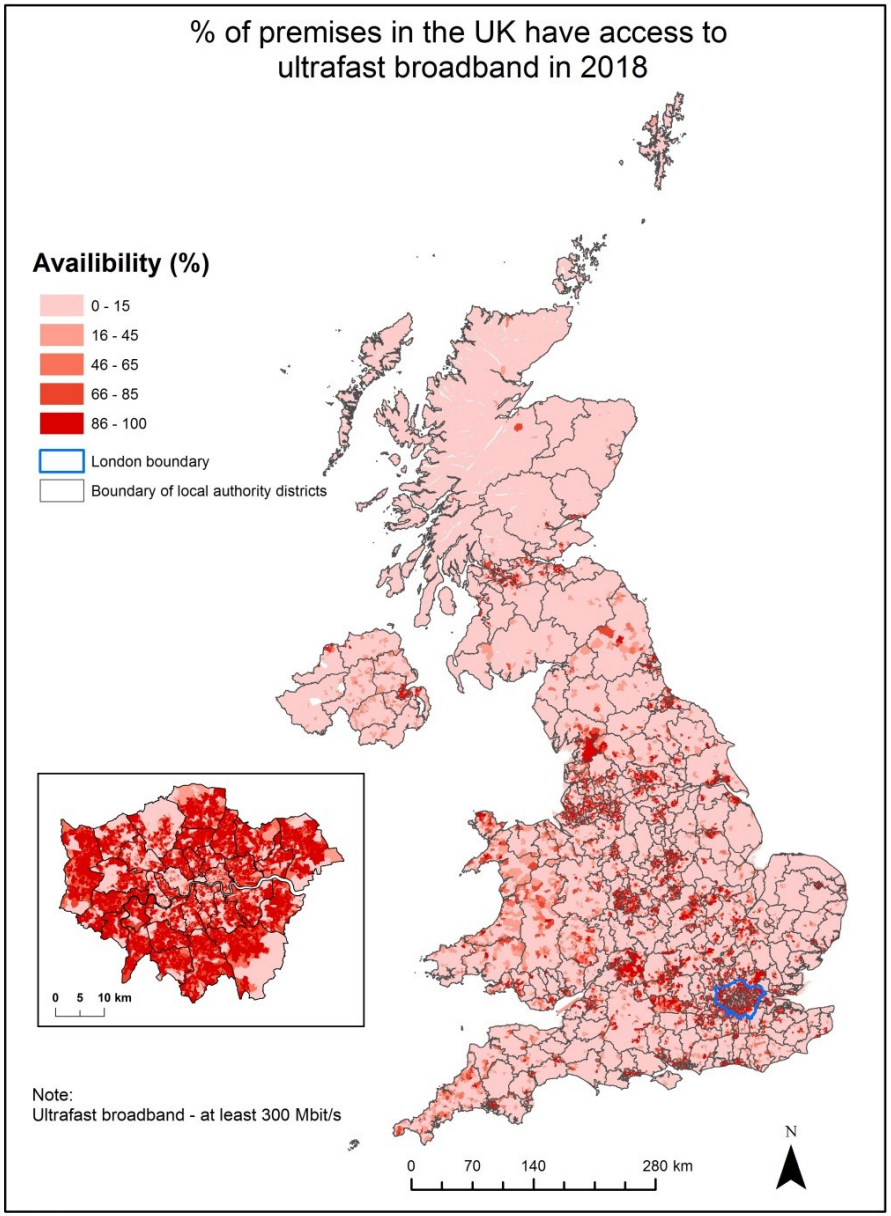

Figure 33 Ultrafast broadband coverage, 2018

Web of institutions

The challenge of Industry 4.0 is about the transformation of entire systems of production, management and governance[54] and requires sectoral and spatial integration. Despite the publication of the UK national industrial strategy, there remains a lack of spatial assessment. Rather than thinking strategically about the geographical implication of technological change on future industrial development, the government focuses on:

> *Local Industrial Strategies, led by Mayoral Combined Authorities or Local Enterprise Partnerships, will promote the coordination of local economic policy and national funding streams and establish new ways of working between national and local government, and the public and private sectors.*[55]

The above statement only applies to England, as the devolved administrations in Wales, Scotland and Northern Ireland have their own approaches and priorities.

Administrative vs functional boundaries

In order to harness the potential pool of a professional and high skilled workforce and other development resources, the planning of cities has to be seen within the broader spatial context in which they closely interact and connect. The problem of using administrative areas is that it may distort the spatial dynamics operating between a city and its wider spatial hinterland. In the under-bounded city, the administratively defined city is smaller than the physical urban aggregate, while the opposite is true for an over-bounded city. The use of administrative boundaries, rather than economic functional areas (for example, labour and housing markets), can give an understated or exaggerated impression of urban performance.

The incongruence between decision-making accountability geographies of administrative areas and functional geographies[56] means that decisions such as voting on potential congestion charges will impact on commuters who live outside the administrative boundaries. The mismatch between administrative

[54] https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

[55] Press release from the Department for Business, Energy & Industrial Strategy and the Rt Hon Greg Clark MP https://www.gov.uk/government/news/local-industrial-strategies-to-drive-growth-across-the-country

[56] Solis, P., Vanos, J.K. and Forbis Jr., R.E. (2017) The decision-making/accountability spatial incongruence problem for research linking environmental science and policy, Geographical Review, 107(4): 680-704.

and functional boundaries also means that there is uncertainty over the actual spatial contextual effects on individual behaviours and outcomes. As argued by the Smith Institute and Regional Studies Association[57]:

> *The trouble, however, with the messy world of work, business and enterprise is that it obstinately refuses to acknowledge municipal boundaries. People cross council boundaries on their way to work: businesses are not bounded by the horizons of their local council when hiring staff or setting up new operations.*

Local Enterprise Partnerships and economic reality

LEPs are voluntary partnerships between local authorities and local private sector businesses and have taken on responsibility for significant amount of central government funding. They are responsible for Enterprise Zones and funding bids such as the Single Local Growth Fund. LEPs also received the Growing Places Fund for infrastructure development and delivering projects under the EU Structural and Investment Funds.

LEP areas are supposed to follow functional economic market areas (which are larger than travel-to-work-areas). But, this has resulted in some very complex situations. Of the 38 LEPs, 75 local authorities belong to two LEPs and there are 14 areas where two LEPs overlap[58]. This complexity is shown in Figure 34, for instance, the Solent LEP covers two unitary authorities, five district councils, and parts of four other district councils in Hampshire, whilst the rest of Hampshire is part of the 'Enterprise M3' LEP alongside western parts of Surrey[59]. Figure 35 further shows the relationship between LEPs and travel-to-work-areas (TTWAs). While some LEPs neatly map onto a grouping of TTWAs, some just criss-cross various TTWAs.

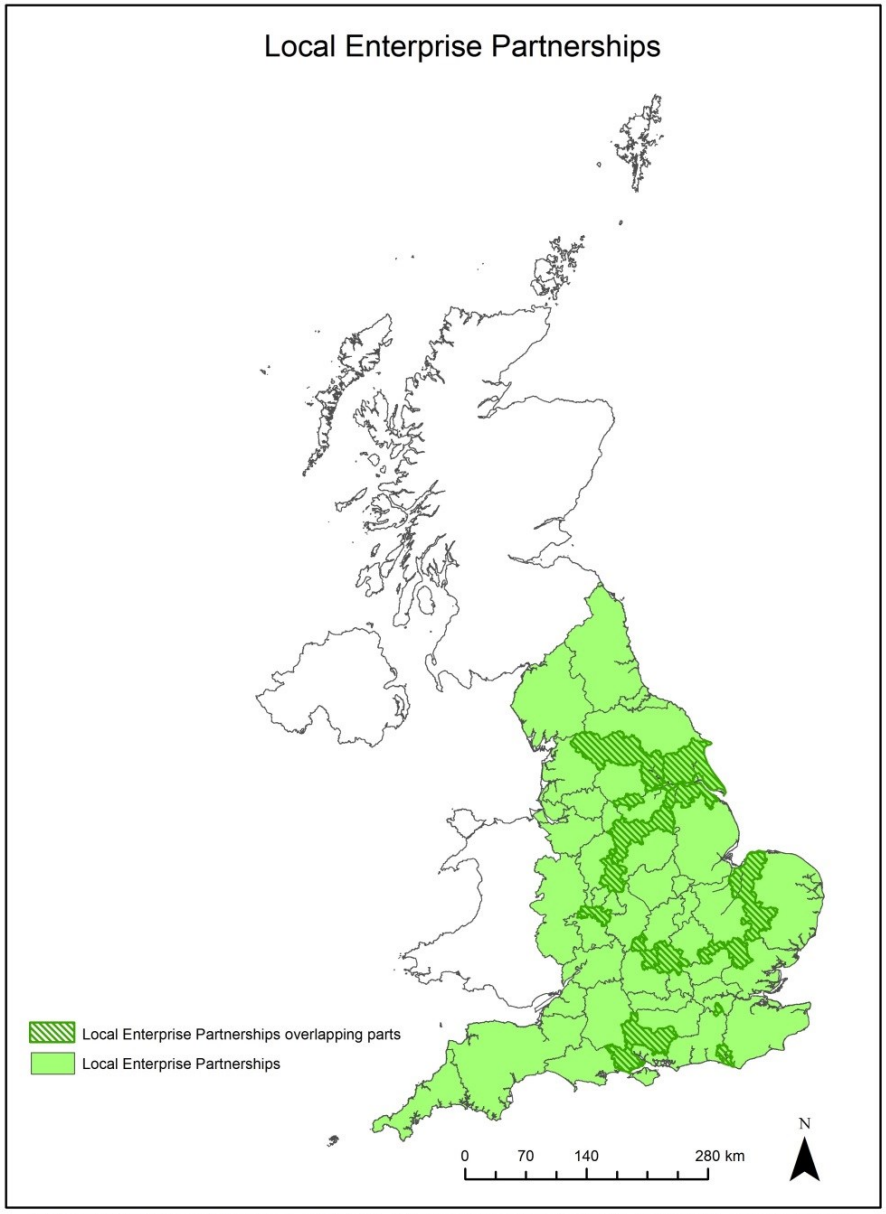

Figure 34 Local enterprise partnerships and the overlapping areas, April 2019

[57] Ward, M. and Hardy, S. (eds) (2013) Where next for Local Enterprise Partnerships?, The Smith Institute, with Regional Studies Association, London, p.4.

[58] Cusack, R. (2018) Revealed; the areas embroiled in a LEP boundary tug of war, 8 November 2018. https://www.lgcplus.com/politics/devolution-and-economic-growth/revealed-the-areas-embroiled-in-a-lep-boundary-tug-of-war/7026632.article

[59] https://citizensassembly.co.uk/areas-and-area-boundaries/

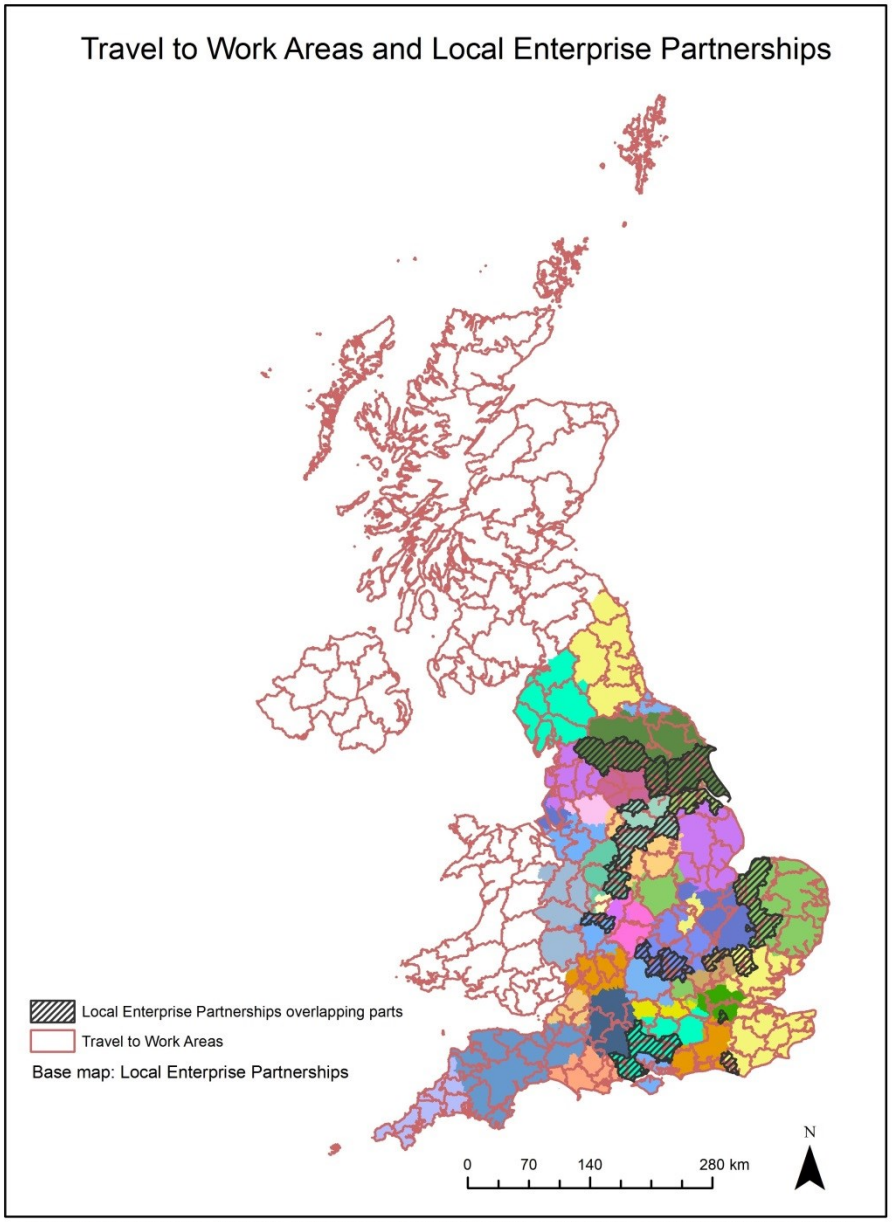

Figure 35 Travel-to-work-areas and local enterprise partnership areas

Concerns were expressed by Greg Clark[60], the Secretary State of Business, Enterprises & Industrial Strategy[61]:

> *We have been concerned that some local and regional boundaries do not reflect functional economic areas. We wish to enable partnerships to better reflect the natural economic geography of the areas they serve and hence to cover real functional economic and travel to work areas.*

The Ministry of Housing, Communities & Local Government (MHCLG)[62] therefore asked LEPs to come up with proposal to revise their geographies to better reflect their functional economic areas and to remove overlapping areas. The overlapping geographies were argued as diluting the accountability and responsibility of the LEPs for setting local industrial strategies.

However, the issue of LEPs is not just about geography. As argued by Pike et al. (2015:201), *'their role and contribution is being compromised by a fragmented and shifting landscape of economic development governance and the absence of a longer-term vision and plan for their evolution.'*[63] The Audit Commission[64] is also very critical in its review of the LEPs and pointed out that *'LEPs are highly dependent on local authorities, and the sustainability of this support is uncertain'* and *'there is a risk that LEPS do not possess the resources necessary to deliver Growth Deal projects'*.

Combined authorities and travel-to-work-areas

Under the devolution agenda, the formation of combined authorities (CAs) with elected mayors is seen by the government as the mechanism to stimulate economic growth outside London. More importantly, as explained by the MHCLG[65]:

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[60] Ward, M. (2019) Local Enterprise Partnerships, House of Commons Library Briefing Paper No. 5651, 28 March 2019. P.5.

[61] Ward, M. (2019) Local Enterprise Partnerships, House of Commons Library Briefing Paper No. 5651, 28 March 2019. P.5.

[62] HM Government (2018) Strengthened Local Enterprise Partnerships, MHCLG, London. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/728058/Strengthened_Local_Enterprise_Partnerships.pdf

[63] Pike A, Marlow D, McCarthy A, O'Brien P, Tomaney J. (2015) Local institutions and local economic development: the Local Enterprise Partnerships in England, 2010-, *Cambridge Journal of Regions, Economy and Society*, 8 (2), 185-204.

[64] Audit Commission (2016) Local Enterprise Partnerships (Department for Communities and Local Government), the Comptroller and Audit General, National Audit Office, London, March 2016, p.8.

[65] HM Government (2018) Strengthened Local Enterprise Partnerships, MHCLG, London, p.7.

Part of the case for establishing these bodies over specific geographies is that these are functional economic areas that are conducive towards the development of strategy, policy and interventions.

Given the emphasis placed on the importance of functional economic areas, Figure 36 overlays the boundaries of CAs with TTWAs. Out of the 10 CAs, only West of England, Greater Manchester, Tees Valley, Cambridgeshire & Peterborough, Liverpool, and West Midlands have an elected mayor. When examining Figure 36, the match between CAs and TTWAs is not straightforward and only West Yorkshire and Sheffield CAs have a good fit with their TTWAs.

Mayoral combined authorities and Local Enterprise Partnerships

As made clear by the MHCLG[66], there is a need to have closer alignment and collaboration between mayoral CAs and LEPs to achieve administrative efficiency and create greater economic impact. However, the precise nature of the relationship between them has not been clearly spelt out as it has to take local governance arrangements into account. The relationship between CA and LEP geographies is shown in Figure 37. As it currently stands, the situation is very complex and the boundaries of many CAs cut across a number of TTWAs.

This can be further explored by zooming into a number of case study areas: the West Midlands, the Liverpool and Greater Manchester CAs. Figure 37 shows that the West Midlands Combined Authority (WMCA) has a poor fit with a number of TTWAs and Figure 38[67] shows its complex layers of institutions with 12 local authorities and 3 LEPs (Black Country, Greater Birmingham & Solihull, and Coventry & Warwickshire). Since both the LEPs and WMCA are supposed to take a lead on developing economic and industrial strategies, this structure is rather difficult to penetrate and will no doubt confuse potential investors and inevitably cause duplicating efforts and increased transaction costs.

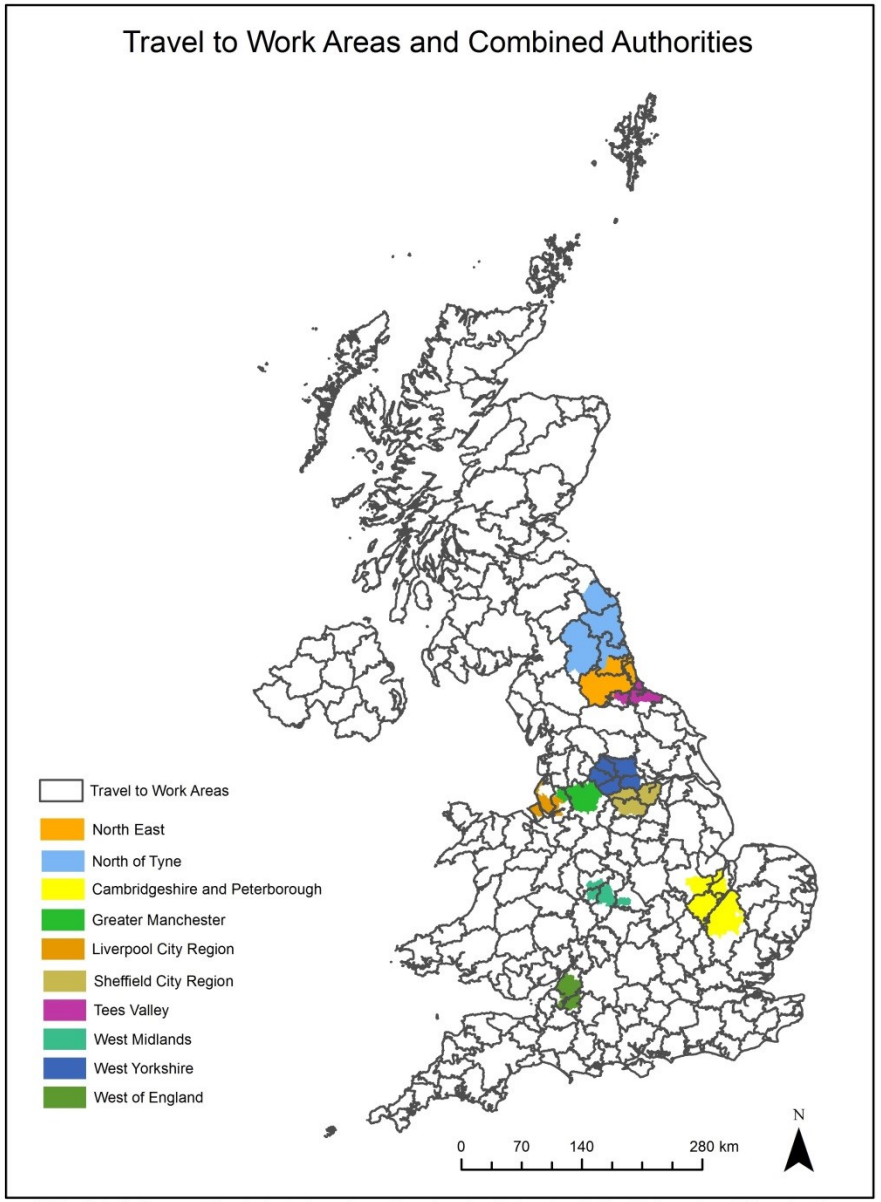

Figure 36 Travel-to-work-areas and combined authorities

[66] HM Government (2018) Strengthened Local Enterprise Partnerships, MHCLG, London, p.7.
[67] https://www.blackcountrylep.co.uk/about-us/west-midlands-combined-authority/

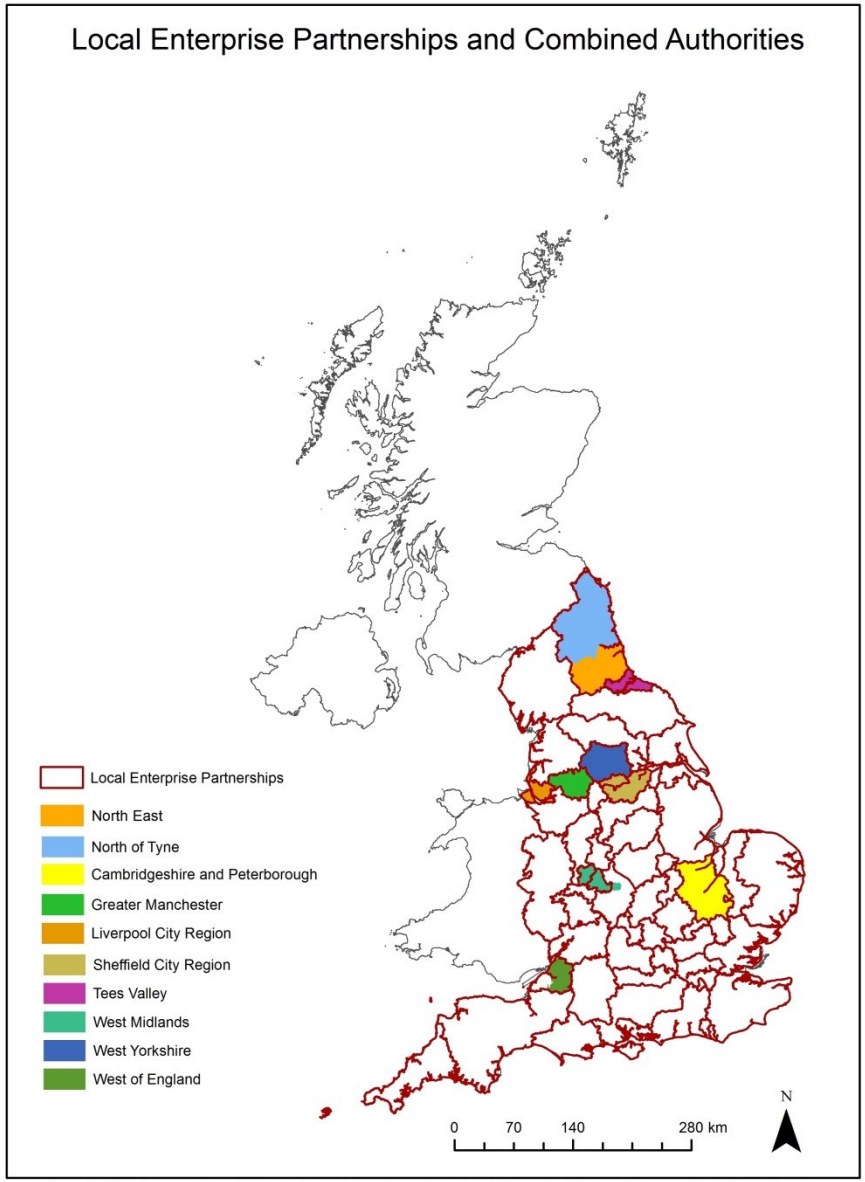

Figure 37 Local enterprise partnership areas and combined authorities

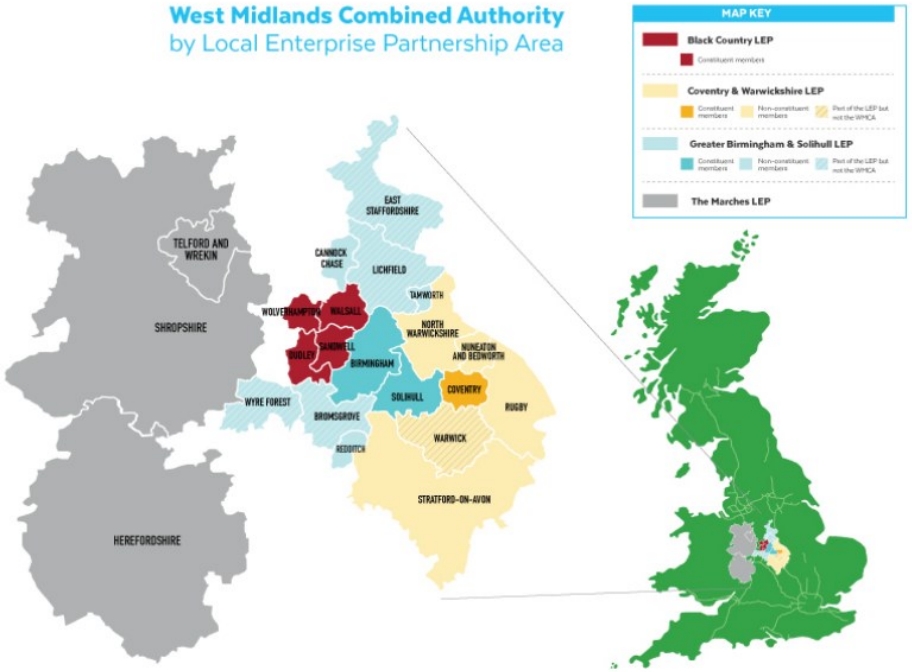

Figure 38 West Midlands Combined Authority and local enterprise partnership areas
Source: https://www.blackcountrylep.co.uk/about-us/west-midlands-combined-authority/

The other example involves two CAs, the Liverpool City Region and the Greater Manchester CA and three local authorities (Cheshire East, Cheshire West & Chester, and Warrington). Although the two CAs and three local authorities map rather neatly onto their respective LEPs, they are supposedly reflecting the functional economic reality. When mapping these boundaries against the TTWAs in Figure 39, it is clear that both the Liverpool and Greater Manchester CAs are under-bounded as their TTWAs are much larger than the administrative boundaries. The Manchester TTWA also covers a large chunk of the northern part of Cheshire East and part of High Peak; which explains why a regional 'Science and Innovation Audit' was carried out for Greater Manchester and Cheshire East.

Another complication is related to the interaction across the four authorities and three LEPs over one TTWA that covers Halton and St. Helens (Liverpool CA/LEP), Wigan (Greater Manchester CA/LEP), and Warrington (Cheshire & Warrington LEP). This means that the three LEPs and five authorities have major interactions with each other. For example, the Daresbury Laboratory is a major element of regional science infrastructure and is located at Halton where scientists from both Manchester and Liverpool Universities are actively involved in the research projects. This does raise the issue of, even without overlapping areas, whether the LEP and CA geographies really reflect the economic reality. The example here suggests that they tend to be under-bounded and fail to fully capture the catchment areas. This means that the economic impact and synergy of this area in aggregate will be understated.

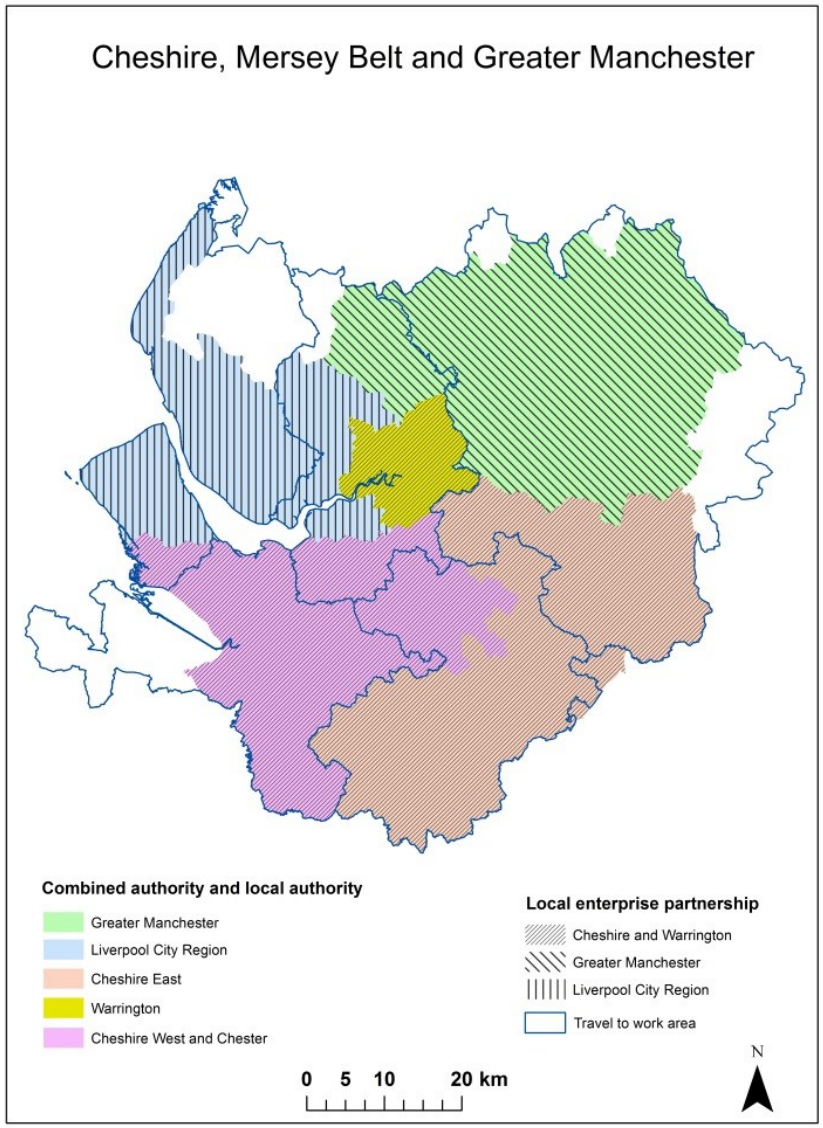

Figure 39 Functional areas of Cheshire, Merseyside and Greater Manchester

Industry 4.0: differential spatial landscape

The geographical patterns of the economic structure, labour market conditions, drivers of productivity and the institutional contexts examined in this report highlight major spatial variations across different parts of the UK in terms of their existing capacities, strengths and weaknesses in meeting the challenge of industry 4.0.

Industrial specialisation and spatial variations

After decades of industrial restructuring, different places have their own specialisation and enterprise culture. The density of large business, with 250+ employees, is found to be higher in large urban areas. There is a high density belt running from central London to Swindon along the M4 corridor and a smaller spatial cluster in Manchester-Trafford-Warrington along the M62 corridor, as well as clusters in the two capital cities of Edinburgh and Belfast (see Figures 4 and 5). However, shire locations tend to perform better in terms of overall businesses density whereas none of the core cities perform above the national level. Traditional manufacturing only accounts for less than 10% of UK's GVA and is highly concentrated in locations outside London and the South East, whereas the total GVA share exhibits the opposite spatial pattern. The information & communication and professional, scientific & technical sectors are heavily clustered around London and the South East where low level of manufacturing employment is found. In terms of the life science sector, over 2,000 firms are clustering around London, Cambridge, Oxford and the M4 corridor. There are also major clusters in south Wales running from Cardiff to Swansea, the Cheshire-Runcorn-Liverpool-Manchester area, the Scottish central belt, and the Nottingham-Coventry-Loughborough-Leicester area.

Dominant driver of the London/South East super agglomeration cluster

The high concentration of businesses in central London, in absolute and density terms, is of a different magnitude from the rest of the country. On the whole, London and South East England have a much stronger labour market, with higher than average levels of economic active age population, higher pay levels, and larger proportions of the skilled workforce with NVQ4+. The London/South East spatial cluster also dominates UK's R&D spending and research landscape, especially in the golden triangle of London-Oxford-Cambridge. This super region has also benefitted from the major infrastructure of international airports, seaport tonnage as well as superfast and ultrafast broadband connectivity. Outside London/South East, the better performing local authority areas tend to be the core cities and Edinburgh as well as some shire areas, notably Cheshire and Warwickshire.

The lock-in effects of government spending patterns

The path dependency of economic development and the lock-in effects that hinder transformative changes can be related to market behaviour as much as to political culture. As shown in this report, national infrastructure expenditure, R&D spending and superfast broadband investment has been heavily skewed by the government towards London and the South East. In the case of R&D spending and broadband investment, the government spend does not match up with that from the private sector and other funding sources. This systematic funding bias has contributed to spatial lock-in effects and status quo and does not provide a level playing field across different parts of the UK.

The rhetoric of functional economic areas vs spatial agglomeration

The wholesale adoption of LEPs as the agents to deliver local growth development strategies raises different concerns. LEP areas are supposed to follow functional economic market areas, but they are also voluntary partnerships between local authorities and local private sector businesses. This has resulted in overlapping areas and criss-crossing of various TTWAs. Likewise, the boundaries of CAs are expected to reflect functional geographies. The two layers of institution simply create further complex intersections between two sets of boundaries. As illustrated by the map overlay analysis with TTWAs, both LEPs and CAs tend to be under-bounded and do not fully capture their spatial hinterlands in terms of the functional economic area. This means that the economic impact and synergy of these areas in aggregate tend to be understated rather than optimised. While the government is keen to get rid of the overlapping areas of LEPs, such problems may simply reflect the complex reality of cross-commuting and the issue of under-bounding. Whilst the government is promoting agglomeration economies, the key spatial units of delivery seem to be under-bounded and form an artificial barrier that runs against the dynamic forces of spatial agglomeration.

Local strategies to deal with global challenge

The 5G revolution will further accelerate the convergence of digital, physical and biological spheres to bring unprecedented change in the scope, complexity and velocity of system transformation. By opening up different possibilities and opportunities in the production and consumption realm, new technologies will have a major impact on the political, industrial and social worlds. As warned by the Word Economic Forum, the challenge is for governments to think strategically and to consider the importance of the geographical impact of technology and the impact of geography on technology. However, the current position of the UK is to adopt an *aspatial* national industrial strategy, supported by local industrial strategies, local infrastructure assessments and local planning for housing. The strategic thinking is left to mayoral CAs with little extra funding support, especially in many northern regions in England. Joined-up thinking across the four countries is only vaguely mentioned. It is difficult to see how key stakeholders can think outside the box to conceive policy innovations along the line suggested by the World Economic Forum. There is an urgent need to develop a more flexible and integrative institutional framework to engender strategic thinking to harness development potential across different parts of the UK.

Spatial clusters for Industry 4.0: what will it look like?

With the different layers of administrative and functional geographies across the UK, no single set of boundaries can fully address the complexity of spatial interactions across different areas. This is clearly illustrated in Figure 40 where commuting flows are mapped onto functional urban regions as defined by Eurostat's Urban Audit. More importantly, functional economic geographies are a movable feast and can expand or contract in different directions depending on the dynamics of interaction of activities.

Bearing in mind these caveats, Figure 41 outlines the indicative clusters that have emerged from the analysis to highlight areas that show higher than national average performance in most indicators. Given the gravity of the challenge ahead to address the uneven spatial landscape of economic development in the face of industry 4.0, Figure 41 simply aims to throw a stone in the water to kick-off debate. It is also important to point out that, for more strategic and long-term thinking, due consideration has to be given to environmental issues, social justice, housing demand and landuse constraints. For instance, Figure 42 highlights the acute tension between housing demand and the planning constraints of the green belt and areas of outstanding natural beauty in London and many parts of the South East. Figure 43 also highlights different levels of flood risk in England and Wales. It is clear that areas with higher flood risk levels tend to be in coastal locations and along the main rivers of the Thames, Trent, Ouse and Avon. The river catchment areas are often the major urban conurbations and issues of global warming and flood risk are key considerations when planning for a sustainable and resilient industrial future.

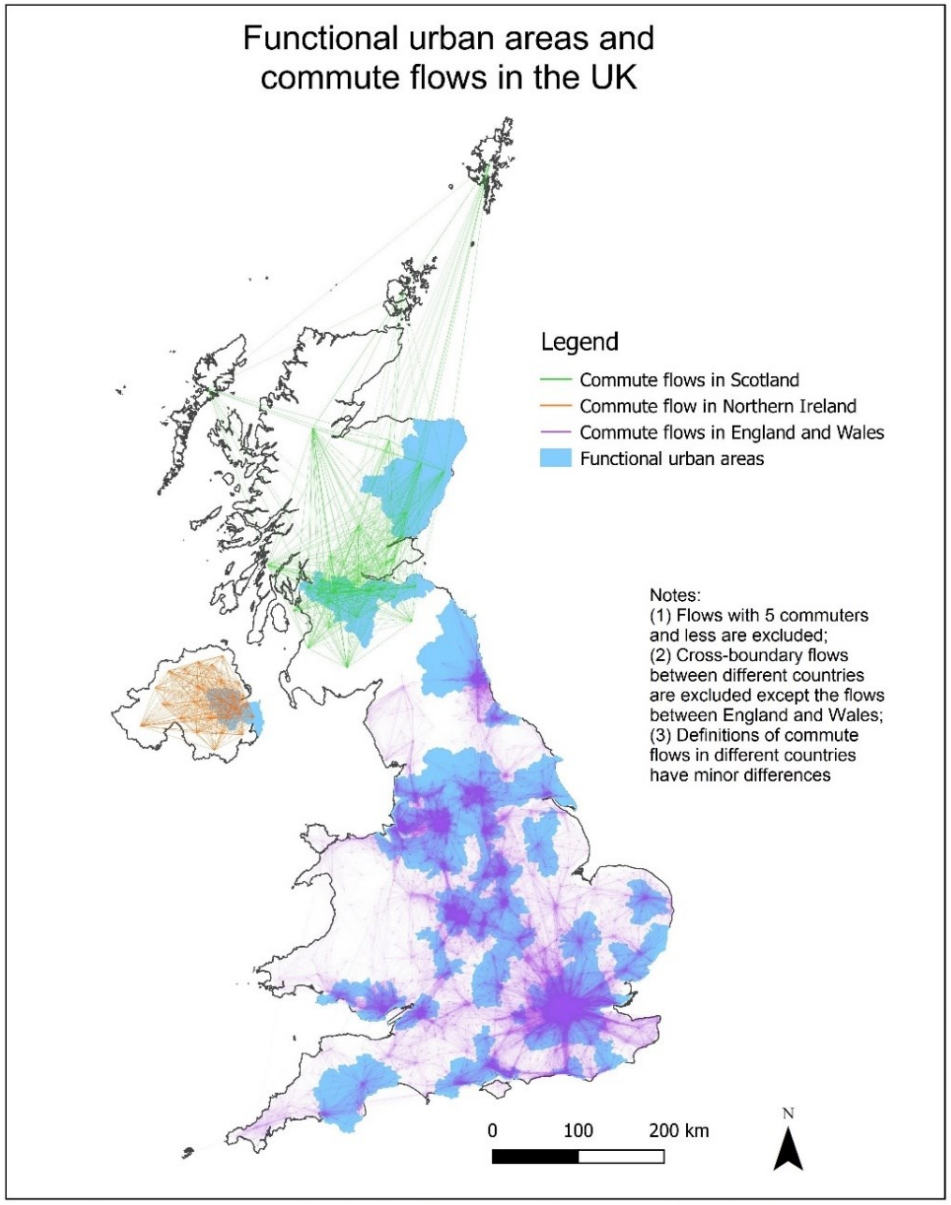

Figure 40 Commuting flows and functional urban areas

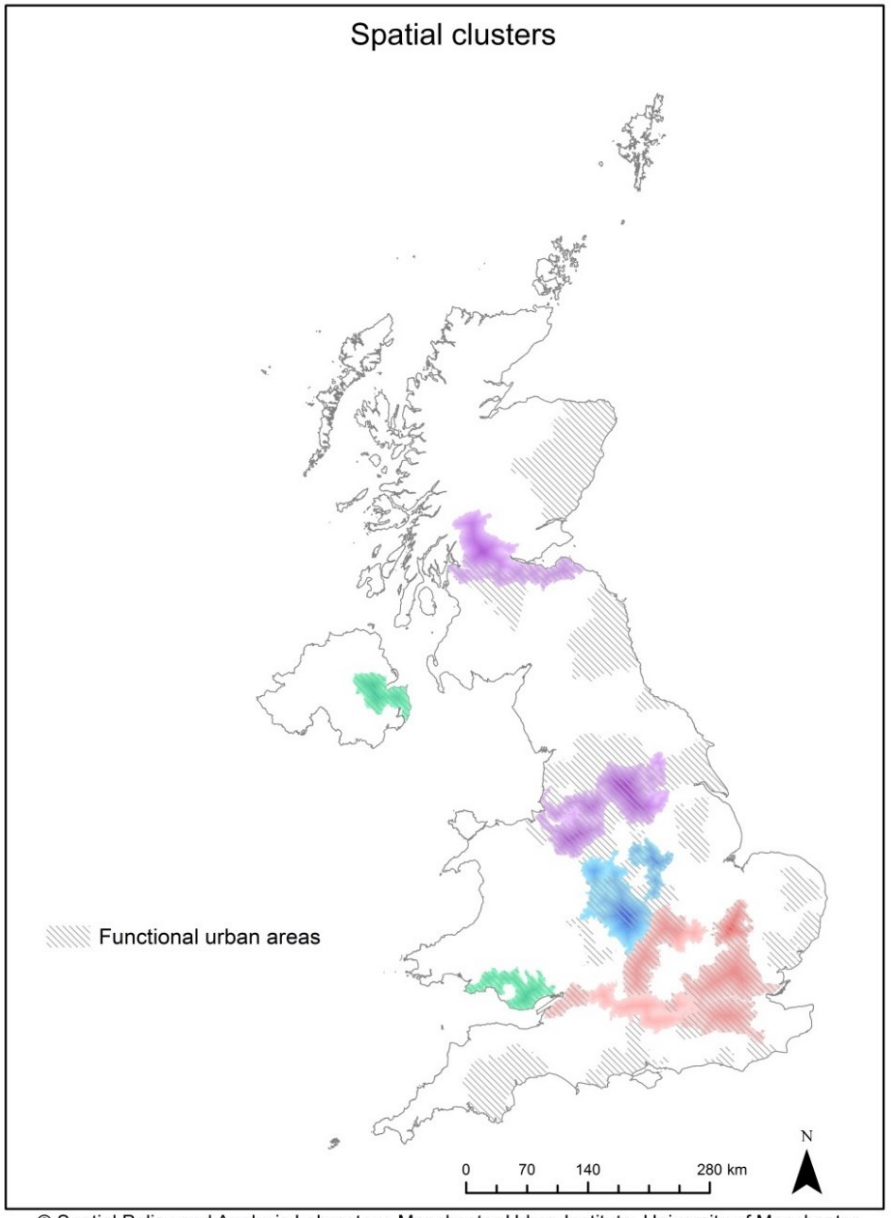

Figure 41 Indicative spatial clusters emerging from the analysis

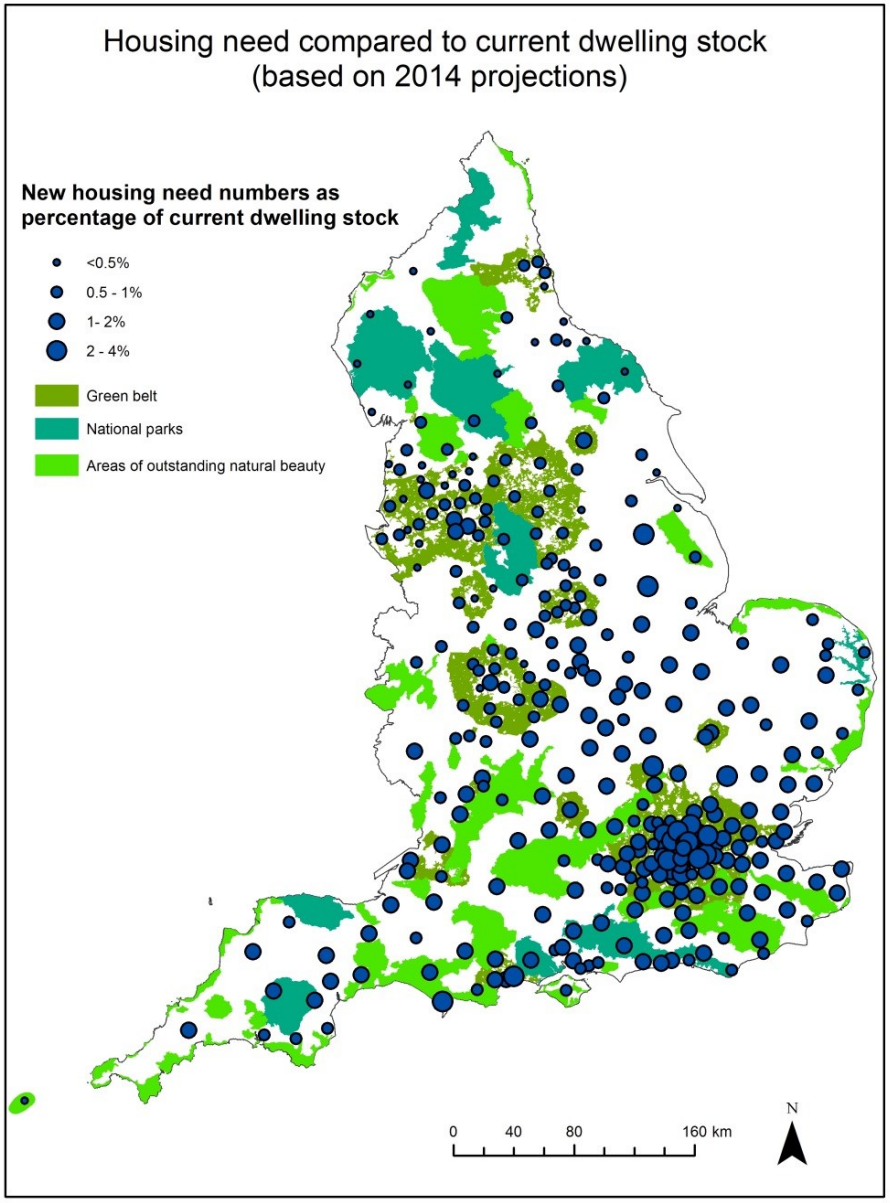

Figure 42 Projected housing needs and the planning constraints

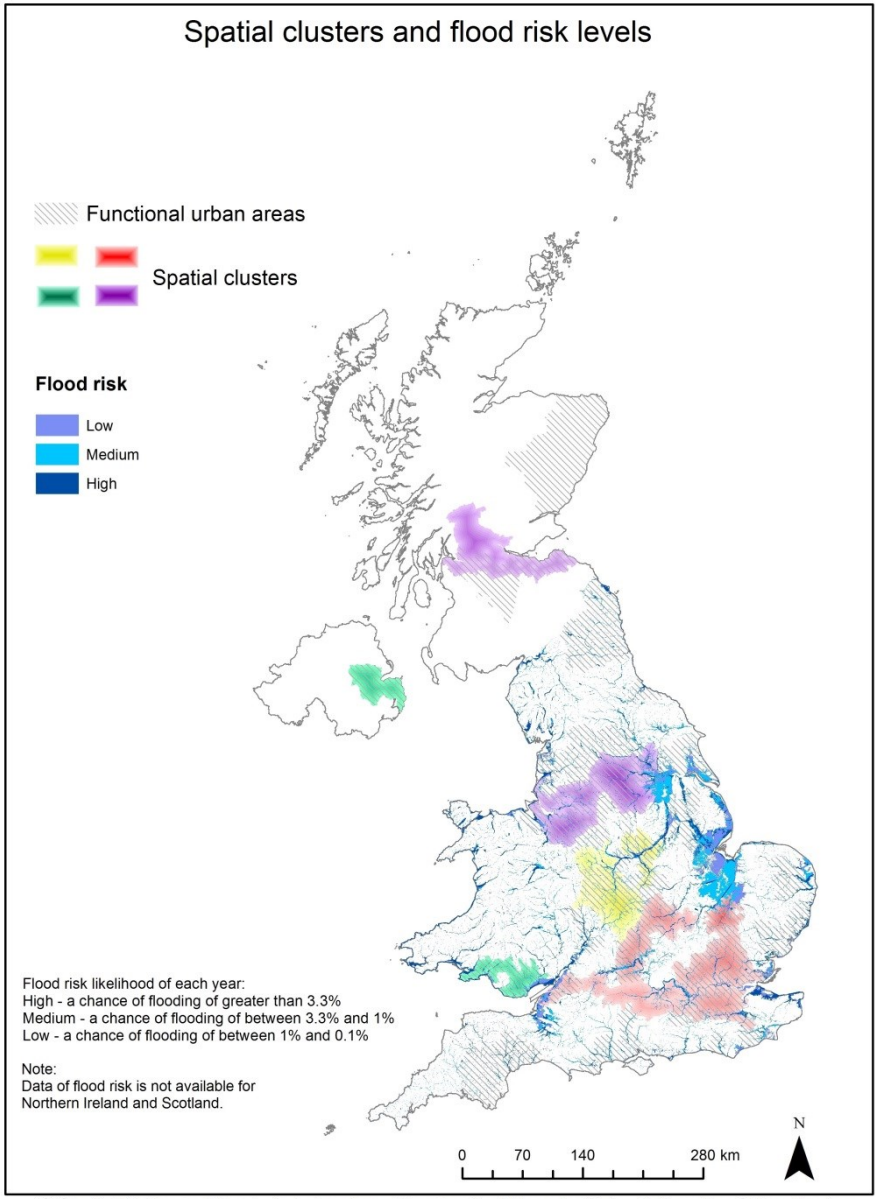

Figure 43 Spatial clusters and flood risk

Appendix: Data sources and notes

Figure	Theme	Unit	Data source	Note
Figure 1	Drivers of the four industrial revolutions		World Economic Forum (https://www.weforum.org/agenda/2015/09/navigating-the-next-industrial-revolution2/)	
Figure 2	GVA share in the manufacturing sector in 2016	Local authority	Office for National Statistics (https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/regionalgrossvalueaddedbalancedbylocalauthorityintheuk) See details in the table 'Regional Gross Value Added (Balanced) by Local Authority in the UK'	Calculated as '% of the UK total'
Figure 3	GVA share in 2016	Local authority		
Figure 4	Number of businesses in 2017 Number of large-scale businesses in 2017	Local authority	**Business**: Office for National Statistics (https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/datasets/ukbusinessactivitysizeandlocation) Dataset: UK business: activity, size and location (2017) See details in 'Table 5' **Population**: Office for National Statistics (1) Population structure (https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/annualmidyearpopulationestimates/mid2017) See details in the table for 'Figure 5' (2) Population estimates (https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland) See details in the table 'MYE2: Population estimates: Persons by single year of age and sex for local authorities in the UK, mid-2017'	A business/enterprise is the smallest combination of legal units (generally based on VAT and/or PAYE records) which has a certain degree of autonomy within an Enterprise Group. A large-scale business is defined as a business with 250 employees or above.
Figure 5	Number of businesses per 10,000 economically active population in 2017 Number of large-scale businesses per 10,000 economically active population in 2017	Local authority		
Figure 6	Employment share in the manufacturing sector in 2017	Local authority	Business Register and Employment Survey (1) Data for Great Britain	Calculated as '% of the UK total'

Figure 7	Employment share in the information and communication (IC) sector in 2017	Local authority	Official labour market statistics (https://www.nomisweb.co.uk) Sea details in the dataset of 'Business Register and Employment Survey' (2) Data for Northern Ireland BRES Publications and Tables 2017 (https://www.nisra.gov.uk/publications/bres-publications-and-tables-2017) See details in the table 'Employee jobs by DCA and Industry Section'	
Figure 8	Employment share in the professional, scientific, and technical (PST) sector in 2017	Local authority		
Figure 9	Above average UK employment share of manufacturing, IC and PST sectors	Local authority	See details in the data sources of Figure 6, 7, and 8.	Overlay map by using the indicators in Figure 6, 7, and 8
Figure 10	High share of manufacturing and above average IC and PST sectors	Local authority	See details in the data sources of Figure 6, 7, and 8.	Overlay map by using the indicators in Figure 6, 7, and 8
Figure 11	Number of life science companies	Company location	UK Biotech Database (http://ukbiotech.com/uk/portal/map.php)	The locations of life science companies were extracted from the website and processed by the research team.
Figure 12	Share of life science companies	Local authority	See details in the data source of Figure 11	
Figure 13	Job density in 2017	Local authority	Official labour market statistics (https://www.nomisweb.co.uk) Sea details in the dataset of 'Jobs density'	Jobs density is defined as the number of jobs in an area divided by the resident population aged 16-64 in that area.
Figure 14	Average annual pay for all employees in 2018	Local authority	Annual Survey of Hours and Earnings (1) Data for Great Britain Official labour market statistics (https://www.nomisweb.co.uk) Sea details in the dataset of 'Annual Survey of Hours and Earnings' (2) Data for Northern Ireland ASHE tables in ODS (https://www.nisra.gov.uk/publications/ashe-tables-ods)	
Figure 15	Percentage of economically active population in 2017	Local authority	Office for National Statistics (https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigr	

			ation/populationestimates/bulletins/annualmidyearpopulationestimates/mid2017) See details in the table for 'Figure 5'	
Figure 16	Unemployment rate by local authorities in 2019	Local authority	**Unemployment:** Office for National Statistics (https://www.ons.gov.uk/employmentandlabourmarket/peoplenotinwork/unemployment/datasets/claimantcountbyunitaryandlocalauthorityexperimental/current) See details in the dataset 'CC01 Regional labour market: Claimant Count by unitary and local authority (experimental)' **Population**: Refer to the data sources of Figure 4 and Figure 5	Unemployment rate is defined as the ratio of claimant count to population aged from 16 to 64.
Figure 17	Projected population change from 2014 to 2039	Local authority	(1) England data Office for National Statistics (2016-based population projections) (https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/localauthoritiesinenglandtable2) (2) Scotland data National Records of Scotland (2016-based population projections) (https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/population/population-projections/sub-national-population-projections/2016-based/detailed-tables) (3) Northern Ireland data Northern Ireland Statistics and Research Agency (2016-based population projections) (https://www.nisra.gov.uk/publications/2016-based-population-projections-areas-within-northern-ireland) (4) Wales data StatsWales (2014-based population projections) (https://statswales.gov.wales/Catalogue/Population-and-Migration/Population/Projections/Local-Authority/2014-based)	The 2016-based projections by local authority are not available for Wales. For Wales, the population change was calculated by using the 2014-based projections.
Figure 18	Residents aged 16 to 64 in employment with NVQ4+	Local authority	(1) Great Britain data Annual population survey (https://www.nomisweb.co.uk) See data in 2017 (2) Northern Ireland data	The data in 2017 are not available for Northern Ireland (NI). So the data used for NI

			Northern Ireland Statistics and Research Agency (https://www.ninis2.nisra.gov.uk/Download/Census%202011/CT0409NI.ods) Census data in 2011	are from the 2011 census.
Figure 19	Commute flows of the UK in 2011		Census flow data (http://wicid.ukdataservice.ac.uk/) See details in the table 'WU03UK'.	Flows with 5 commuters and less are excluded; Cross-country flows are excluded except the flows between Wales and England.
Figure 20	Commute flows of different socio-economic traits of workers in England, 2011		See the interactive portal: http://www.commute-flow.net/ and Hincks, S., Kingston, R., Webb, B. and Wong, C. (2017) A new geodemographic classification	
Figure 21	GERD of EU countries, 2008 and 2016	Country	Eurostats: Europe 2020 indicators - R&D and innovation (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Europe_2020_indicators_-_R%26D_and_innovation#General_overview) See details in 'Figure 2'	
Figure 22	Gross domestic expenditure on research and development by sector and region in 2017	Region	Office for National Statistics Gross domestic expenditure on research and development, UK: 2017 (https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/ukgrossdomesticexpenditureonresearchanddevelopment/2017) See details in the table for 'Figure 6'	The data for North East and North West were estimated by using the data in 2016
Figure 23	UK share of estimated R&D expenditure in 2016	NUTS 2 region	**GDP data** Eurostat: Regional gross domestic product by NUTS 2 regions - million EUR (https://ec.europa.eu/eurostat/web/products-datasets/-/tgs00003) **Estimated % of local GDP on R&D expenditure** Eurostat: Intramural R&D expenditure (GERD) by NUTS 2 regions (https://ec.europa.eu/eurostat/web/products-datasets/-/tgs00042)	UK share of estimated R&D expenditure was calculated based on estimated % of local GDP on R&D expenditure and regional gross domestic product.
Figure 24	Estimated % of local GDP on R&D expenditure in 2016	NUTS 2 region	See details in the data source of Figure 23	
Figure 25	Research market share index in 2014	University	Research Fortnight rankings for REF 2014 (https://www.theguardian.com/news/datablog/ng-interactive/2014/dec/18/university-research-excellence-framework-2014-full-	Market share was estimated by Research Fortnight that how

			rankings)	much the university will get of the overall available funding next year based on its REF results.
Figure 26	Life science and research market share index		See details in the data sources of Figure 12 and Figure 25.	Overlay map
Figure 27	Research Market Share and government and higher education R&D expenditure		See details in the data sources of Figure 22 and Figure 25.	Overlay map
Figure 28	Research Market Share and total R&D expenditure		See details in the data sources of Figure 23 and Figure 25.	Overlay map
Figure 29	English regional projects and programmes in £'s per capita	Region in England	HM Treasury NIP data , recalculated by Wong and Webb (2014) See details in: Wong, C. and Webb, B. (2014) Planning for Infrastructure: challenges to northern England, Town Planning Review, 85, 683-708.	
Figure 30	International scheduled terminal passengers in 2018	Airport	Civil Aviation Authority (https://www.caa.co.uk/Data-and-analysis/UK-aviation-market/Airports/Datasets/UK-Airport-data/Airport-data-2018/) Calculated based on 'Table 10_1_EU_and_Other_Intl_Pax_Traffic' in 2018	
Figure 31	Major port traffic in 2017	Port	Maritime and shipping statistics (https://www.gov.uk/government/statistics/port-freight-statistics-2017-final-figures) See details in 'Table: port0302'	
Figure 32	% of premises unable to receive 30Mbit/s in 2018	Output area	Ofcom Connected Nations (https://data.gov.uk/dataset/e218662f-2bdb-4e16-b4a8-8c16fdfd52bd/ofcom-connected-nations-previously-called-infrastructure-report-uk-internet-speeds-and-coverage-broadband-wifi-and-mobile#licence-info) See details in the dataset of 'Fixed output area 201801'	The speed of superfast broadband is from 30 to 300 Mbit/s
Figure 33	% of premises have access to ultrafast broadband in 2018	Output area		The speed of ultrafast broadband is at least 300 Mbit/s
Figure 34	Local enterprise partnerships		**Local enterprise partnerships** (1) Boundaries-2017 Office for National Statistics: Open Geography Portal (http://geoportal1-ons.opendata.arcgis.com/datasets/d4d519d1d1a1455a9b82331228f77489_2) (2) Overlapping parts (2018) Lichfields: Review of LEP geographies	Overlay maps of different institutional boundaries
Figure 35	Travel-to-work areas and local enterprise partnerships			
Figure 36	Travel-to-work-areas and combined authorities			

Figure 37	Local enterprise partnerships and combined authorities		(https://lichfields.uk/media/4376/lep-geography-review_august-2018.pdf) **Travel-to-work areas** Office for National Statistics: Open Geography Portal (http://geoportal.statistics.gov.uk/datasets/travel-to-work-areas-december-2011-ultra-generalised-clipped-boundaries-in-united-kingdom) **Combined authorities** Office for National Statistics: Open Geography Portal (http://geoportal1-ons.opendata.arcgis.com/datasets/89f12fc184d045a1a7ca9dd14fb4df3e_0)	
Figure 39	Cheshire, Merseyside and Great Manchester			
Figure 38	West Midlands Combined Authority and local enterprise partnership areas		Black Country LEP (https://www.blackcountrylep.co.uk/about-us/west-midlands-combined-authority/)	
Figure 40	Functional urban areas and commute flows		**Functional urban areas** Office for National Statistics (https://data.gov.uk/dataset/8ae85d1a-dad9-4185-80eb-87ef8188171e/urban-audit-functional-urban-areas-december-2016-full-clipped-boundaries-in-the-united-kingdom) **Commute flows** See details in data sources of Figure 19 and Figure 20	
Figure 41	Indicative spatial clusters emerging from the analysis		**Spatial clusters** Based on the analysis conducted by the research team **Functional urban areas** Office for National Statistics (https://data.gov.uk/dataset/8ae85d1a-dad9-4185-80eb-87ef8188171e/urban-audit-functional-urban-areas-december-2016-full-clipped-boundaries-in-the-united-kingdom)	Overlay map of spatial clusters and functional urban areas

Figure 42	Housing need compared to current dwelling stock	Local authority	**Housing need** Ministry of Housing, Communities & Local Government (https://www.gov.uk/government/consultations/planning-for-the-right-homes-in-the-right-places-consultation-proposals) See details in 'Housing need consultation data table' **Current dwelling stock** Ministry of Housing, Communities & Local Government (https://www.gov.uk/government/statistical-data-sets/live-tables-on-dwelling-stock-including-vacants) See details in 'Table 100: number of dwellings by tenure and district, England' **Area of outstanding natural beauty** Natural England Open Data (http://naturalengland-defra.opendata.arcgis.com/datasets/areas-of-outstanding-natural-beauty-england) **Green belt** Ministry of Housing, Communities & Local Government (https://data.gov.uk/dataset/d7fcc345-6028-4266-836c-1d7cc6b034c5/english-local-authority-green-belt-dataset) **National parks** Office for National Statistics (https://geoportal.statistics.gov.uk/datasets/national-parks-august-2016-full-extent-boundaries-in-great-britain)	Overlay map of projected housing needs and the planning constraints
Figure 43	Spatial clusters and flood risk		**Spatial clusters** Based on the analysis conducted by the research team **Flood risk** Environment Agency- Risk of Flooding from Rivers and Sea England data (https://data.gov.uk/dataset/bad20199-6d39-4aad-8564-26a46778fd94/risk-of-flooding-from-rivers-and-sea) Wales data	Data for Northern Ireland and Scotland is not available

			(http://lle.gov.wales/catalogue/item/FloodZ2/?lang=en)	
Table 1	Share of UK's gross expenditure on R&D by sector and region in 2017	Region	See details in the data source of Figure 22	
Table 2	Types of Broadband Connectivity in May 2018		Hutton, G. and Baker, C. (2018) Superfast broadband in the UK, House of Commons Library Briefing Paper, CBP06643, 13 November, p.5.	
Table 3	Funding spent on contracts under the superfast broadband programme in 2018		Broadband Delivery UK data on local broadband projects based on contacts signed at 24 September 2018 and adapted from Hutton and Baker (2018). See details in 'Box2' of the briefing paper by Hutton and Baker (2018)	

https://www.mui.manchester.ac.uk/spal/

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