# New insights on regional capital investment in the UK, 1997 to 2019


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## Abstract

Recent work by the Office for National Statistics (ONS) as part of their subnational statistics development programme has developed new estimates of regional capital investment, with asset breakdowns for the first time, as well as detailed geographic and industrial breakdowns, a longer time series, and improved methods. We use this Subnational Development dataset to establish new insights about the geography of capital investment in the UK between 1997 and 2019. We provide a range of descriptive analyses of these estimates, correlations and comparisons with other macroeconomic variables (including productivity), and a comparison of the Subnational Development dataset with previous estimates of regional capital investment from the Regional Accounts. One contribution is to develop region-specific deflators for capital investment, not present with the ONS datasets, such that we can explore the real growth of investment over time. We find that more productive regions tend to invest relatively more in intangible assets, and that these patterns are persistent over time.

## 1. Introduction

It is well known that productivity is a fundamental driver of living standards, and thus productivity differences across regions of a country can dictate variations in income and living standards across the population. This can facilitate regional inequality, and have implications for political, social, and economic outcomes.

A key driver of productivity levels and growth rates is the availability of capital assets. Capital can be both substitute and complement to other factors of production, notably labour – for instance, capital assets can enable automation and replacement of workers, and/or greater availability of capital assets per worker can enable more efficient production. Understanding regional variation in productivity is therefore enhanced by regional data on capital assets.

The preferred measure of capital input in productivity analysis is capital services, which aims to measure the flow of productive services delivered by the capital stock. Capital services measures give relatively more weight to assets that depreciate more quickly (such as ICT equipment and intangibles), since they are used more intensively in production. The data demands for capital services measures are substantial, and notably require capital stocks measures that are broken down by asset. In turn, capital stocks measures require long runs of capital investment data, along with appropriate deflators and assumptions about depreciation and retirement of those assets.

The Office for National Statistics (ONS) has an aim to produce regional multi-factor productivity (MFP) statistics (ONS, 2021b), which will require (amongst other things) regional capital services estimates. As part of the development towards that goal, and as part of their subnational statistics development programme, ONS published new experimental estimates of regional capital investment with an asset breakdown for the first time in 2022 (ONS, 2022a) – henceforth, we refer to these as the "Subnational Development" estimates.

Prior to these new Subnational Development estimates, ONS already published a set of estimates of regional capital investment (Gross Fixed Capital Formation (GFCF) in the national accounting terminology) as part of ONS' Regional Accounts – regional equivalents of the National Accounts. GFCF is a component of the expenditure measure of GDP, and so a necessary component of the Regional Accounts – henceforth, we shall refer to these as the "Regional Accounts" estimates. ONS transmitted these estimates to Eurostat as it was required to do (and since the UK left the EU, now transmits them to the OECD), and so also published the data on the ONS website for transparency. However, ONS included a substantial health warning about these data, advising users to "exercise caution" (ONS, 2019).[1] The Regional Accounts estimates of regional capital investment have a more limited industry and regional breakdown than the Subnational Development estimates, and no asset breakdown.

The contribution of this paper is two-fold. First, we document the similarities and differences, both methodologically and empirically, between the new Subnational Development estimates and existing Regional Accounts estimates of regional capital investment. Second, we provide some initial exploratory analysis of the new Subnational Development estimates,

[1] "These tables are official UK statistics that have not been assessed as fully compliant with the Code of Practice and are therefore not designated as National Statistics. Users are advised to exercise caution in the use of these estimates. This is due to concerns over the quality of the regional source data that are used to compile these estimates." (ONS, 2019)

which enable new insights into regional capital investment in the UK. These are the first official UK estimates of regional capital investment that contain an asset breakdown, so we explore that dimension of the data in some detail. It is worth noting that this paper does not provide any causal evidence for the behavioural of regional capital investment.

Using the new Subnational Development estimates, we explore the investment intensity and composition of investment across the UK, and how these change over time. We also explore the relationship between investment and productivity using more robust data than was previously available. These data are used to examine the relationship between investment in different asset types and productivity in the UK for the first time. While capital stocks and capital services measures are more relevant for productivity than capital investment, investment measures can still be informative if interpreted correctly.

We do not explore the industrial breakdown of the data in this paper, for two reasons. First, we preferred to focus on the asset-breakdown given it was available for the first time in this data and, in our view, of greater interest. The dataset is also large, covering three levels of geographical breakdown (a total of 232 regions), five asset groups, 21 industries (and the total), and 24 years – this makes it difficult to consider all dimensions in a single paper. Second, there is potential weakness in the industry breakdowns in the Subnational Development estimates. ONS (2022a) notes that statistical disclosure concerns required them to model some industry breakdowns rather than using the source data fully. To avoid spurious results arising from these quirks of the data, especially at more detailed levels of geography, we have used the industry breakdown sparingly.

The paper proceeds as follows. Section 2 provides a brief review of the literature on measuring regional capital investment, in the UK and internationally, and analysis with such data. In Section 3 we describe the Subnational Development and Regional Accounts estimates of regional capital investment, including the methods and underlying data sources, and the dimensions of the resultant data. Section 3 also details the sources of other data we use in the analysis, and the construction of deflators for regional capital investment developed in this paper (Annex A offers more details). Section 4 briefly compares the two datasets empirically. Section 5 presents a range of descriptive analysis of the Subnational Development estimates, including on the distribution and composition of investment, the relationship with productivity, and the relationship with other variables that may affect investment. Section 6 discusses the findings, and Section 7 concludes and offers some thoughts for the development of regional capital stocks estimates.

## 2. Literature

There is relatively little literature on regional capital investment, in the UK and internationally, due largely to data limitations. This section provides a non-exhaustive review of literature in this area, with a focus on the UK context. To our knowledge, there is very little recent literature for the UK, likely due to limitations of source data until recently. Indeed, Zymek and Jones (2020) and the 'Levelling Up White Paper' (UK Government, 2022) both note the lack of available data and research on regional capital investment and stocks in the UK.[2]

[2] "To our knowledge, there is no high-quality data available on stocks of capital per worker across UK regions." (Zymek and Jones, 2020, p.30).

### 2.1. Historic official estimates of regional capital investment in the UK

Regional estimates of capital investment were published by ONS as part of the regional accounts between 1977[3] (data for 1971-1975) and 2003[4] (data for 1995-2000). Thereafter the estimates were still made available on the ONS website annually since at least 2016 (data for 2000-2013) as a “user requested dataset”, with a substantial health warning. In 2016, ONS digitised historic regional Gross Fixed Capital Formation (GFCF) data from 1974 to 1995 and made them available on the ONS website.[5]

Historic estimates of regional GFCF were made possible due to the collection of data on capital investment from local units as part of the Annual Census of Production (ACoP). The history of ACoP (and subsequent surveys, including the Annual Business Inquiry and the Annual Business Survey) is described comprehensively by Smith and Penneck (2009). They document that ACoP asked respondents for capital investment estimates by “local units” (physical sites) between the 1970s and 1993, after which the collection of such data was discontinued as it was considered too burdensome. As such, the regional investment estimates between the 1970s and 1993 are likely to have been of good quality, albeit not consistent with the current concept of GFCF, or the geographic and industrial classifications used today. After 1993, regional investment data had to be allocated to regions via different (less accurate) means, which led to the publication of the data being discontinued after 2003.

The only comprehensive analysis of regional capital investment in the UK published by ONS to our knowledge was Cope and Flanagan (2003), as part of the Economic Trends December 2003 publication. The estimates at this time were based on data from the Annual Business Inquiry 2 (ABI/2), with data available for 1998 to 2000. The estimates were consistent with the European System of Accounts (ESA) 1995, meaning that the coverage of GFCF is not consistent with the same concept today; notably, research and development (R&D) had not yet been capitalised. These were also the first estimates to be based on the Nomenclature of Territorial Units for Statistics (NUTS) geographic breakdown, where previously they had been disaggregated by “Standard Statistical Regions”.

### 2.2. Regional capital stock estimates by Cambridge Econometrics

Consultancy firm Cambridge Econometrics have a series of work estimating regional capital stocks across EU countries, on behalf of the European Commission. The original work, described in Cambridge Econometrics (2010) and Derbyshire, Gardiner, and Waights (2013), involved the development of capital stocks estimates for NUTS2 regions in all 27 EU countries. This used regional Gross Fixed Capital Formation (GFCF) data available from Eurostat, as provided by member states, with industry breakdowns, typically from 1995 to 2007. The source regional GFCF data contained incomplete asset breakdown, so Cambridge Econometrics imputed this on the basis of national shares in some cases. For the UK, this was an earlier vintage of the Regional Accounts capital investment data we consider in this paper, with modifications. Given substantial gaps in the investment data at

[3] https://escoe-website.s3.amazonaws.com/wp-content/uploads/2023/03/14235407/ET-289-Regional-accounts.-Further-estimates-for-1975-including-regional-fixed-investment-Nov-1977.pdf
[4] https://escoe-website.s3.amazonaws.com/wp-content/uploads/2020/01/01233003/ET-601-Economic-Trends-Dec-2003.pdf
[5] https://www.ons.gov.uk/economy/regionalaccounts/grossdisposablehouseholdincome/adhocs/006226historiceconomicdataforregionsoftheuk1966to1996

the time, they used various “filling-in mechanisms”, including the use of various ratios and scalars.

These estimates were updated in subsequent years, as described in Gardiner, Fingleton, and Martin (2020) and Gardiner, Fingleton, Martin and Barbieri (2022), and now form part of the European Commission’s ARDECO[6] database. This used updated regional GFCF data (available from Eurostat, as provided by member states), and updated methodologies for the capital stocks estimates. The source data at this time did not include an asset breakdown, so the authors instead applied depreciation rates and deflators at the more aggregated level of total investment, by broad industry group and region.

The authors use these regional capital investment and capital stocks to conduct analysis, including studies on the role of the capital stock in regional total factor productivity (TFP) in the UK (Gardiner, Fingleton, and Martin, 2020). They find an important role of capital stock in explaining geographic dispersion in productivity levels across the UK, although find that the importance of the (measured) capital stock is falling over time, which they attribute to a rising importance of human capital. These findings depend crucially on the quality of the regional capital stocks data, and thus on the quality of the regional capital investment data and associated assumptions. In the UK context, this stems ultimately from the Regional Accounts estimates (which ONS says they have quality concerns about (ONS, 2019)). The use of total investment, rather than disaggregation by asset, also means the deflators and depreciation rates will be suboptimal. The authors had little choice but to use these data as there was no alternative source until recently.

### 2.3. Other work on regional capital investment in the UK

To our knowledge there is limited work on the geography of total capital investment or business investment in the UK other than that published by ONS. Much more is known about the geography of components of total capital investment, including research and development (R&D) and public investment.

The geography of R&D expenditure has been studied by a range of authors, using the geographic information available from the various R&D surveys run by the ONS, and administrative data for the government and Higher Education sectors. For instance, Forth and Jones (2020) explore R&D expenditure by business, government, non-profits, and universities, principally by NUTS1 and NUTS2 geographies. A common interest is the extent to which R&D expenditure is or is not concentrated around the so-called “Golden triangle” of universities in Oxford, Cambridge, and London (sometimes known as “Loxbridge”).

Various authors have also studied the geography of public investment, also sometimes referred to as “infrastructure” (although we would note that not all infrastructure is publicly funded, and not all public investment is in infrastructure). For instance, Rutherford (2018) documents various metrics relating public spending on transport systems. The Infrastructure and Projects Authority (IPA)’s “National Infrastructure and Construction Pipeline”[7] contains information on the geographic distribution of past and proposed infrastructure investment; regional analysis of the pipeline is included in Infrastructure and Projects Authority (2021).

[6] https://www.eui.eu/Research/Library/ResearchGuides/Economics/Statistics/DataPortal/ERD
[7] https://www.gov.uk/government/publications/national-infrastructure-and-construction-pipeline-2021

Much less is known about regional business investment, especially in recent work. One exception is work by Richard Harris, who has conducted considerable analysis of productivity and capital at firm-level, often focussing on the manufacturing industry. Harris (1983) developed regional capital stock estimates for the manufacturing industry, using earlier data from Gleed and Rees (1979) and updating it using data from the Annual Census of Production. Harris (1997) updates and extends regional capital stock estimates for productivity analysis, again building principally from firm-level data, adjusting for premature scrapping of the capital stock which varies across regions. Harris and Trainor (1997) analyse productivity growth in manufacturing industries in UK regions between 1968 and 1991, including the role of capital stocks. Harris and Moffat (2015) estimate total-factor productivity at the firm-level, using firm-level capital stock estimates, and analyse the results for Local Enterprise Partnerships (LEPs).

We suspect that the lack of research explicitly on regional capital investment is due in large part to the unavailability of high-quality data, which the Subnational Development estimates of regional capital investment from ONS begins to address.

### 2.4. Regional capital investment and capital stock estimates in other countries

All member states of the European Union are required to produce estimates of regional Gross Fixed Capital Formation (GFCF) as part of their Regional Accounts and transmit these data to Eurostat. The UK's contribution to this is the Regional Accounts estimates of capital investment described in section 3.1 of this paper, and the ONS now sends these data to the OECD instead of to Eurostat following the UK's departure from the EU.

As such, regional GFCF data exist for all EU countries. In most cases these data are available for 2000 onwards, up to a fairly recent year, although this varies somewhat by country. The Regional Accounts requirements are for geographic breakdown at NUTS2 level (equivalent to ITL2 in the UK), and for a fairly high-level industry aggregation. The data are provided in current prices only. Data can be accessed from the Eurostat statistics website[8], and the European Commission's ARDECO database (see section 2.2 and footnote 6).

Countries are required to follow the guidance in the Eurostat "Manual on regional accounts methods" (Eurostat, 2013), of which sections 7 and 8 deal with GFCF.

Countries with federal or state systems may have a greater incentive to develop high-quality data with geographical disaggregation. Statistics Canada publishes an impressive suite of GFCF and capital stocks data, for its 13 territories and provinces, extending back to 1961.[9] This data includes more detailed asset breakdowns than the new Subnational Development estimates of capital investment, but no industry detail.

The Australian Bureau of Statistics publishes data on private new capital investment for its 9 states, based on its quarterly Survey of New Capital Expenditure.[10] The data are quarterly, extend back to 1987, and are available in current prices and chained volume measures (adjusted for inflation). A limited asset breakdown is included, with series for "Buildings and structures" and "Plant and Machinery" as well as "Total" investment. No industry breakdown

[8] https://ec.europa.eu/eurostat/databrowser/product/page/nama_10r_2gfcf
[9] https://www150.statcan.gc.ca/n1/daily-quotidien/211117/dq211117b-eng.htm
[10] https://www.abs.gov.au/statistics/economy/business-indicators/private-new-capital-expenditure-and-expected-expenditure-australia/latest-release

is available in the state-level data. These data are survey outputs, and not fully consistent with National Accounts concepts or measures.

The most comprehensive regional capital investment data available in any country in the world to our knowledge is Spain, developed by the BBVA Foundation and Valencian Institute of Economic Research (Ivie).[11] Since 1995 they have published detailed breakdowns of capital investment and capital stocks with regional breakdowns. The dataset today contains annual data on capital investments and capital stocks, with detailed industry and asset breakdowns for 19 geographies (17 regions and two autonomous cities) (NUTS2 level) and over 50 provinces (NUTS3 level) in Spain. The data run from 1964 to 2021 for the regional data, and to 2019 for the provincial data. The asset breakdown is even more detailed than available in the national GFCF data in the UK, and since 2021 also includes uncapitalised intangible assets. The industry breakdown is more detailed at regional level (25 industries) than provincial level (15 industries), but still very detailed in each case.

To our knowledge, the new Subnational Development regional capital investment dataset in the UK includes more industrial, regional, and asset disaggregation than available in most countries.

## 3. Data and methods

This section outlines the existing Regional Accounts estimates (section 3.1) and new Subnational Development estimates (section 3.2) of regional capital investment from the ONS, especially the methods used in the different datasets. It also outlines the construction of price deflators for regional capital investment (section 3.3), developed in this paper (and described in more detailed in Annex A), and supplementary data used for analysis in this paper (section 3.4).

Table 1 provides a summary of the dimensions of the two regional capital investment datasets published by the ONS. Both are annual and cover around 20 years, with some industry breakdown and some regional breakdown. The new Subnational Development estimates provide an asset breakdown while the Regional Accounts estimates do not, and the Subnational Development estimates also offer more industry and regional breakdown than the Regional Accounts estimates.

Table 1 – Summary of regional capital investment datasets

| | **Regional Accounts dataset (existing)** | **Subnational Development dataset (new)** |
|---|---|---|
| Method | Industry-based approach | Asset-based approach |
| Time span | 2000-2020 | 1997-2020 |
| Regional granularity | ITL1, ITL2 | ITL1, ITL2, ITL3 |
| Asset breakdown | None | 5 major asset groupings |
| Industry breakdown | Industry groups (11 + Total) | Industry sections (21 + Total) |
| Periodicity | Annual | Annual |

[11] https://www.fbbva.es/bd/el-stock-y-los-servicios-del-capital-en-espana/

### 3.1. Regional Accounts estimates of regional capital investment

The estimates of regional capital investment (GFCF) from the ONS Regional Accounts are published annually, with the latest data covering the years 2000 to 2020. The approach is 'industry-based', with the ONS Regional Accounts Quality and Methodology Information (QMI) describing it as "top-down" (ONS, 2019). The data were transmitted to Eurostat, as was required of all member countries; since the UK left the EU, these data are now transmitted to the OECD. However, the ONS publish the data with a health warning. The QMI (ONS, 2019) says: "Domestic publication was discontinued following the 2003 publication, due to concerns regarding quality and the lack of suitable data sources."

The "top-down" method uses a regional indicator for each industry to apportion the national investment total of each industry to the regions. For instance, ONS (2019) describes how a regional indicator from Defra (Department for Environment, Food and Rural Affairs) is used to apportion the national investment data for the agriculture industry (SIC 2007 section A) to regions. A majority of industries use data on capital investment from the Annual Business Survey (ABS) to regionalise national GFCF data of each industry. Data on total net GFCF from the ABS is apportioned from reporting units (statistical level) to local units (site level), based principally on the spread of employment data; the resultant regional pattern is used to allocate the national GFCF data of each industry to regions. Regional apportionment uses other data, such as employment figures from the Business Register and Employment Survey (BRES) for some industries (such as finance, which is mostly not covered by the ABS).

There are two assets for which a bespoke regional allocation is used: dwellings, and research and development (R&D). More details are in ONS (2019).

The estimates are published for 11 industry groups, which are SIC 2007 sections or groups of sections.[12] No breakdown by asset is available. Estimates are provided at ITL1 geographic level (9 English regions, Scotland, Wales, and Northern Ireland) and at ITL2 level (41 regions, and extra-regio).

There are several drawbacks to these data. The estimates have no asset breakdown, which is important for analysis relating to productivity, such as the calculation of capital services measures, understanding the role of ICT and intangible investment, and so forth. The level of regional and industry breakdown is also limited. The method used does not account for differential regional patterns by asset (with the exception of dwellings and R&D), which implicitly assumes that the regional pattern of investment in all assets is equivalent within each industry, which is unlikely to be true. While the ABS is a large business survey, it does not cover all industries and does not collect data on all capital assets – as such, it can at best give a partial idea of the regional pattern of capital investment. All assets not captured in the ABS (such as entertainment originals) are implicitly given the same pattern as those assets which are included. Industries not sampled for the ABS (especially finance) use even weaker proxies of investment, such as employment.

[12] Production (BCDE), with manufacturing (C) also provided separately; retail and wholesale, transportation, and accommodation and food services (GHI); professional services, and admin services (MN); public admin and defence, education, and health and social care (OPQ); arts and entertainment, other services, and households as employers (RST).

In sum, this dataset is unlikely to give good estimates of regional capital investment given the quality of the data and methods used. The dimensions of the data also mean it is of limited use for analysis. Until recently it was, however, the only option for researchers.

### 3.2. Subnational Development estimates of regional capital investment

The newly published dataset results from the ONS Subnational Development programme, instigated by renewed interest in regional economic statistics in the UK. These new estimates (referred to as the Subnational Development estimates in this paper) use a different approach to the Regional Accounts estimates, following an 'asset-based' method and more 'bottom-up' than 'top-down' (compared with an industry-based top-down approach in the Regional Accounts estimates). The data are published as "experimental statistics"[13] by ONS, and ONS (2022a) says they "anticipate that there will be further user engagement, quality assurance and development of these statistics."

The regional breakdown extends to ITL3 level which has 179 regions, as well as ITL2 (41 regions) and ITL1 (12 regions and countries). These are the same geographical classifications used in productivity statistics published by ONS, and a range of other economic statistics, enabling comparison and analysis. The dataset also expands the industry breakdown by providing estimates at the SIC 2007 section-level without any aggregations thereof, for a total of 21 industries (and the total). The estimates cover 1997 to 2020.

The data published in the Subnational Development dataset uses a high-level asset breakdown of five asset groups, outlined in Table 2. The asset coverage is consistent with the national accounts, and the asset breakdown in the dataset is an aggregation of the asset breakdown in official GFCF statistics. The breakdown separates ICT equipment and intangible assets given interest from productivity scholars in these assets. No further breakdowns are available publicly.

The new approach is an 'asset-based' approach which finds regional indicators for 18 asset-types and combines this with regional industry information where available to estimate regional capital investment at the industry-asset level. The benefit of this approach is the use of regional information for each asset, enabling a wider range of data sources, methods, and modelling assumptions to be used. For instance, the new estimates make regional estimates of own-account software investment using data from the Annual Survey of Hours and Earnings (ASHE), following the same method as the national estimates.[14] While the Regional Accounts estimates of capital investment would allocate own-account software investment in the same way as ships or buildings, using data from the ABS, the Subnational Development estimates can reflect the unique properties of own-account software to better distribute the investment across the country. This method also ensures consistency with national estimates since the same method as the national estimates is used at regional level.

[13] For more on "experimental statistics", see https://www.ons.gov.uk/methodology/methodologytopicsandstatisticalconcepts/guidetoexperimentalstatistics

[14] For a description of the method and data sources used in national estimates of own-account software investment in the UK, see Martin (2022).

Table 2 – Breakdown of asset types used in estimation and publication of the Subnational Development estimates of regional capital investment

| Asset grouping – published | Asset types – estimation level |
|---|---|
| Buildings and structures | Dwellings<br>Other buildings and structures (roads)<br>Other buildings and structures (general)<br>Costs of ownership transfer on non-produced assets<br>Other buildings and structures (land improvements) |
| Transport equipment | Ships<br>Road transport vehicles<br>Other transport equipment (including aircraft) |
| ICT equipment | Computer hardware<br>Telecoms |
| Other tangible assets | Other machinery and equipment<br>Cultivated assets<br>Weapons systems |
| Intangible assets | Research and development<br>Mineral exploration and evaluation<br>Computer software and databases (purchased)<br>Computer software and databases (own-account)<br>Entertainment, literary or artistic originals |

*Source: ONS (2022a).*
*Notes: Only the "publication level" is available publicly, and hence is the level of detail available for use in this paper.*

Given the asset approach, the new Subnational Development estimates use a wide range of data sources and methods, described in the accompanying article (ONS, 2022a) and dataset. Examples include project-level construction data from Barbour ABI for estimates of other buildings and structures; regional house completion data for dwellings; and data from the Department for Transport, and local and central government, for roads. Estimates of R&D are little changed from the Regional Accounts estimates (albeit extended to ITL3). For assets without bespoke methods or datasets, the apportioned ABS data are used, and then constrained to national totals. Approaches for some assets vary across the time series, notably for buildings and structures which changes in 2008 from using data from the ABS to using commercial data from Barbour ABI from 2008 onwards. For assets which use the ABS, the change from the Annual Business Inquiry (ABI) to the ABS in 2008 may also impact consistency over time.

In total, the Subnational Development estimates make estimates for 18 asset-types, which are then aggregated into five asset groups for publication, and thus this is the level available for use in this paper. The five asset groups are:

- Buildings and structures (including dwellings)
- Information and communications technology (ICT) equipment
- Transport equipment
- Other tangible assets (other machinery and equipment, and cultivated assets)
- Intellectual property products (intangible assets)

The asset grouping strikes an effective balance between statistical quality issues and usability. The separation of ICT equipment and intangible assets from other assets is important for productivity scholars. A drawback is the inclusion of dwellings with non-dwellings buildings, making it more difficult to understand non-residential investment (also known as “business investment” in the UK); however, all dwellings investment is allocated to the real estate industry (SIC 2007 section L) so can be excluded easily.

The Subnational Development dataset offers considerably more granularity than the Regional Accounts estimates, which enables a range of new analysis. For instance, the lower level of regional granularity allows for an understanding of local capital investment, useful for local policymakers, and shows the differences within larger regions where before this was not possible. As previously described, the asset breakdowns are a big step forward for productivity analysis. Most fundamentally, the new Subnational Development estimates are thought to be higher quality than the existing Regional Accounts estimates, so even at more aggregated geographic levels should improve the reliability of analysis.

The new approach in the Subnational Development dataset has greatly improved the level of detail available and uses a range of new methods and data sources which are likely to improve quality of the regional capital investment estimates. However, ONS also note the potential for further improvement, and some shortcomings of these estimates. In particular, ONS (2022a) notes that the risk of statistical disclosure and some gaps in data availability have required the use of some modelling to fill gaps, which may have distorted regional allocations for some assets. For instance, ONS describe how estimates for the agriculture industry may have been affected: “estimates of investment in some assets by organisations in industry A (agriculture) appear to be overstated in urban areas and understated in rural areas” (ONS, 2022a). ONS says they will develop these estimates further in due course subject to user feedback and additional research.

### 3.3. Construction of price deflators for regional capital investment

Both datasets considered in this paper contain regional capital investment estimates in current prices only; that is, they are not adjusted for inflation. For analysis of growth over time, it is important to control for price changes. As such, this paper constructs price indices for regional capital investment, and so computes constant price (real) estimates of capital investment for each region.

Regional price data for capital investments are not available, so we cannot reflect regional variations in price trends for capital investment perfectly. The best we can do is reflect, to the greatest extent possible, differences in asset and industry mix within each region. That is our approach to deflation for regional capital investment.

In short, we use implied deflators from national industry-by-asset investment data (that is, UK GFCF data consistent with the UK National Accounts), weighted together to match the composition of investment in each region. There are several more technical details outlined in Annex A.

### 3.4. Other data used in the analysis

We use a number of other datasets to shed light on regional capital investment. Most of these are sourced from the ONS and follow the ITL regional breakdowns.

Data on gross value added (GVA) by region are sourced from the ONS Regional Accounts. Data are available from 1998 to 2020, in current and constant prices, for ITL1, ITL2 and ITL3 breakdowns, and with considerable industry breakdown in each case. More details are available in ONS (2019).

We source data on population by ITL region from ONS Regional Accounts, based on mid-year population estimates from ONS. More details are available in ONS (2019).

Data on hours worked and productivity are taken from ONS sub-national productivity statistics. Data are available from 2004 to 2019, for ITL1, ITL2 and ITL3 breakdowns. No industry breakdown is available for ITL2 and ITL3, and only a limited industry breakdown is available for ITL1. More details are available in ONS (2022b) and ONS (2017).

We also use data on inflows of Foreign Direct Investment (FDI), published as part of ONS' suite of FDI statistics. Inflows of FDI by ITL1 and ITL2 regions are available from 2015 to 2020. An industry breakdown is available (with less detail at ITL2 level), but with a large number of suppressions for statistical disclosure reasons which make the data difficult to use. More details are available in ONS (2022c).

Data on the number of businesses are extracted from *nomis*[15], based on information from the Inter-Departmental Business Register (IDBR). Breakdowns on a geographical basis consistent with the ITL classification are only available from 2016 onwards. For more information on the IDBR and associated business statistics see ONS (2022d).

## 4. Comparison of datasets

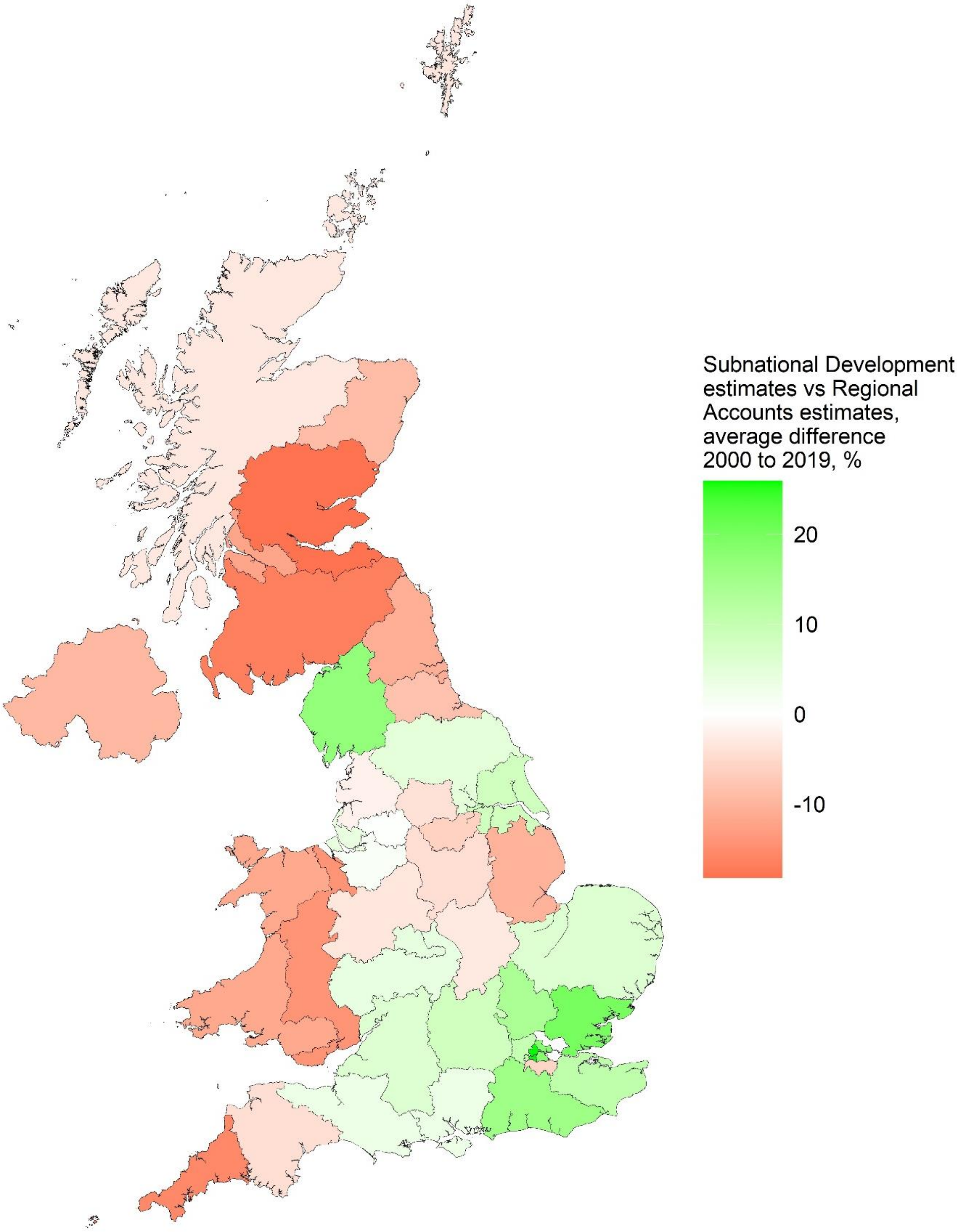
This section briefly analyses differences between the Subnational Development and Regional Accounts estimates of regional capital investment published by ONS (see section 3.1 and 3.2 for a description of these datasets).

Figure 1 shows the percentage difference between the two sets of estimates of regional capital investment, averaged over 2000 to 2019, for ITL2 regions. Areas in green have more investment in the Subnational Development estimates, and areas in red have more investment in the Regional Accounts estimates. Comparison is only possible for total investment (since there is no asset breakdown in the Regional Accounts estimates), and at ITL2 and ITL1 georaphical level (since the Regional Accounts estimates did not cover ITL3).

Investment estimates are higher in parts of London, the South East and East of England in the new Subnational Development estimates, which likely reflects improved estimates of investment in dwellings that better account for the value of the dwelling rather than just their number (ONS, 2022a). Investment is also notably higher in the Subnational Development estimates in Cumbria, Lincolnshire, and Gloucestershire, Wiltshire and the Bristol/Bath area. Not all of London and the South East have higher estimates however, with Outer London to the south in particular having lower estimates. There are substantially lower estimates in much of Scotland, Wales, Northern Ireland, and much of the Midlands.

[15] https://www.nomisweb.co.uk/default.asp

Figure 1 – Percentage differences between Regional Accounts estiamtes and Subnational Development estimates of total capital investment, 2000 to 2019 average, ITL2 regions




*Source: ONS, authors' calculations.*
*Notes: Areas in green are estimated to have more investment in the Subnational Development estimates, and areas in red are estimated to have more investment in the Regional Accounts estimates.*

The Subnational Development estimates are slightly better correlated with other economic variables than the Regional Accounts estimates. Table 3 shows correlation coefficients between investment and GVA, hours worked, and population, at ITL1 and ITL2 level, for the two sets of regional investment estimates. At ITL1 level there is little to chose between the two sets of investment estimates. At ITL2 level, the Subnational Development estimates are on average slightly better correlated with GVA, and slightly worse correlated with population, than the Regional Accounts estimates, although the differences are small. Of course, having closer correlations does not necesssarily mean the new estimates are better, and having a perfect correlation would be indicative of a suboptimal “top-down” method for estimating investment. However, economic theory would suggest a fairly stong positive relationship between investment and other macroeconomic variables, such as those in Table 3.

Table 3 – Correlation coefficients between total investment and other variables, by ITL level, Subnational Development and Regional Accounts datasets, average and range

| | **GVA (current prices) (2000 – 2019)** | **Hours worked (2004 – 2019)** | **Population (2000 – 2019)** |
|---|---|---|---|
| ITL1 | | | |
| Subnational Development dataset (new) | 0.97<br>(0.93 – 0.99) | 0.97<br>(0.95 – 0.99) | 0.92<br>(0.87 – 0.96) |
| Regional Accounts dataset (existing) | 0.95<br>(0.92 – 0.97) | 0.97<br>(0.95 – 0.98) | 0.93<br>(0.89 – 0.96) |
| ITL2 | | | |
| Subnational Development dataset (new) | 0.93<br>(0.86 – 0.97) | 0.93<br>(0.91 – 0.95) | 0.65<br>(0.54 – 0.76) |
| Regional Accounts dataset (existing) | 0.89<br>(0.80 – 0.95) | 0.92<br>(0.90 – 0.95) | 0.70<br>(0.56 – 0.80) |

*Source: ONS, authors’ calculations.*

*Notes: Means are unweighted averages across years for which data are available (see column headers for years). Values in brackets on the second line of each cell are the minimum and maximum yearly correlation coefficient.*

Table 4 does similarly to Table 3 but for correlations of investment intensity (investment per hour worked, and investment divided by GVA) and productivity (output per hour worked). The Subnational Development estimates appear much better correlated with productivity than the Regional Accounts estimates. For both ITL1 and ITL2, the correlation of investment per hour worked with productivity is much larger in the Subnational Development estimates than in the Regional Accounts estimates. We would expect a positive association between investment per hour and labour productivity, given capital deepening (increasing capital stock per hour worked) is one driver of labour productivity growth in growth accounting decompositions. These results, along with those from Table 3, suggest that the new Subnational Development regional investment estimates better reflect economic reality than the existing Regional Accounts estimates.

Table 4 – Correlation coefficients between output per hour worked and investment intensity, by ITL level, Subnational Development and Regional Accounts datasets, average and range

| | Investment / GVA (2004 – 2019) | Investment / Hours worked (2004 – 2019) |
|---|---|---|
| ITL1 | | |
| Subnational Development dataset (new) | -0.36 (-0.71 – 0.08) | 0.61 (0.30 – 0.83) |
| Regional Accounts dataset (existing) | -0.55 (-0.74 – -0.38) | 0.18 (-0.33 – 0.56) |
| ITL2 | | |
| Subnational Development dataset (new) | -0.24 (-0.44 – 0.03) | 0.44 (0.21 – 0.71) |
| Regional Accounts dataset (existing) | -0.37 (-0.65 – -0.08) | 0.19 (-0.10 – 0.41) |

*Source: ONS, authors' calculations.*
*Notes: Means are unweighted averages across years for which data are available (2004 to 2019). Values in brackets on the second line of each cell are the minimum and maximum yearly correlation coefficient.*

## 5. Exploratory analysis of Subnational Development estimates

The results are organised by type of analysis: section 5.1 provides a high-level summary of the distribution of capital investment across the UK; section 5.2 explores links between capital investment and productivity at regional level, including the composition of investment across the regional productivity distribution; section 5.3 considers some factors affecting capital investment, including past investment behaviours of the region and foreign direct investment (FDI); and section 5.4 looks at the growth of capital investment over time across the UK, and the potential impact of Brexit on regional investment growth.

### 5.1. Regional distribution of capital investment

Table 5 summarises the correlations between the Subnational Development regional investment estimates and other macroeconomic variables of interest, for each of the three ITL classification levels, and for each asset type. The correlations are calculated in each year with contemporaneous data – that is, on repeated cross-sections. The average correlation coefficient across the years is given, along with the range over the years given. The years used reflect data availability of the non-investment variables.

The correlation coefficients are mostly quite high, indicating a fairly close relationship between the investment estimates and the other economic variables. This is to be expected, since larger regions would tend to have larger GVA, hours worked, and investment. This might also partially reflect the methods used to construct the investment estimates since they in part depend on the apportionment of survey data according to employment (which itself will be related to both GVA and hours worked).

In general, investment is better correlated with GVA, hours worked and population at higher levels of regional aggregation than at lower levels. Correlations are typically stronger with GVA and hours worked, than with population, especially at lower levels of regional aggregation – this is reassuring, since correlations with these economic variables should be stronger. Correlations with GVA and hours worked tend to be weaker with investment in transport equipment than any of the other asset groups, likely reflecting the volatile and skewed nature of investment in transport equipment. Correlations with population tend to be strongest for buildings and structures than other assets, likely because the buildings and structures asset includes dwellings and most infrastructure assets (such as roads), which one would expect to be more closely related to population than other assets.

Table 5 – Correlation coefficients between investment and other variables, by ITL level, by asset, average and range

| | **GVA (current prices) (1998 – 2019)** | **Hours worked (2004 – 2019)** | **Population (1998 – 2019)** |
|---|---|---|---|
| ITL1 | | | |
| Total investment | 0.97<br>(0.93 – 0.99) | 0.97<br>(0.95 – 0.99) | 0.92<br>(0.87 – 0.96) |
| Buildings and structures | 0.96<br>(0.89 – 0.99) | 0.96<br>(0.93 – 0.99) | 0.91<br>(0.81 – 0.98) |
| Transport equipment | 0.76<br>(0.63 – 0.97) | 0.85<br>(0.74 – 0.95) | 0.90<br>(0.83 – 0.96) |
| ICT equipment | 0.98<br>(0.95 – 1.00) | 0.97<br>(0.94 – 0.99) | 0.90<br>(0.85 – 0.95) |
| Other tangible assets | 0.93<br>(0.89 – 0.98) | 0.96<br>(0.93 – 0.98) | 0.93<br>(0.88 – 0.95) |
| Intangible assets | 0.92<br>(0.87 – 0.96) | 0.91<br>(0.87 – 0.95) | 0.86<br>(0.82 – 0.90) |
| ITL2 | | | |
| Total investment | 0.93<br>(0.86 – 0.97) | 0.93<br>(0.91 – 0.95) | 0.65<br>(0.54 – 0.76) |
| Buildings and structures | 0.86<br>(0.77 – 0.95) | 0.88<br>(0.78 – 0.93) | 0.72<br>(0.52 – 0.88) |
| Transport equipment | 0.66<br>(0.42 – 0.88) | 0.72<br>(0.58 – 0.82) | 0.62<br>(0.16 – 0.80) |
| ICT equipment | 0.92<br>(0.86 – 0.98) | 0.89<br>(0.86 – 0.94) | 0.54<br>(0.38 – 0.70) |
| Other tangible assets | 0.86<br>(0.80 – 0.92) | 0.83<br>(0.79 – 0.88) | 0.52<br>(0.38 – 0.65) |
| Intangible assets | 0.90<br>(0.86 – 0.93) | 0.86<br>(0.80 – 0.90) | 0.49<br>(0.45 – 0.52) |
| ITL3 | | | |
| Total investment | 0.89<br>(0.83 – 0.93) | 0.89<br>(0.85 – 0.92) | 0.63<br>(0.55 – 0.73) |
| Buildings and structures | 0.79<br>(0.61 – 0.91) | 0.82<br>(0.64 – 0.89) | 0.69<br>(0.55 – 0.83) |
| Transport equipment | 0.56<br>(0.26 – 0.76) | 0.58<br>(0.40 – 0.72) | 0.53<br>(0.22 – 0.78) |
| ICT equipment | 0.86<br>(0.78 – 0.92) | 0.83<br>(0.80 – 0.88) | 0.52<br>(0.40 – 0.65) |
| Other tangible assets | 0.81<br>(0.73 – 0.86) | 0.80<br>(0.77 – 0.84) | 0.54<br>(0.42 – 0.65) |
| Intangible assets | 0.80<br>(0.75 – 0.85) | 0.73<br>(0.69 – 0.79) | 0.40<br>(0.36 – 0.43) |

*Source: ONS, authors' calculations.*
*Notes: Means are unweighted averages across years for which data are available (restricted by the non-investment variables, see column headers for years). Values in brackets on the second line of each cell are the minimum and maximum yearly correlation coefficient.*

Investment is well correlated with GVA and hours worked in part because all the variables reflect the economic size of the region. It is therefore useful to define a measure that accounts for this size and allows us to compare regions on a more equal footing. We shall construct a measure of “investment intensity” as investment in current prices divided by gross value added (GVA) in current prices. A similar measure, which we shall call “investment per hour”, is constructed as investment in current prices divided by hours worked. In each case, the numerator and denominator relate to the same year. We can do this for each of the asset types, and total investment.

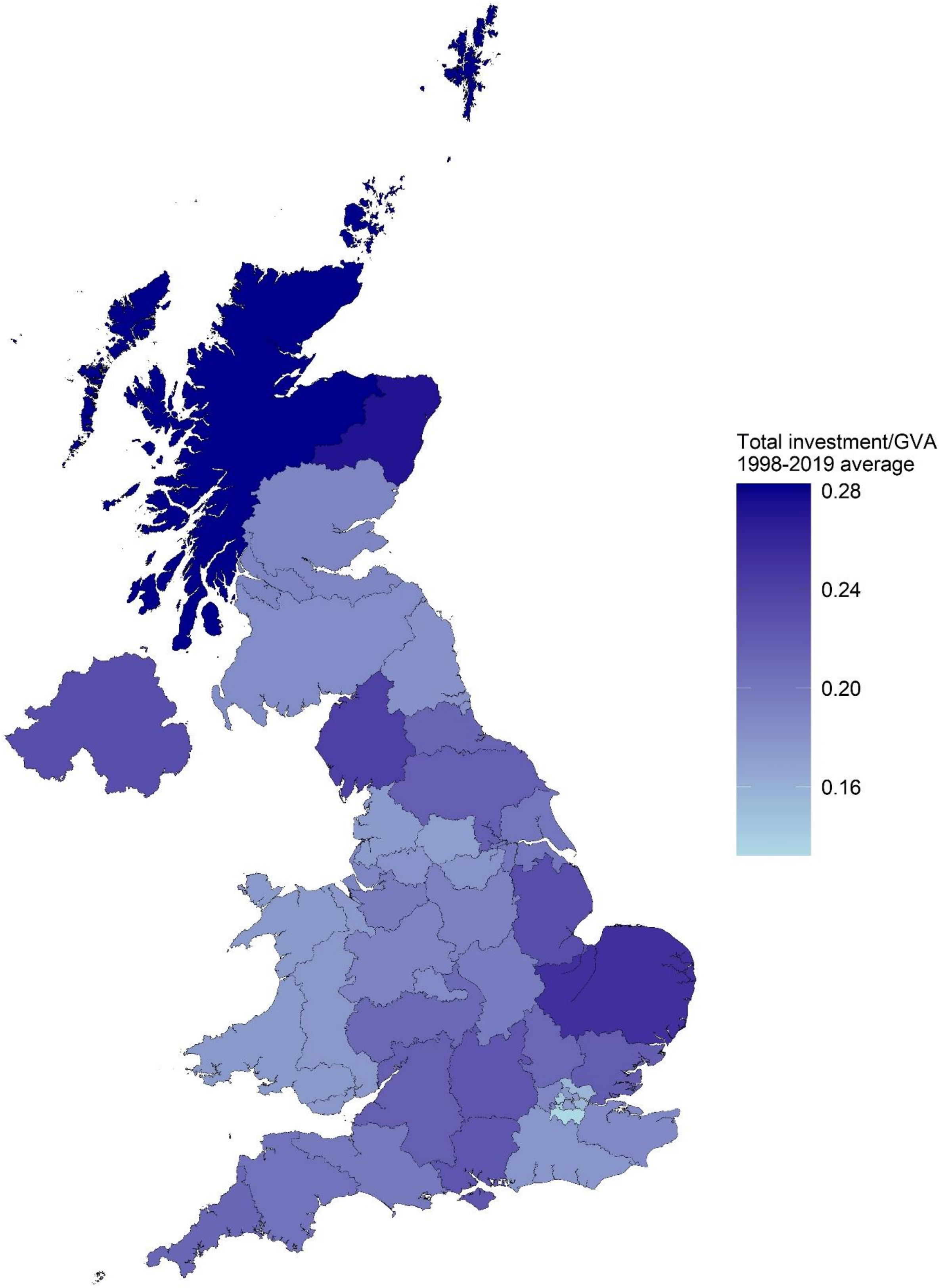
Figure 2 shows the pattern of total investment intensity (total investment divided by GVA) across the country (defined by ITL2 regions), on average between 1998 and 2019. There is substantial variation across the UK. ITL2 regions with the highest investment intensity include the Scottish Highlands, Aberdeenshire, Cumbria, East Anglia, most of the South West of England, and Northern Ireland. Broadly, investment intensity appears lower in the North of England and the Midlands than in the South (with some exceptions), and relatively low across most of Wales. Surprisingly, London and the South East appear to have low investment intensity, which likely reflects their relatively high levels of GVA.

Figure 3 shows the share of intangible investment in total investment, by ITL2 region, on average between 1998 and 2019. Higher intangible shares are prevalent in the East and South East of England, and to a lesser extent London. Areas of high intangible shares form a ‘ring’ around London, with the share declining as the distance from London increases – this would be consistent with the so-called “Golden triangle” of universities in Oxford, Cambridge, and London (sometimes known as “Loxbridge”). There is also a hotspot in Cheshire. The intangible share tends to be lowest in most of Scotland, the North of England, and the East Midlands.

Annex B includes an equivalent chart for ITL3 regions, where more detailed patterns emerge – for instance, the intangible share appears higher around major cities, such as Belfast, Edinburgh, and Glasgow. However, care must be taken in interpreting the results for any individual ITL3 region. ONS (2022) notes that for some assets the ITL3 level estimates use some modelling, which includes “grouping ITL3 regions” to avoid risks of statistical disclosure. As such some ITL3-level estimates, particularly by asset, may not be as precise as the ITL2-level estimates. We still believe, however, that the general patterns and relationships at ITL3-level are informative.

Figures 4a to 4d show the shares in total investment of each of the tangible asset groups: buildings and structures (including commercial and industrial buildings, structures, and dwellings), ICT equipment, transport equipment, and other tangible assets (including other machinery and equipment, cultivated assets, and weapons systems). The pattern for buildings and structures is largely the opposite of that for intangibles in Figure 3, with shares typically higher outside the East, South East and London (with the exception of West London). This does not necessarily mean these regions are doing a lot of investment in buildings, but rather the investment they are doing is relatively more skewed towards buildings than other regions. Consider West and North Wales: both areas have a high share of investment in buildings according to Figure 4a; however, Figure 2 shows that these areas have a low total investment intensity (total investment divided by GVA).

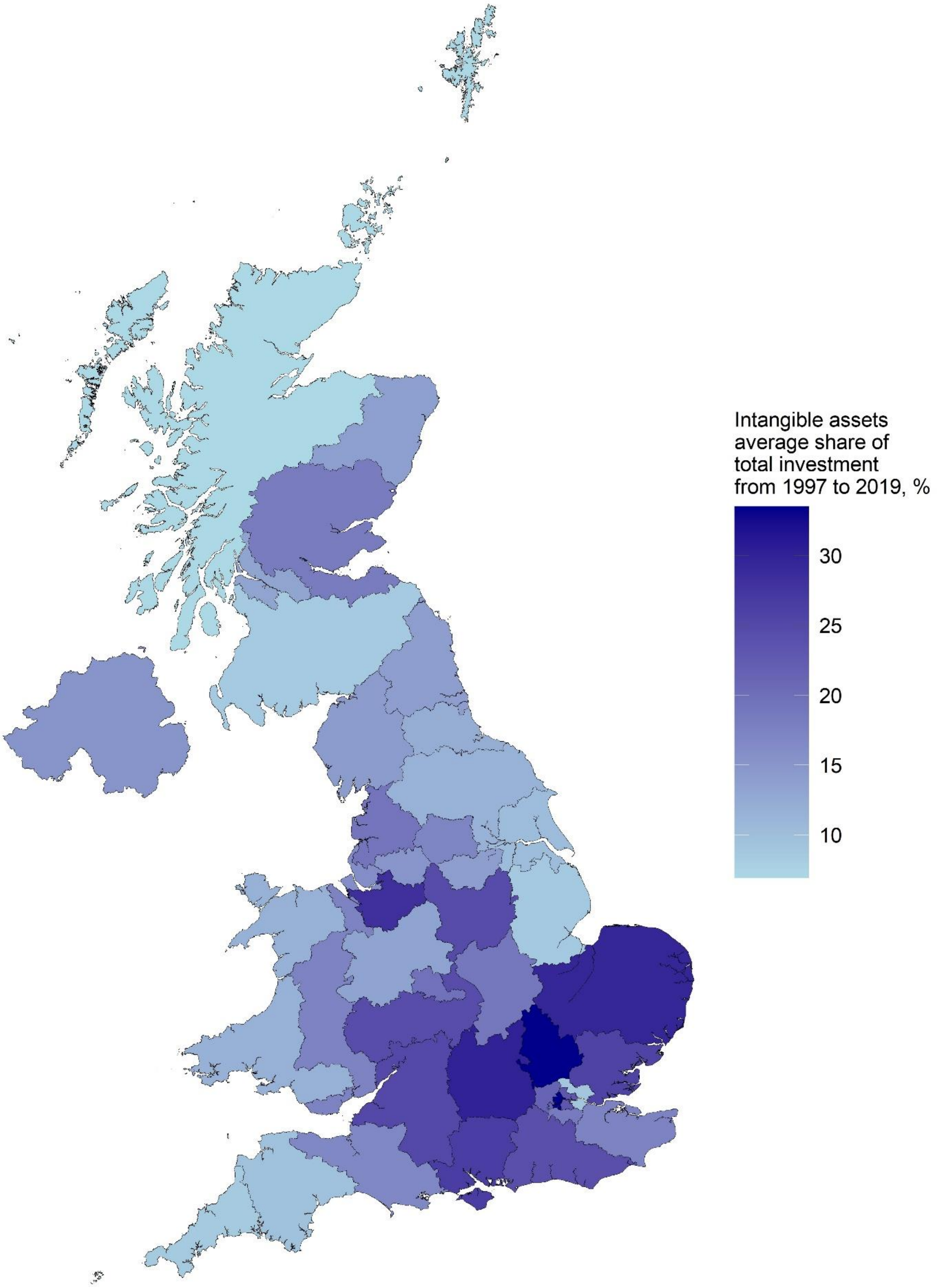
Figure 2 – Total investment intensity, 1998 to 2019 average, current prices, ITL2 regions




*Source: ONS, authors' calculations.*

*Notes: Investment intensity is investment divided by GVA. Range starts in 1998 due to availability of regional GVA data.*

Figure 3 – Intangible assets share of total investment, 1997 to 2019 average, ITL2 regions




*Source: ONS, authors' calculations.*

Figures 4a to 4d – Tangible assets share of total investment, by asset, 1997 to 2019 average, ITL2 regions

Figure 4a – Buildings and structures

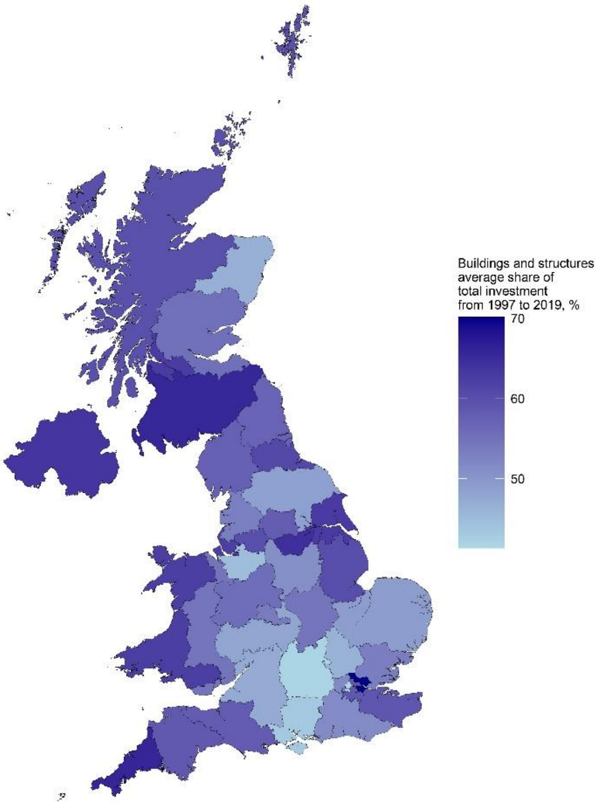



Figure 4b – ICT equipment

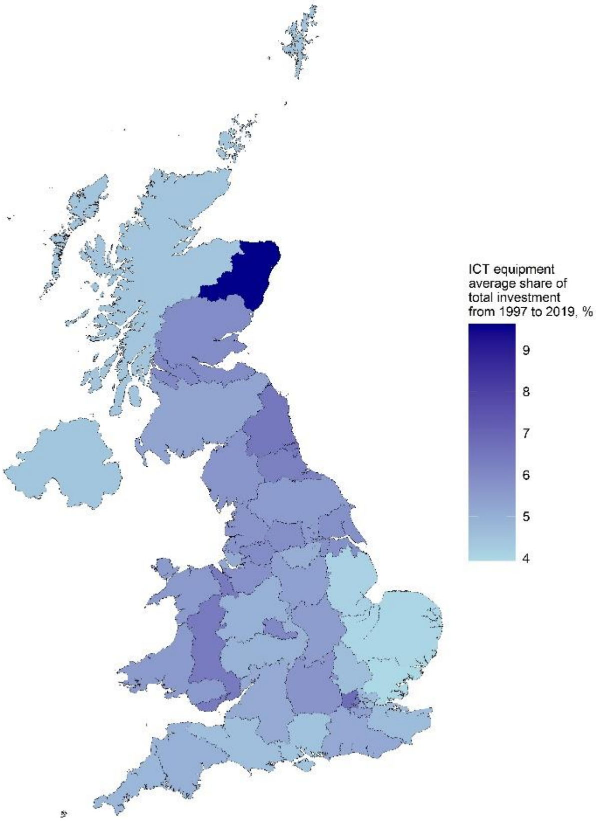



Figure 4c – Transport equipment

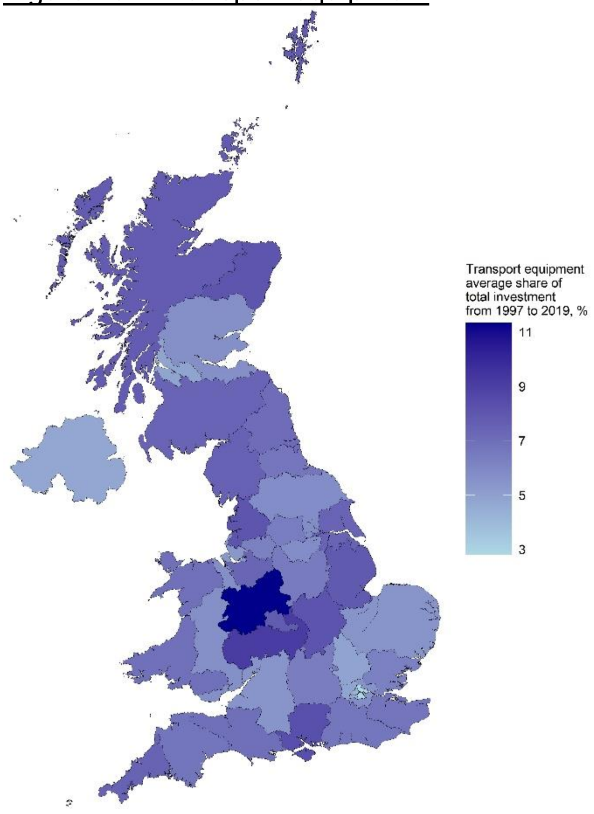
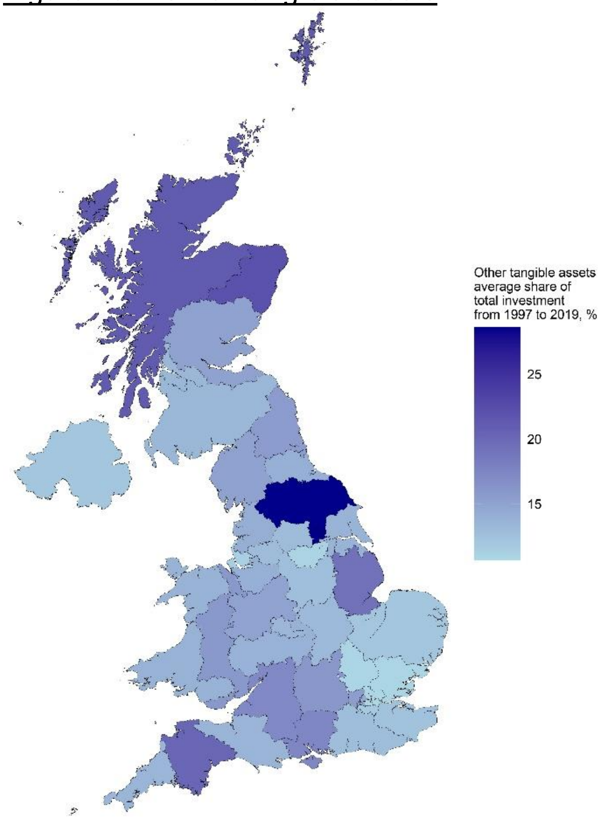



Figure 4d – Other tangible assets




*Source: ONS, authors' calculations.*
*Notes: Scales vary by asset.*

There is relatively little variation in the proportion of investment in ICT equipment (Figure 3b). Aberdeenshire has a relatively high share, which could be associated with the oil and gas operations in that region, or a relatively more recent emergence of a financial services industry in that area. Other regions with above average shares of ICT equipment investment are West London, Birmingham, and much of the North of England.

The share of investment in transport equipment is much lower in London than elsewhere in the UK. The highest share is in Shropshire and Staffordshire. The shares appear slightly higher in regions with coastal areas, for instance Hampshire and Northern Scotland. For other tangible assets, there is a very high share in North Yorkshire, covering the Yorkshire Moors, which may be associated with weapons systems – excluding the public administration and defence industry reduces the prominence of other tangible assets in this region. The other tangible assets share is also high in Devon (which includes Exmoor) possibly for a similar reason, and in Lincolnshire and the Scottish Highlands.

Investment appears to vary more within regions than between them. Table 6 shows a measure of variability of two investment measures (investment per hour worked, and investment intensity), for all five assets and total investment, for ITL3 regions within each ITL1 region, and between ITL1 regions. The measure of variability is the coefficient of variation, which is the standard deviation divided by the mean; this makes the measure scale invariant, and thus suitable for comparison across regions of different size and scale. We use investment per hour worked and investment intensity such that variation does not reflect differences in the size of each region.

Row 1 of Table 6 shows, for total investment and then for each of the assets, and for two measures of investment, that variation between ITL1 regions is relatively low. The largest variations between ITL1 regions are for intangible assets and transport equipment. The remaining rows show the variation between ITL3 regions within each ITL1 region. In almost all cases, the variation within ITL1 regions is greater than the variation between ITL1 regions – this is summarised in the final row. Variation within ITL1 regions is often high for transport equipment, likely reflecting its lumpy and unusual nature – for instance, it is particularly high in the South East, reflecting variation between high transport investment intensity in Southampton, and lower intensity elsewhere. Variation is also often high for intangibles, for instance in the East and East Midlands (reflected also in Figure 3). Variation is more uniform and lower for buildings and structures, since all regions will invest in dwellings, buildings and structures to some degree.

The specific coefficients of variation for between ITL3 regions within ITL1 regions in Table 6 should not be over-interpreted. As previously noted, estimates for some ITL3-level regions, particularly by asset, may be unreliable. However, the broader point of Table 6 – that within-region variation is greater than between-region variation – we believe is robust to any data issues in specific instances.

Table 6 – Coefficients of variation within and between ITL1 regions, investment per hour worked and investment intensity, by asset, 1998 to 2019 average

| | Total investment | | Buildings and structures | | ICT equipment | | Transport equipment | | Other tangible assets | | Intangible assets | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **/Hour** | **/GVA** | **/Hour** | **/GVA** | **/Hour** | **/GVA** | **/Hour** | **/GVA** | **/Hour** | **/GVA** | **/Hour** | **/GVA** |
| Between ITL1s | 0.15 | 0.12 | 0.15 | 0.17 | 0.18 | 0.14 | 0.25 | 0.24 | 0.18 | 0.16 | 0.41 | 0.35 |
| Within: | | | | | | | | | | | | |
| East | 0.37 | 0.34 | 0.34 | 0.32 | 0.34 | 0.31 | 0.76 | 0.66 | 0.39 | 0.40 | 1.02 | 0.98 |
| East Midlands | 0.35 | 0.27 | 0.31 | 0.29 | 0.37 | 0.29 | 0.34 | 0.36 | 0.35 | 0.32 | 1.09 | 0.92 |
| London | 0.39 | 0.40 | 0.55 | 0.54 | 0.52 | 0.50 | 0.87 | 0.83 | 0.53 | 0.51 | 0.53 | 0.47 |
| North East | 0.25 | 0.25 | 0.36 | 0.33 | 0.48 | 0.44 | 0.18 | 0.18 | 0.41 | 0.39 | 0.45 | 0.39 |
| North West | 0.34 | 0.30 | 0.46 | 0.40 | 0.36 | 0.35 | 0.33 | 0.33 | 0.35 | 0.35 | 0.72 | 0.71 |
| Northern Ireland | | 0.22 | | 0.28 | | 0.32 | | 0.28 | | 0.38 | | 0.34 |
| Scotland | 0.33 | 0.33 | 0.45 | 0.42 | 0.50 | 0.44 | 0.64 | 0.65 | 0.63 | 0.61 | 0.54 | 0.52 |
| South East | 0.27 | 0.27 | 0.25 | 0.29 | 0.43 | 0.37 | 1.07 | 0.96 | 0.63 | 0.63 | 0.76 | 0.74 |
| South West | 0.26 | 0.24 | 0.26 | 0.28 | 0.42 | 0.33 | 0.26 | 0.26 | 0.64 | 0.66 | 0.62 | 0.54 |
| Wales | 0.21 | 0.20 | 0.31 | 0.26 | 0.28 | 0.27 | 0.22 | 0.27 | 0.26 | 0.29 | 0.39 | 0.46 |
| West Midlands | 0.32 | 0.24 | 0.33 | 0.28 | 0.49 | 0.39 | 0.29 | 0.35 | 0.53 | 0.51 | 0.78 | 0.65 |
| Yorkshire and The Humber | 0.28 | 0.24 | 0.37 | 0.32 | 0.38 | 0.33 | 0.29 | 0.28 | 0.58 | 0.57 | 0.33 | 0.32 |
| # ITL1s greater than Between | 11/11 | 12/12 | 11/11 | 12/12 | 11/11 | 12/12 | 9/11 | 11/12 | 11/11 | 12/12 | 9/11 | 10/12 |

*Source: ONS, authors' calculations.*

*Notes: GVA data covers 1998 to 2019; hours worked data covers 2004 to 2019. Variation within relates to coefficient of variation between ITL3 regions within ITL1 region. Coefficient of variation is standard deviation divided by mean. Hours worked data for ITL3 regions within Northern Ireland not available.*

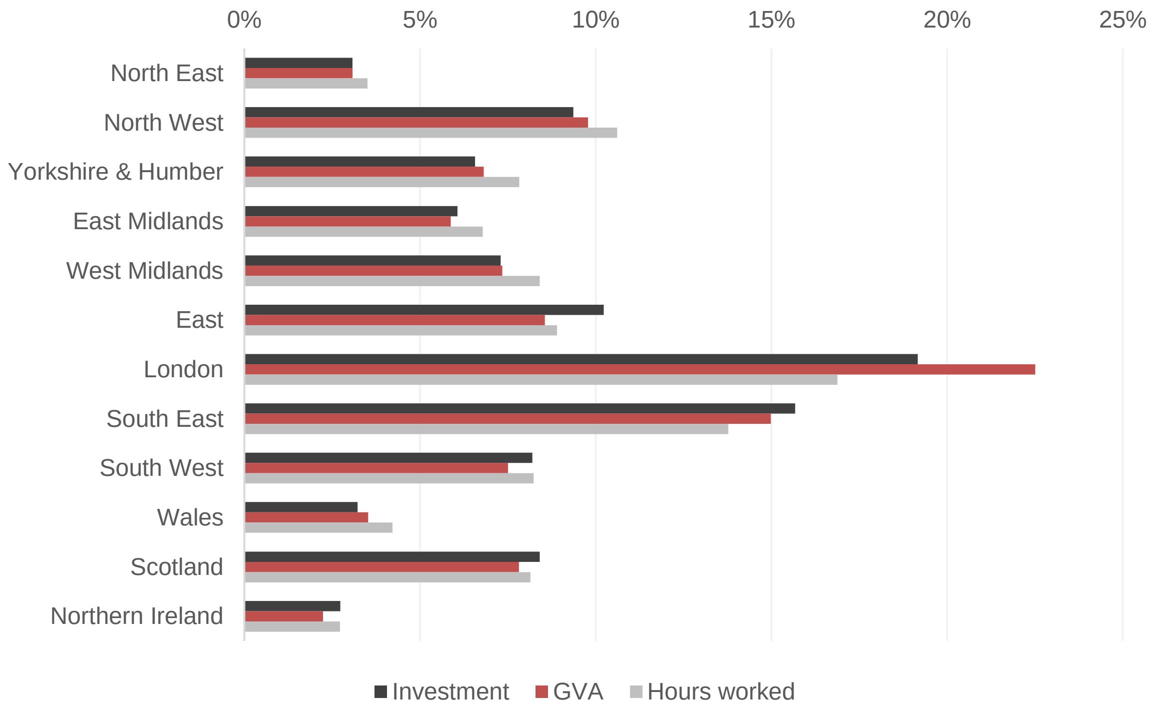
### 5.2. Links with labour productivity

We shall use GVA per hour worked as our labour productivity measure, so it is worth considering the relationship between investment and both GVA and hours worked. Figure 5 shows the share that each ITL1 region accounts for in total UK investment, hours worked, and GVA on average between 2004 and 2019. London accounts for the most of each variable, but a substantially larger share of total GVA (23%) than of investment (19%) or hours worked (17%). Since London accounts for a larger share of GVA than hours worked, it must be more productive than the UK average – a region accounting for exactly the same share of both would have a level of productivity equal to the UK average. The South East is the only other region to account for a larger share of UK GVA than UK hours worked, and thus the only other ITL1 region more productive than the UK average.

Turning to investment, London accounts for a larger share of UK investment than of hours worked, implying it has a level of investment per hour worked higher than the UK average. But London's share of investment is lower than its share of GVA, implying below average levels of investment intensity (defined as investment divided by GVA). This might seem counterintuitive but is a direct result of its high productivity levels. More productive regions will have higher GVA, and thus appear to have lower investment intensity (investment/GVA).

Economically, this could reflect a range of factors. Some industries are more capital intensive than others, and the industrial composition of regions will differ. Regions with a lot of capital-intensive industries might be expected to have higher levels of investment, all else equal. But such regions will also tend to be more productive (as measured by labour productivity), implying higher levels of GVA. The result on investment intensity is less clear. Regions that are less productive might also have greater propensity to grow, and thus attract more capital investment from government or outside investors. This could create a negative association between the level of productivity and level of investment at a point in time.

Figure 5 – ITL1 region shares of UK totals of capital investment, GVA, and hours worked, 2004 to 2019 average




*Source: ONS, authors' calculations.*

In growth accounting analysis of productivity, growth in output is decomposed into growth in inputs of labour and capital, and a residual term known as total factor productivity (TFP). Growth in capital input has an assumed positive association with growth in output. This can be re-expressed as a decomposition of changes in labour productivity by dividing both output and inputs by the volume of labour, such that growth in labour productivity can be decomposed into "capital deepening" (capital stock per unit of labour input) and TFP.

In sum, we would expect a positive relationship between investment per hour worked and labour productivity, but the association between investment intensity (investment/GVA) and productivity is less clear.

Table 7 tests these relationships in the data, showing correlation coefficients of output per hour worked with investment per hour worked and with investment intensity (investment divided by GVA). This is repeated for each level of geographical breakdown, and for each asset as well as total investment. The cells show the average correlation coefficient between 2004 and 2019, and below that the range of annual correlation coefficients.

Table 7 – Correlation coefficients between output per hour worked and investment (divided by hours worked, and by GVA), by ITL level, by asset, average and range, 2004 to 2019

| | **Investment / GVA (2004 – 2019)** | **Investment / hours worked (2004 – 2019)** |
|---|---|---|
| ITL1 | | |
| Total investment | -0.36<br>(-0.71 – 0.08) | 0.61<br>(0.30 – 0.83) |
| Buildings and structures | -0.51<br>(-0.89 – 0.01) | 0.30<br>(-0.35 – 0.77) |
| Transport equipment | -0.38<br>(-0.66 – 0.10) | 0.06<br>(-0.36 – 0.66) |
| ICT equipment | -0.22<br>(-0.61 – 0.15) | 0.65<br>(0.43 – 0.83) |
| Other tangible assets | -0.34<br>(-0.65 – -0.04) | 0.42<br>(0.20 – 0.55) |
| Intangible assets | 0.26<br>(0.12 – 0.46) | 0.59<br>(0.49 – 0.69) |
| ITL2 | | |
| Total investment | -0.24<br>(-0.44 – 0.03) | 0.44<br>(0.21 – 0.71) |
| Buildings and structures | -0.37<br>(-0.65 – -0.09) | 0.13<br>(-0.17 – 0.42) |
| Transport equipment | -0.32<br>(-0.55 – 0.04) | -0.01<br>(-0.27 – 0.32) |
| ICT equipment | -0.01<br>(-0.33 – 0.19) | 0.40<br>(0.13 – 0.54) |
| Other tangible assets | -0.17<br>(-0.34 – -0.08) | 0.19<br>(-0.01 – 0.29) |
| Intangible assets | 0.29<br>(0.21 – 0.43) | 0.56<br>(0.49 – 0.63) |
| ITL3 | | |
| Total investment | -0.17<br>(-0.31 – -0.02) | 0.31<br>(0.21 – 0.40) |
| Buildings and structures | -0.24<br>(-0.46 – -0.04) | 0.13<br>(0.04 – 0.23) |
| Transport equipment | -0.19<br>(-0.40 – -0.07) | -0.01<br>(-0.14 – 0.11) |
| ICT equipment | -0.05<br>(-0.14 – 0.03) | 0.32<br>(0.19 – 0.42) |
| Other tangible assets | -0.15<br>(-0.20 – -0.11) | 0.13<br>(0.06 – 0.19) |
| Intangible assets | 0.13<br>(0.05 – 0.17) | 0.35<br>(0.27 – 0.39) |

*Source: ONS, authors' calculations.*
*Notes: Means are unweighted averages across years for which data are available (2004-2019). Values in brackets on the second line of each cell are the minimum and maximum yearly correlation coefficient.*

As previously this analysis does not control for other potentially important factors, and therefore should not be interpreted as causal. Rather, it is a simple way of summarising some high-level relationships in the data and suggesting areas that may benefit from further analysis.

Investment intensity has, on average, a negative correlation with output per hour worked in most cases, although often these are close to zero and are often not statistically significantly negative. The most negative correlations on this basis are for buildings and structures (which includes dwellings), and transport equipment. The exception is intangible assets, which has a positive correlation on average at all three levels of geographic breakdown.

These findings are consistent with PwC (2019), who plot the relationship between GVA per job in 2017 (another labour productivity measure), and two investment measures at the level of the Local Enterprise Partnership (LEP)[16]. Their two investment measures are total investment as a share of GVA in 2017 (on the basis of the Regional Accounts investment data, as that was all that was available at the time), and research and development (R&D) expenditure as share of GDP in 2016. They find a weak negative relationship for total investment, and a weak positive association for R&D (which is a subset of intangible investment), consistent with Table 7.

By contrast, investment per hour worked has, on average, a positive correlation with output per hour worked in almost all cases. This is strongest for investment in ICT equipment and intangible assets, and weakest for investment in transport equipment, which has a near zero relationship. The average correlation coefficient on total investment per hour worked is also strongly positive in all cases. This is consistent with capital deepening (increasing capital input per unit of labour input) being a factor associated with growth in labour productivity.

Figure 6 shows how the composition of investment changes across the productivity distribution of ITL2 regions, where the investment composition and productivity quintiles are the average from 2004 to 2019.[17] Regions with the highest levels of productivity (quintiles 4 and 5) do a much larger share of their investment in intangible assets than regions with lower levels of productivity. This is accommodated by relatively lower proportions of investment in buildings and structures (and in the highest quintile, in transport equipment) than other regions. Investment in ICT equipment and other tangible assets makes up a fairly similar proportion across the productivity distribution based on this breakdown.

Figure 7 does similarly to Figure 6, but with deciles of the productivity distribution on an ITL3 geographic basis. The findings are very similar, with the highest productivity deciles seeing a much larger share of their investment in intangibles relative to lower-productivity regions, accommodated primarily by lower shares of investment on buildings and structures. There is also a slight increase in the share of investment on ICT equipment as the productivity deciles increase, based on this breakdown. There is a falling share for transport equipment, as seen more starkly in Figure 6.

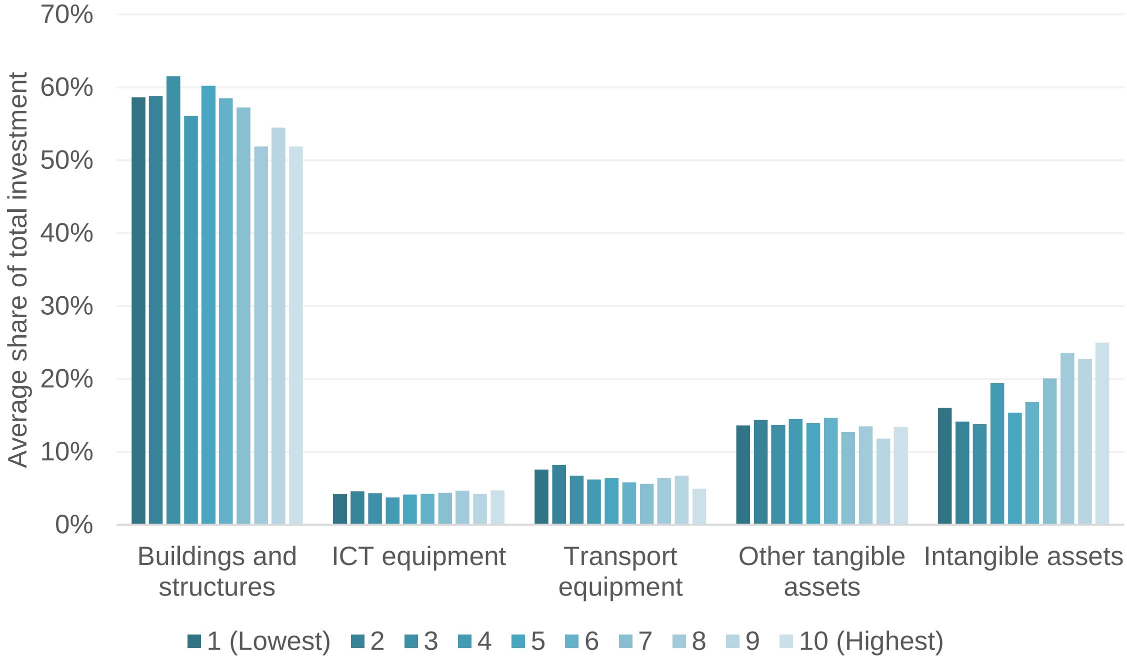
[16] There are 38 LEPs in England, some of which overlap. In terms of geographic disaggregation, they are closest to ITL2 level, but somewhat more detailed in places.

[17] We calculate the investment composition for each year and take a simple arithmetic average across years. For the productivity quintile, we average chained volume measure (CVM) output per hour worked levels across years, and then construct quintiles from the resultant distribution. The charts show simple unweighted averages across regions in the quintile. Given variations in size between ITL2 and ITL3 regions, the absolute level of the shares can vary between Figure 6 and Figure 7; we focus instead on the pattern across the productivity distribution.

Figure 6 – Asset share of total investment, by productivity quintile, ITL2 regions, UK, 2004 to 2019 average


*Source: ONS, authors' calculations.*
*Notes: Quintile 1 is lowest productivity, quintile 5 is highest productivity. There are around 8 ITL2 regions per quintile. Productivity quintiles based on arithmetic average of output per hour worked in chained volume measures (CVMs). Investment shares are simple averages across years. Unweighted averages across regions within productivity quintiles.*

Figure 7 – Asset share of total investment, by productivity decile, ITL3 regions, Great Britain, 2004 to 2019 average




*Source: ONS, authors' calculations.*
*Notes: Decile 1 is lowest productivity, decile 10 is highest productivity. There are approximately 17 ITL3 regions per decile. Productivity deciles based on arithmetic average of output per hour worked in chained volume measures (CVMs). Investment shares are simple averages across years. Productivity estimates by ITL3 region are unavailable for Northern Ireland, so this Figure relates only to Great Britain, while Figure 6 relates to the UK at ITL2 level. Unweighted averages across regions within productivity quintiles.*

The relationship between intangible investment and productivity can also be seen in Table 8, which shows correlation coefficients between the share of investment in each asset and the level of productivity in the same year, for three levels of geographic breakdown. On average between 2004 and 2019, the share of intangible investment in total investment had a correlation coefficient of 0.48 with the level of output per hour worked across ITL1 regions. Over those years that figure ranged from 0.26 to 0.75: always positive but not always as strong. By contrast, the share of investment in buildings and structures, transport equipment and other tangible assets was on average negatively related to productivity, and for ICT equipment it was only weakly positive. The same pattern holds when considering ITL2 and ITL3 geographic breakdowns, although the positive association for intangibles is diminished somewhat at the more detailed geographic breakdown.

Since these are shares of the same total and thus add to 100%, the correlations cannot all be positive – indeed, they must in some way average to about 0, since positive correlation for the share of one asset implies a negative correlation for the share of a different asset. The negative correlations for buildings and structures, transport equipment, and other tangible assets does not mean these investments reduce productivity. Rather, the key result of Table 8 is that intangible investment, and to a lesser extent investment in ICT equipment, appear relatively more important for regional productivity outcomes than most tangible assets. The correlation on the buildings and structures asset might be skewed by the inclusion in this category of dwellings, which is likely fairly orthogonal to productivity.

Table 8 – Correlation coefficients between asset shares of total investment and output per hour worked, by ITL level, average and range (2004 to 2019)

| | **ITL1 (UK)** | **ITL2 (UK)** | **ITL3 (GB)** |
|---|---|---|---|
| Buildings and structures | -0.41<br>(-0.82 – -0.03) | -0.35<br>(-0.67 – -0.12) | -0.21<br>(-0.40 – -0.07) |
| ICT equipment | 0.11<br>(-0.23 – 0.42) | 0.18<br>(-0.13 – 0.40) | 0.09<br>(-0.03 – 0.29) |
| Transport equipment | -0.28<br>(-0.58 – 0.30) | -0.28<br>(-0.52 – 0.13) | -0.21<br>(-0.38 – -0.09) |
| Other tangible assets | -0.08<br>(-0.39 – 0.22) | -0.08<br>(-0.24 – 0.05) | -0.07<br>(-0.17 – 0.05) |
| Intangibles | 0.48<br>(0.26 – 0.75) | 0.46<br>(0.32 – 0.66) | 0.33<br>(0.21 – 0.45) |

*Source: ONS, authors' calculations.*

*Notes: Productivity estimates for ITL3 regions in Northern Ireland are not available, so the ITL3 breakdown represents only Great Britain, while the ITL1 and ITL2 breakdowns represent the UK. Correlations were calculated using contemporaneous asset shares and productivity levels. Means are unweighted averages across years for which data are available (2004-2019). Values in brackets on the second line of each cell are the minimum and maximum yearly correlation coefficient.*

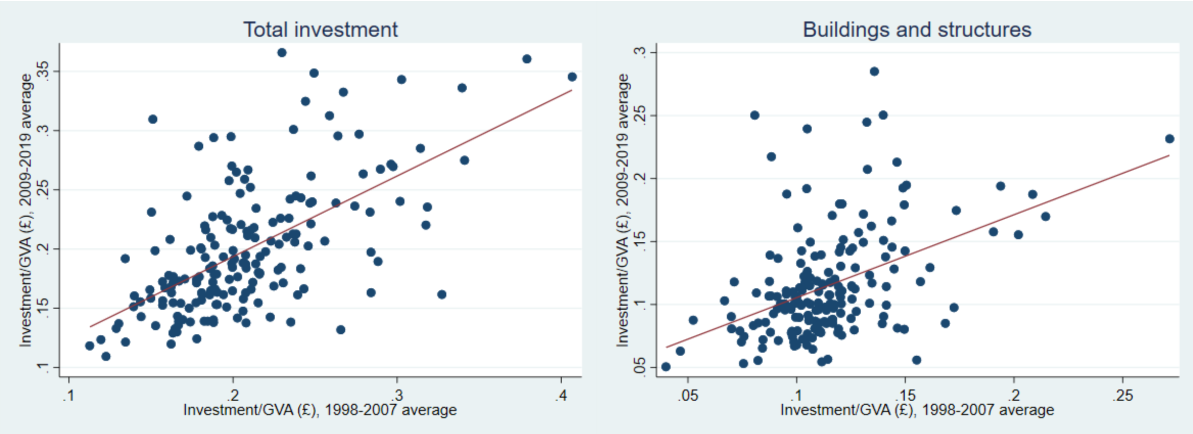
### 5.3. Factors affecting investment

There are many theoretical drivers of capital investment, but data on few of these is available at the necessary geographical disaggregation in the UK context. For instance, data on urban/rural classification of areas is defined at local authority level but is less meaningful at ITL3 level (and above) since these are typically larger and more heterogeneous areas. As such, this section considers only a handful of potential correlates, and does so individually rather than jointly. Future work could consider the joint effects of a range of explanatory factors.

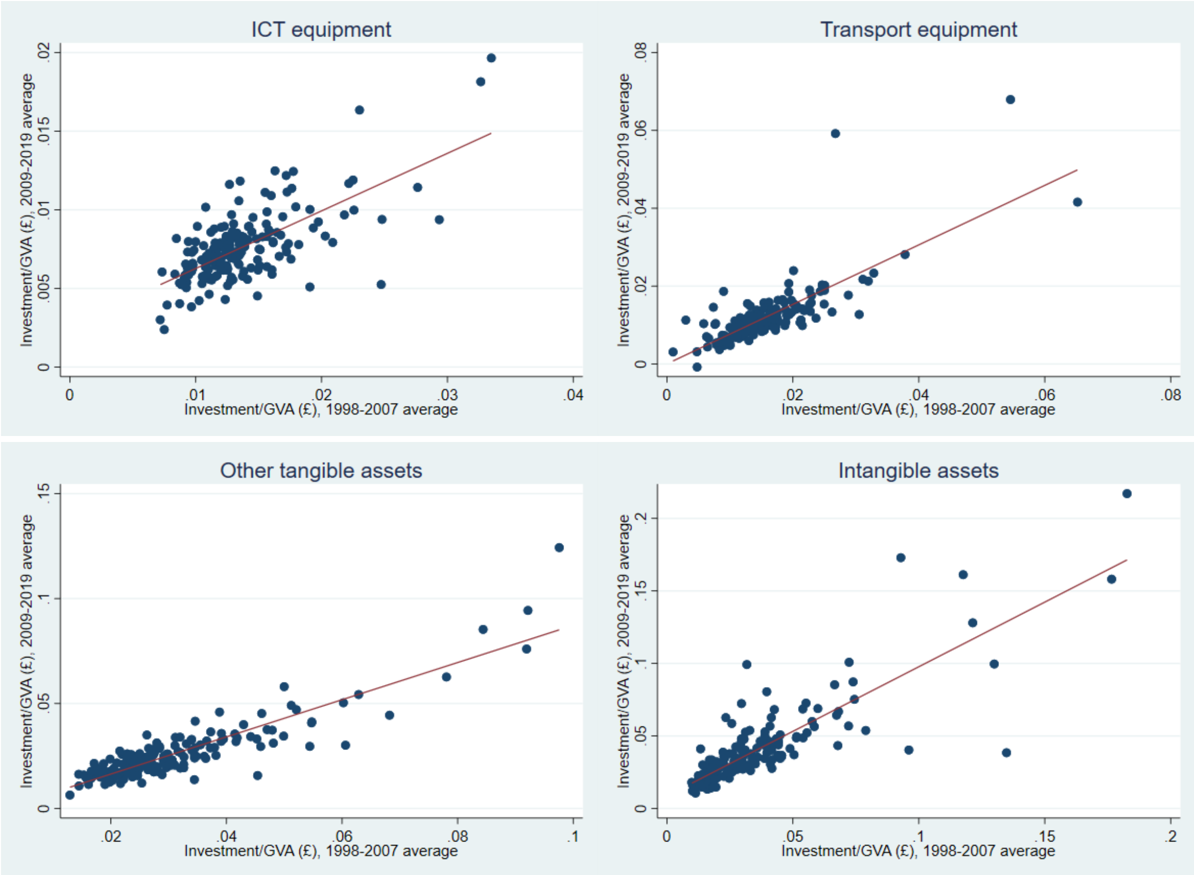
One determinant of current capital investment is likely past capital investment.[18] Figures 8a to 8f show scatterplots of investment intensity (investment divided by GVA in current prices) in the decade before the 2008 economic downturn, with the decade after, for each of the assets available (and total investment), for ITL3 regions. These mostly show a fairly tight positive correlation, indicating persistence in investment behaviour of the regions over time. That is, the investment intensity of a region in the decade before the 2008 economic downturn is quite similar to the investment intensity of that region in the decade after 2008, and that is true for most regions for most asset types.

The weakest correlation is for investment in buildings and structures, which might reflect the fact that these have much longer service lives than other assets, and so past investment might reduce the need for future investment. Since buildings and structures investment is such a large part of total investment in most regions, the dispersion in the scatterplot for buildings and structures means that the scatterplot for total investment is also similarly dispersed. Over shorter time horizons there might be more persistence in investment intensity since some investment projects (mainly large construction projects) might take place over a number of years; however, this effect is unlikely to be relevant over the longer term, as considered in Figures 8a to 8f.

<u>Figures 8a to 8f – Persistence in investment intensity over time, total investment and by asset, 1998 to 2007 and 2009 to 2019, ITL3 regions</u>




[18] The current capital stock is likely also relevant for current capital investment, but we do not have estimates of the capital stock. Using past capital investment is a reasonable proxy for current capital stock since the capital stock is the accumulation of past capital investments. This proxy will be better for assets with shorter service lives (faster depreciation rates).




*Source: ONS, authors' calculations.*
*Notes: Each dot is an ITL3 region.*

Figure 9 extends this to consider convergence between regions over time, by comparing investment per hour worked in the late 1990s, to the growth in investment per hour worked over the subsequent two decades.[19] Small dots represent ITL2 regions and crosses represent ITL1 regions, with ITL2 regions coloured the same as their corresponding ITL1 region. The UK average level and growth rate are marked with grey lines close to the middle of the chart.

The chart has four quadrants:

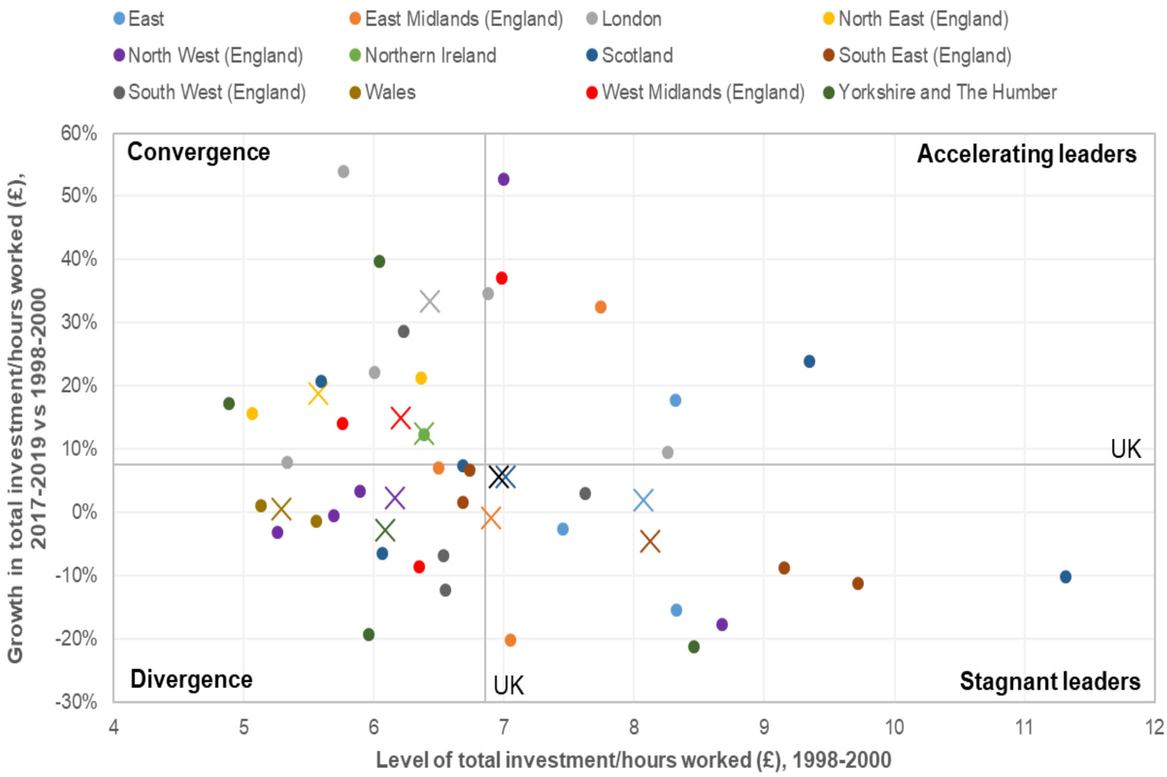
- Convergence – below average initial level, and above average growth
- Divergence – below average initial level, and below average growth
- Stagnant leaders – above average initial level, and below average growth
- Accelerating leaders – above average initial level, and above average growth

The theory of convergence (see for instance Galor, 1996) would suggest that regions with low initial levels investment would have high growth rates in order to "catch up", and regions with high initial levels of investment would have low growth rates, and thus the two would converge. This is largely apparent in Figure 9, with a weak negative correlation between initial level and subsequent growth. That is, many regions are in either the "Convergence" quadrant, or the "Stagnant leaders" quadrant. There are three ITL1 regions, and many of

[19] Chart design inspired by a presentation by Matilde Mas at the World KLEMS conference in Manchester in October 2022.

their ITL2 regions, in the “Divergence” quadrant – Wales (light brown), Yorkshire and the Humber (dark green), and the North West (purple). Interestingly, the North West also has one ITL2 region in the “Accelerating leaders” quadrant – this is Cumbria, which has seen large investments in energy projects in recent years. There are no ITL1 regions in the “accelerating leaders” quadrant, but there are a handful of ITL2 regions, including the Highlands and Islands (Scotland, dark blue), Herefordshire, Worcestershire and Warwickshire (West Midlands, red), East Anglia (East of England, light blue), Lincolnshire (East Midlands, orange), Inner London East and Outer London West and North West (grey), and the aforementioned Cumbria.

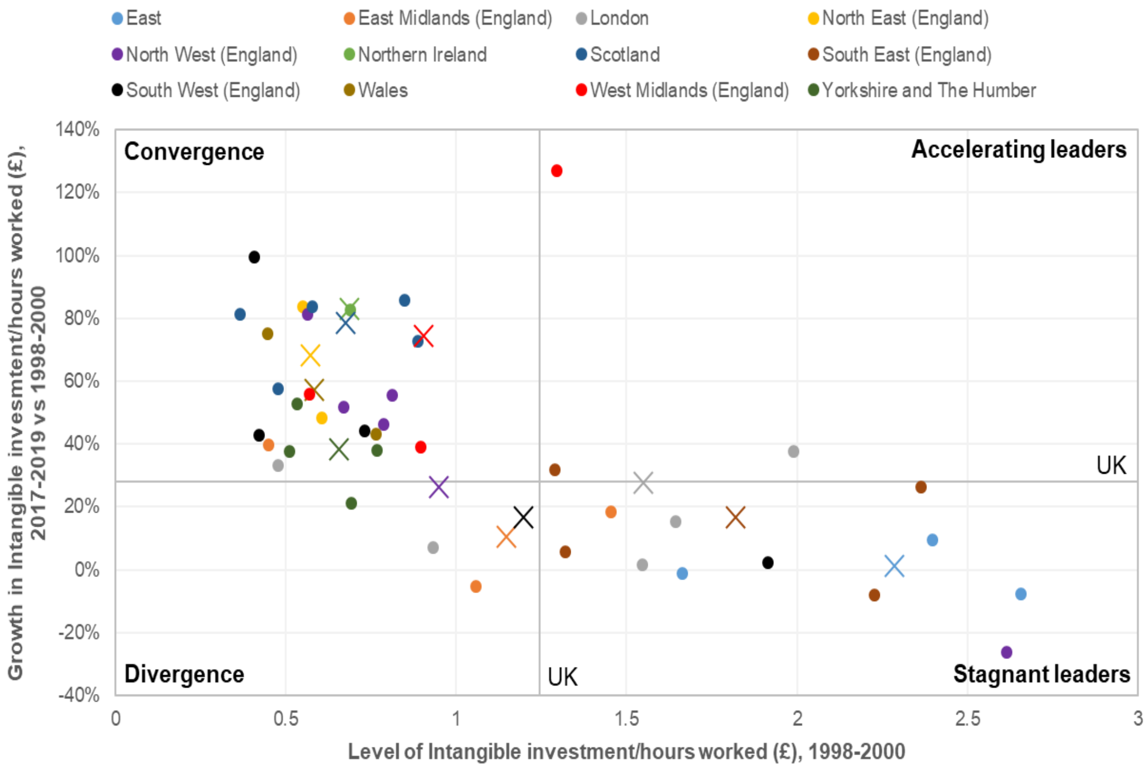
Figure 9 – Level and growth of total investment per hour worked, 1998 to 2000 and 2017 to 2019, ITL1 and ITL2 regions




*Source: ONS, authors’ calculations.*
*Notes: Small dots represent ITL2 regions and crosses represent ITL1 regions, with ITL2 regions coloured the same as their corresponding ITL1 region. The UK average level and growth rate are marked with grey lines close to the middle of the chart.*

Figure 10 does similarly to Figure 9, but with intangible investment per hour worked. The convergence story is even stronger here than for total investment in Figure 9. Again, no ITL1 regions are in the “accelerating leaders” quadrant, although London (grey) is on the border. The only three ITL2 regions in this quadrant are Herefordshire, Worcestershire and Warwickshire (West Midlands, red), Inner London West (grey), and Surrey, East and West Sussex (South East, brown). There are three ITL1 regions in the “divergence” quadrant, although in all cases their ITL2 regions are quite widely dispersed.

Figure 10 – Level and growth of intangible investment per hour worked, 1998 to 2000 and 2017 to 2019, ITL1 and ITL2 regions




*Source: ONS, authors' calculations.*
*Notes: Small dots represent ITL2 regions and crosses represent ITL1 regions, with ITL2 regions coloured the same as their corresponding ITL1 region. The UK average level and growth rate are marked with grey lines close to the middle of the chart.*

As well as past investment activities, another possible factor affecting capital investment is foreign direct investment (FDI). FDI is akin to a source of funds for businesses, which may be used to invest in capital assets. If so, we might expect to find a positive relationship between inward FDI and capital investment at regional level.

Data on regional FDI are published by ONS, but only available at ITL1 and ITL2 level, and only for 2015 to 2020. To avoid any distortions from the coronavirus pandemic we restrict analysis to 2015 to 2019. The most appropriate concept for exploring the link between FDI and capital investment is likely "net inflows" which measures the balance between gross inflows (new money being invested in the UK from abroad) and disposals of inflows (previous inflows being returned to investors abroad). Note that disposals of inflows are not the same as outflows (investments by the UK into foreign countries). We use "net inflows" as our main measure, and also consider gross inflows[20] as a robustness check.

The FDI data have many suppressions for statistical disclosure reasons, making data for any individual year likely to be very noisy. We therefore aggregate the five years of FDI data by

[20] Our measure of "gross inflows" is the sum of the following components of the ONS regional FDI dataset: "Foreign companies' share of UK subsidiaries' and associates' net profits", "Acquisition of UK companies' share and loan capital", "Increase in amounts due to foreign parents on the inter-company account", and "Increase in amounts due to foreign parents on the branch head-office account".

taking a simple arithmetic average across the years.[21] In doing so, we hope that suppressions are approximately randomly distributed across regions within the five-year span. We also average capital investment across the same five years for comparison – thus we consider correlations of approximately contemporaneous FDI and capital investment.

Given FDI is most relevant to the market sector, rather than government, we construct a market sector total investment estimate by removing predominantly non-market industries. Specifically, we remove the public administration and defence (SIC 2007 section O), education (section P) and health and social care (section Q) industries, which are largely government-run industries in the UK. We also exclude the real estate industry (section L) in order to exclude investment in the dwellings asset (which is allocated only to the real estate industry), since FDI is unlikely to be relevant for dwellings.

Finally, we divide both FDI and 'market sector' capital investment by 'market sector' gross value added (GVA) in order to normalise for region size.[22] Bigger regions might be expected to receive more FDI and do more investment purely on account of their size, rather than any link between FDI and capital investment. Dividing both variables by GVA allows for a cleaner look at the link between FDI and capital investment.

Table 9 shows the correlation coefficients between "net inflow" and "gross inflow" FDI and capital investment (all divided by GVA), by asset and for total investment, for ITL2 regions. Surprisingly, there is next to no relationship between FDI and capital investment for most assets, for both measures of FDI – in fact, most correlations are negative, but most are not statistically significantly so. However, for both measures of FDI, there is a positive and significant relationship with intangible investment.

This suggests that inward FDI is only positively related with intangible investment in a region, but not other types of investment. Of course, these simple correlations do not imply a causal link, but do hint at a potentially interesting relationship between FDI and the type of capital investment it motivates.

<u>Table 9 – Correlation coefficients between FDI (net and gross inflows) and capital investment (both divided by GVA), by asset, 2015 to 2019 average, ITL2 regions, UK</u>

| **Asset** | **Net inflows** | **Gross inflows** |
|---|---|---|
| Total | -0.1403 | -0.0893 |
| Buildings and structures | -0.2246 | -0.2773* |
| ICT equipment | -0.2283 | 0.0613 |
| Transport equipment | -0.0607 | -0.1186 |
| Other tangible assets | -0.2698* | -0.0501 |
| Intangible assets | 0.2805* | 0.4076*** |

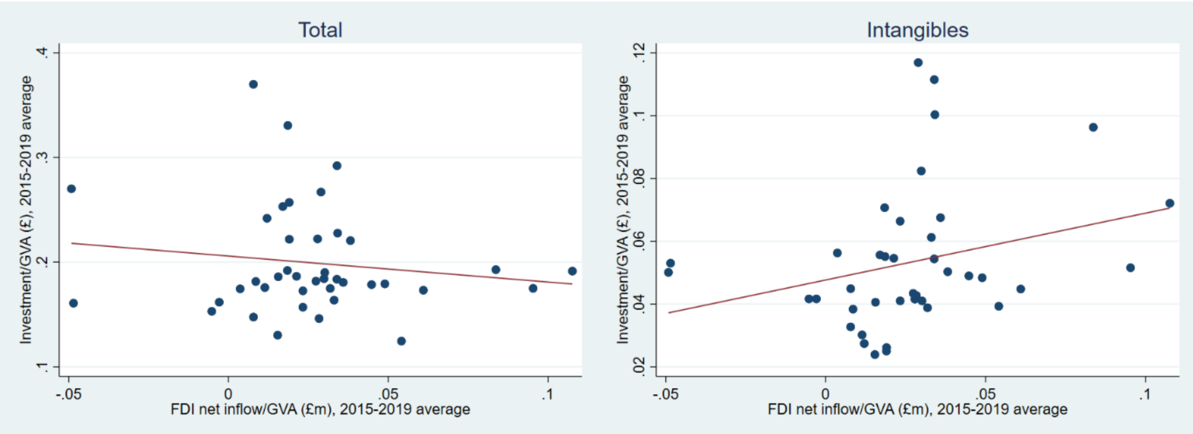
*Statistical significance: *** = 1% level, ** = 5% level, * = 10% level.*

*Source: ONS, authors' calculations.*
*Notes: ITL2 region "Inner London West" excluded as an outlier with extremely high levels of FDI – results are similar if included. "Net inflows" is our preferred measure; "gross inflows" shown as a robustness check.*

[21] We do not account for inflation here since it is not immediately apparent which price index would be appropriate for FDI. The result is that we likely give slightly more weight to later years when the general price level is higher. Inflation over this period was quite low, so we suspect this has little effect on the results.
[22] Another option would be to divide by hours worked, but that is not possible as hours worked data at ITL2 are not available by industry and therefore cannot be computed for the market sector. We use hours worked as the normalising variable in a robustness check when working with whole economy investment data, with much the same result as for GVA.

Figures 11a and 11b show scatter plots of FDI net inflows and capital investment (both divided by GVA) for ITL2 regions, for total investment (11a) and intangible investment (11b). The positive correlation for intangibles is visible, although the fit of the best fit line is not especially strong. By contrast, there is no apparent relationship using total investment.

Figures 11a and 11b – Scatterplots of FDI net inflows and capital investment (total and intangibles) (both divided by GVA), £m, by ITL2 regions, 2015 to 2019 average, UK




*Source: ONS, authors' calculations.*
*Notes: ITL2 region "Inner London West" excluded as an outlier with extremely high levels of FDI – results are similar if included. Lines are unweighted linear best fit lines. FDI net inflows can be negative if disposals exceed gross inflows. Y-axis units are £m of capital investment per £m of GVA. X-axis units are £m of FDI net inflow per £m of GVA. Capital investment measures are for the market sector.*

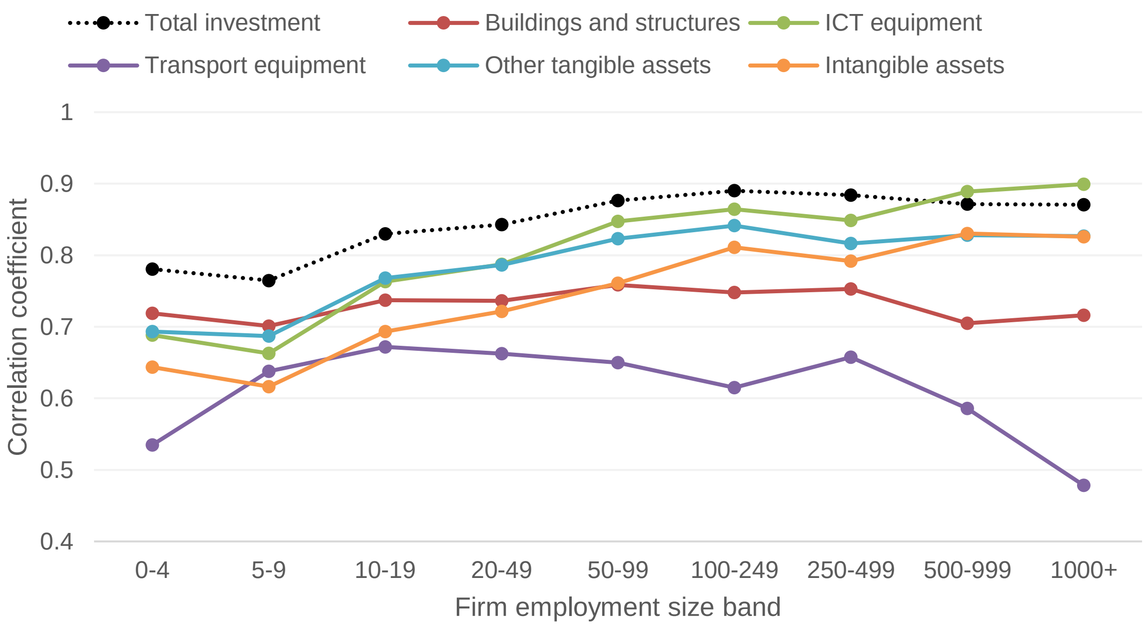
The final factor affecting investment that we consider is the composition of firms in the region. Firms of different sizes might be expected to invest more or less intensively than others. For instance, smaller firms might find it harder to access finance and thus a relatively large share of small firms might reduce average investment in a region. Large businesses might better be able to access finance but might not need to conduct as much investment if they already have a larger capital stock. Young businesses (which are generally small) might need to invest more initially to build their capital stock. These patterns might vary by asset.

Figure 12 plots the correlation coefficient between the number of firms of each size band (based on employment) and investment in each ITL3 region, for total investment and by asset. For most assets, there is a closer correlation (higher correlation coefficient) between the number of large firms and the value of investment, than there is for small firms. This is intuitive, since large firms are expected to invest more in absolute terms on account of their larger size.

The pattern of rising correlation coefficients is especially strong for intangible assets and ICT equipment. This might relate to the ability to gain finance for certain types of investment at different levels of maturity (size) of the business, or the shorter service lives of intangible and ICT assets which might thus need replacing regularly as the firm grows. Larger businesses also tend to have better management practices (ONS, 2021), which might be associated with relatively more intangible investment. For buildings and structures and total investment, the patterns are much flatter. For transport equipment, the correlations are lower, rise initially when moving from the smallest firms to medium-sized, but fall for larger firms.

As in previous sections, this analysis does not control for a range of other important factors and should therefore not be interpreted as causal. However, it offers some indication of how the composition of firms in a region might affect capital investment in that region. A more detailed analysis of the link between firm size and investment across regions is in Annex C.

Figure 12 – Correlation coefficients between investment and the number of firms in a region of various sizes, ITL3 regions, 2019, UK




*Source: ONS, authors' calculations.*
*Notes: X-axis shows employment size bands, which are not equally sized. Y-axis shows simple correlation coefficient between the level of investment and the number of firms.*

## 5.4. Investment growth

Using the estimates of real capital investment developed in this paper (see section 3.3 and Annex A), this section explores the growth in investment over time across regions.

We have a particular interest in exploring how business investment changes after the UK voted to leave the EU in 2016, and how this varies across the UK. Brexit is likely to have reduced business investment through increased uncertainty and expected lower future economic growth. Indeed, Haskel and Martin (2023) suggest that business investment in 2022 is some 10% below where it would have been in the absence of Brexit, and Springford (2022) suggests total investment is some 11% lower than would otherwise be expected based on a "doppelganger" analysis. Bunn *et al.* (2022) estimate that Brexit reduced investment by 23% in 2020/21 using data from the Decision Maker Panel – a survey of businesses.

We restrict our attention to business investment (total investment less government and dwellings investment)[23], since any impact of Brexit on government investment and dwellings investment is less clear. We approximate business investment by excluding industries that are predominantly non-market, as we did in section 5.3 for analysis on FDI. Specifically, we remove the public administration and defence (SIC 2007 section O), education (section P) and health and social care (section Q) industries, which are largely government-run industries in the UK. We also exclude the real estate industry (section L) in order to exclude investment in the dwellings asset (which is allocated only to the real estate industry). We call the result 'market sector' investment.

Table 10 summarises the average annual growth rate of 'market sector' investment, by ITL1 region and country, across different time periods. Between 1997 and 2019, investment grew fastest in Northern Ireland, the East Midlands, and London, and slowest by some margin in the North East.[24] Compounded over 22 years, this means 'market sector' investment doubled in Northern Ireland between 1997 and 2019, while in the North East it grew by a total of just 7%.

<u>Table 10 – Average annual growth (%) in market sector investment, by ITL1 region, various periods</u>

| ITL1 | 1997-2019 | 1997-2016 | 2011-2016 | 2016-2019 |
|---|---|---|---|---|
| Northern Ireland | 3.3 | 3.8 | 3.7 | 0.4 |
| East Midlands | 2.9 | 2.3 | 9.3 | 6.5 |
| London | 2.6 | 2.5 | 5.3 | 3.0 |
| West Midlands | 2.4 | 2.1 | 5.5 | 4.6 |
| East | 2.1 | 2.8 | 6.6 | -2.6 |
| South West | 2.1 | 2.0 | 3.1 | 2.3 |
| Yorkshire & the Humber | 1.9 | 2.1 | 4.6 | 0.1 |
| South East | 1.5 | 2.3 | 4.3 | -3.5 |
| North West | 1.4 | 1.4 | 3.5 | 1.7 |
| Wales | 1.4 | 1.9 | 5.5 | -2.2 |
| Scotland | 1.4 | 2.8 | 6.6 | -7.4 |
| North East | 0.3 | 1.2 | 4.2 | -5.4 |
| *UK business investment* | *1.9* | *2.2* | *5.6* | *0.3* |

*Source: ONS, authors' calculations.*

*Notes: Data ordered by the 1997-2019 column. Average annual growth rates calculated using a compound annual average growth rate between years indicated, inclusive; for instance, values for 1997-2019 are calculated by* $(I_{2019}/I_{1997})^{\wedge}(1/22) - 1$.

In the 5 years up to the Brexit vote in 2016, investment grew sharply in all ITL1 regions and countries, in line with the UK business investment data. This is likely to, in part, reflect recovery from the sharp fall in investment following the 2008 economic downturn. The fastest average annual rate of growth from between 2011 and 2016 was in the East

[23] Strictly, "business investment" as reported by ONS also excludes costs of ownership transfer on non-produced assets ("transfer costs"). This is a relatively small component and not identifiable in the regional data, so we do not make any adjustment for this. We anticipate this makes little difference to the analysis.

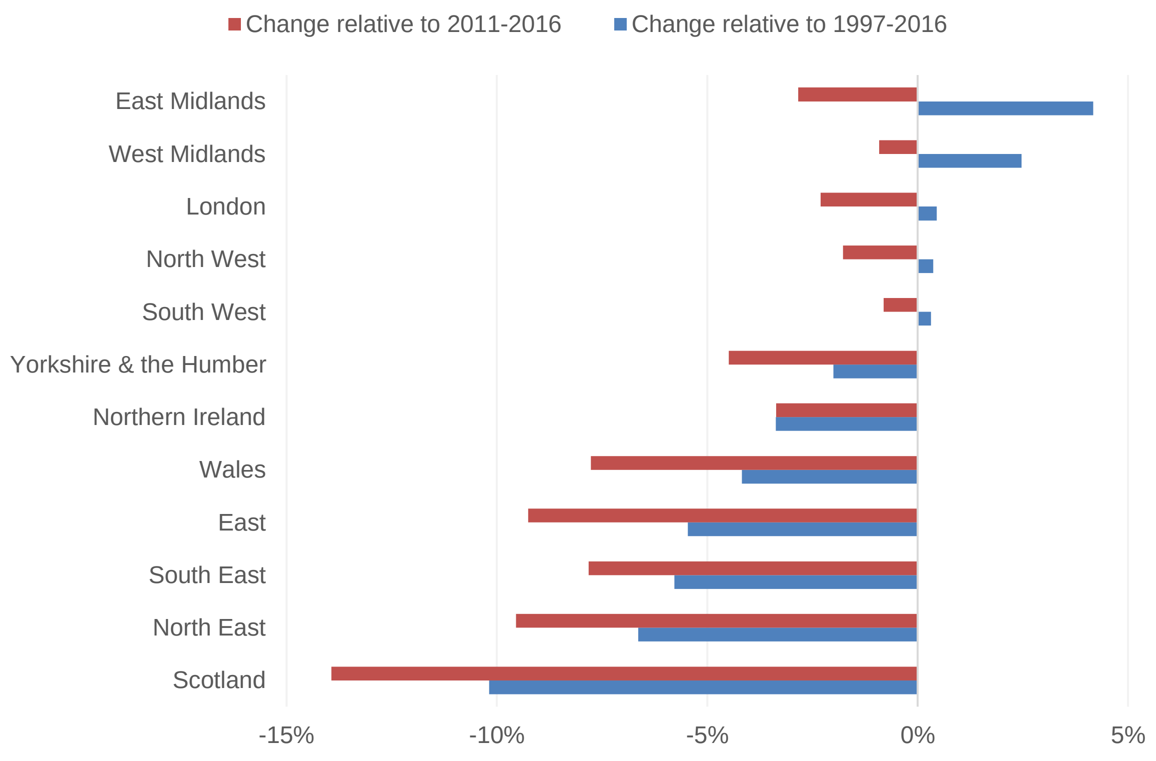
[24] While there is some year-to-year variability, the relative positions are largely unchanged if the base year or end year are varied slightly.

Midlands, and the slowest in the South West, North West, and Northern Ireland (although these areas still saw relatively fast growth in historic terms).

Figure 13 shows the difference between the average annual growth rate of investment from 2016 to 2019, with earlier periods (1997-2016 and 2011-2016).[25] Growth slowed in all ITL1 regions relative to the 2011 to 2016 period and slowed relative to the 1997 to 2016 period in over half of the regions. The largest slowdowns in investment growth, when comparing against the 2011-2016 or 1997-2016 periods, are Scotland, the North East, South East, East of England, and Wales. By contrast, investment after 2016 seems relatively more resilient in the East Midlands, West Midlands, London, North West, and South West. While we do not claim any causality from this simple study, these results might point to an unequal effect of Brexit on business investment across the UK.

We can repeat this exercise by ITL2 region, as shown in Figure 14. Compared to the 1997-2016 period, 28 of 41 ITL2 regions see a slowdown in average annual growth in real market sector investment after 2016. Compared to the 2011-2016 period, 30 of 41 regions see a slowdown. Of the 13 ITL2 regions that do not see a slowdown relative to the 1997-2016 period, three are in the South West, two each are in London, the North West, and the East Midlands, and one each are in Yorkshire and the Humber, and the East of England. The results for ITL2 regions thus largely corroborate the ITL1 data in Figure 13.

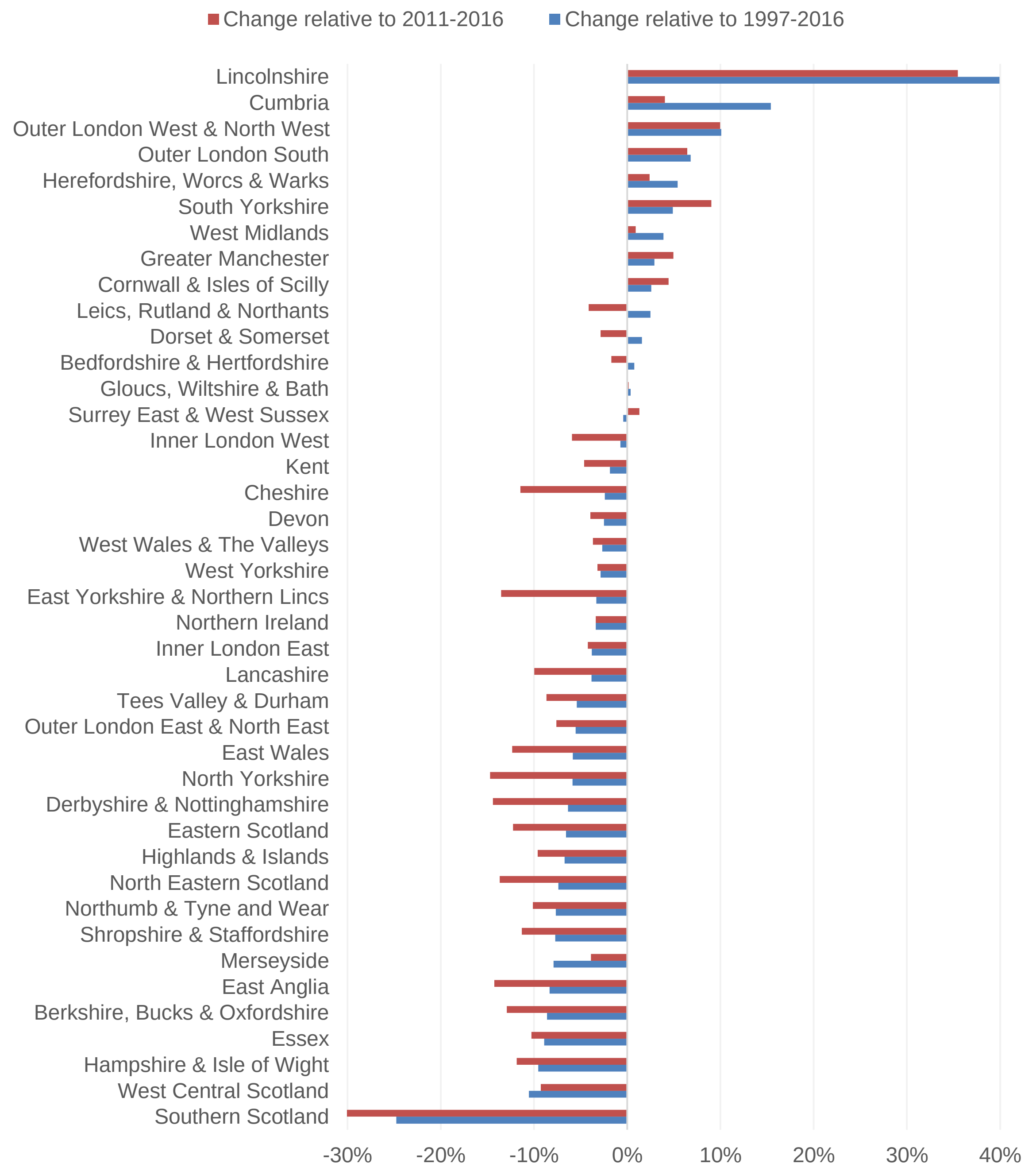
<u>Figure 13 – Change in average annual growth of real market sector investment, 2016-2019 vs earlier period, by ITL1 region</u>




*Source: ONS, authors' calculations*
*Notes: Data ordered by the "Change relative to 1997-2016" series. See Table 10 for underlying data.*

[25] The UK voted to leave the EU in mid-2016.

Figure 14 – Change in average annual growth of real market sector investment, 2016-2019 versus earlier period, by ITL2 region




*Source: ONS, authors' calculations*

*Notes: Data ordered by the "Change relative to 1997-2016" series. X-axis abbreviated for legibility; Southern Scotland change relative to 2011-2016 (red bar) = -30.3%. Some county name abbreviations used for legibility.*

The resilient performances of the East Midlands and North West are partly influenced by unusually fast growth in investment after 2016 in Lincolnshire and Cumbria respectively. In both cases this comes largely from the buildings and structures asset, and we suspect are related to large energy projects. All five of the ITL2 regions in Scotland see a marked slowdown in investment growth after 2016, possibly associated with the decline in the North

Sea oil investment around this time, and reasonably strong growth prior to 2016. There is quite a range of outcomes within the South East, with marked declines in investment growth for Hampshire and the Isle of Wight, and Berkshire, Buckinghamshire and Oxfordshire, but much less slowdown for Kent and Surrey, East and West Sussex. The Eastern parts of London see more of a slowdown after 2016 than the Western parts of London.

Of course, at this level of regional granularity, and using time periods of only a few years, it is possible for the results to be influenced heavily by individual large investment projects. Capital investment is an inherently ‘lumpy’ variable, so year-to-year variation can be large. As such, the results in this section should be interpreted with caution.

## 6. Discussion of findings

In this paper we have explored new experimental regional capital investment estimates from the ONS Subnational Development programme, using them to describe capital investment across the UK in a way that was not possible previously. Our analysis is entirely descriptive, and we do not claim any causality in the relationships we identify with other variables, including foreign direct investment (FDI), productivity and business size. All the results presented in this paper should be interpreted with caution, given that these data are still relatively unexplored and classified by ONS as “experimental”. We urge caution in over-interpreting results at the most detailed geographies given the newness of this breakdown.

Overall, the new Subnational Development dataset appear to accord with high-level expectations on the distribution of capital investment across the UK, and the correlation with other macroeconomic variables. Investment is closely correlated with GVA and hours worked across regions, and to a lesser extent with population, although this will largely just reflect differences in region size. Investment per hour worked (our preferred investment intensity measure) tends to be higher in more productive regions, and this is particularly true for investment in intangible assets. There is evidence of convergence in investment over time across regions: those with initial lower levels of investment intensity tend to see faster real growth in investment over time.

Throughout our analysis, intangible assets have repeatedly stood out as different to other assets with respect to their distribution across the UK and connection with other variables. The share of investment on intangible assets tends to be higher in the South East and East of England, and to a lesser extend London, consistent with the so-called “Golden Triangle” of universities in Oxford, Cambridge, and London (sometimes known as “Loxbridge”). By contrast, other assets tend to have higher shares of investment outside the Greater South East. Intangible investment is the only asset group to be positively correlated FDI, and the asset group best correlated with productivity, based on various levels of geography and in various types of analysis.

In various analysis we have seen quite persistent investment behaviours over time – both in the asset composition of investment that each region invests in, and the composition of investment across the productivity distribution. That said, there does appear to be some convergence over time in real terms.

We have used the asset breakdown in the data extensively in this analysis – something not possible previously. Given the substantial variations across assets, this dimension is clearly important in understanding the geographic distribution of investment and links with other data. We have not, however, used the industry dimension in the data to a large degree. One reason for this is that the dataset is large, with many dimensions, and we preferred to focus on the dimensions that were new and, we felt, more important.

A second reason for focusing little on the industry dimension is potential weakness in the industry breakdowns in the Subnational Development estimates. ONS (2022a) notes that statistical disclosure concerns required them to model some industry breakdowns rather than using the source data fully. They give an example of unusually high investment in the agriculture industry in urban areas, including London, arising from this modelling approach. To avoid spurious results arising from these quirks of the data, we have used the industry dimension of the data only in robustness checks and the creation of approximate market sector estimates of investment.

## 7. Conclusion and steps towards regional capital stock estimates

Based on our analysis, we judge the new Subnational Development estimates of regional capital investment to be an improvement on the Regional Accounts estimates, both in the dimensions available and in the quality of the data. Clearly the dimensions of the data are improved, with the Subnational Development dataset introducing an important asset breakdown, expanding the regional breakdown to ITL3, expanding the industry dimension, and extending the time series. However, more fundamentally, the quality of the estimates also seems better, driven by improved methods and use of a range of new data sources in their construction. We showed that the Subnational Development estimates are better correlated with regional productivity estimates than the Regional Accounts estimates.

In some areas the methods for regional capital investment in the Subnational Development dataset are the same as in the Regional Accounts datasets, particularly for “other tangible assets” (consisting of cultivated assets, weapons systems, and machinery and equipment other than ICT and transport equipment) and ICT equipment. ONS (2022a) say they will continue to develop these estimates subject to user feedback and further research. We hope that future work will focus on improving the methods for these assets, as well as the industry breakdown.

A further drawback of the Subnational Development estimates is the grouping of dwellings with other buildings and structures. Since the estimation of these two components are largely independent, we hope that future publications will separate these assets, as doing so would allow easier analysis of non-residential capital investment, and thus allow better linkages with other data relating to the business economy.

One contribution of this paper is to develop price indices for regional capital investment that account for the industry and asset composition of the region to the greatest extent possible given the data available. In the absence of regional price data, this seems the best that can be done for now. More details are in Annex A, and we are happy to share these price indices with other researchers.

Price indices are one of several additional inputs required to convert these new regional capital investment estimates into capital stock estimates. Other inputs include historic investment data or ‘starting stock’ estimates, and depreciation and retirement profiles. As is common in the development of datasets, historic estimates are likely to be of lower quality than estimates for more recent periods and rely more on modelling and less on primary sources. That said, we judge that the historic data are likely to be relatively high quality where available. As documented in section 2.1, the Annual Census of Production[26] asked respondent for capital investment estimates for “local units” (physical sites) between the 1970s and 1993 (Smith and Penneck, 2009), which would in theory enable “bottom-up” estimates of regional capital investment. These data would need to be adjusted to be consistent with current concepts and classifications.

There are also a range of impressively comprehensive historic statistics available via the ESCoE Historical Data repository[27], and the Bank of England’s Millennium of Macroeconomic Data research dataset[28]. Further, much capital investment is conducted by government or public corporations (especially historically), and this may be easier to locate on a near project-by-project basis using historic sources. We therefore hold in high hopes the ability to construct high-quality historic regional capital investment estimates.

Regarding depreciation and retirement profiles, these could follow the standard assumptions used in official (national) capital stocks estimates. However, there might be good reason to think that these profiles vary across different parts of the UK, not least due to differences in industry and asset composition of that investment. Differences in climate (average temperature, rainfall, wind speed, and so forth), and differences in building materials and techniques across the country (especially historically), might cause depreciation rates for buildings and structures to vary across the UK. This would require considerably more research. However, having the asset breakdown in the Subnational Development investment estimates will enable substantial improvements in assumptions relative to work based on previous regional capital investment estimates (e.g., Gardiner, Fingleton and Martin, 2020), which only had a total investment series to work with.

We hope this paper motivates use of the new Subnational Development estimates by other researchers. The present paper has only scratched the surface of how this dataset could be used, in providing a descriptive summary of how capital investment is distributed across the UK. Further research exploring the link between investment and other economic variables, including multivariate and causal studies, is welcome.

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[26] The predecessor survey of the Annual Business Survey, run by the Central Statistical Office – the previous incarnation of the ONS.
[27] Available from: https://www.escoe.ac.uk/research/historical-data/
[28] Available from: https://www.bankofengland.co.uk/statistics/research-datasets

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## Annex A – Development of deflators

First, we calculate implied deflators by industry and asset from the “Annual gross fixed capital formation by industry and asset” dataset[29] published by ONS. This has data on capital investment in current prices (CP) and chained volume measures (CVMs), for a range of assets and detailed industries.[30] We calculate an implied deflator for each industry for each asset.

The industry detail in the implied deflators is greater than in the regional capital investment data, so we first compute composite deflators for each asset at an industry breakdown that corresponds to the level of detail required. We use contemporaneous shares of current price investment at the national level from the same dataset, constructing a composite Paasche-type index.

In some instances, the asset grouping in the regional capital investment data is perfectly aligned to the breakdown in the implied deflators, so a single national deflator can be applied. In other cases, the target asset breakdown is more aggregated and thus the national deflators must be aggregated. This is the case for “Buildings and structures” (which requires the aggregation of “Other buildings and structures” and “Dwellings”) and “Other tangible assets” (which requires the aggregation of “Other machinery and equipment” and “Cultivated assets”). We aggregate the lower-level asset deflators using contemporaneous shares of current price investment at the national level, constructing a composite Paasche-type index.

Finally, we aggregate to the level of region by asset (or region by total investment) by using the contemporaneous shares of current price regional investment by industry – that is, weighting the deflators together according to the industry structure of investment in each region. Thus, the deflators reflect the asset and industry structure of regional capital investment to the greatest possible extent.

We make a number of small modifications to the implied deflators and regional investment data to ensure the composite deflators are robust to unusual changes in the source data. First, there are instances where the implied deflators from the national industry by asset data are erratic or nonsensical, due to issues of rounding, very small amounts of investment or negative (net) investment. Clearly the true deflators in this case are not erratic, but the implied deflator is, due to the erratic series in current prices and/or CVMs. To avoid these having undue effect on our composite regional investment deflators, we replace any individual deflator movement by the average in that year from other industries if any of the following occur: deflator increased by 50% or more, deflator falls by 50% or more, CP series is positive and CVM series is negative, CP series is negative and CVM series if positive, either CP or CVM series are equal to zero. We also overwrite the implied deflator by the average across regions in the following instances: ICT equipment in the agriculture industry (section A), and ‘other tangible assets’ in the ‘other services’ industry (section S) in all years.

[29] Available at: https://www.ons.gov.uk/economy/grossdomesticproductgdp/datasets/annualgrossfixedcapitalformationbyindustryandasset

[30] There are several instances of series which are supressed for statistical disclosure purposes – we treat these as if the corresponding investment series are zero, which is a reasonable approximation since disclosure issues usually apply to small industries.

Finally, we make adjustments to the implied deflator for ‘other tangible assets’ in the manufacturing and public administration industries in 2005 to deal with the effects of British Nuclear Fuels Limited (BNFL), which was the transfer of nuclear reactors from the government to corporate sector (manufacturing industry) in 2005. This has undesirable effects on the data, and so we make various adjustments to reduce the adverse effects of this on our estimates.

Figures A1 to A6 show aggregate deflators for ITL1 regions, for total investment and each asset, indexed to 1997 = 100. Variations stem only from the asset and industry composition of each ITL1 region, and the variation in deflators between assets and industries in national data. For instance, the ICT deflator is almost[31] identical across all industries, and thus the aggregate ICT deflator is almost identical for all ITL1 regions.

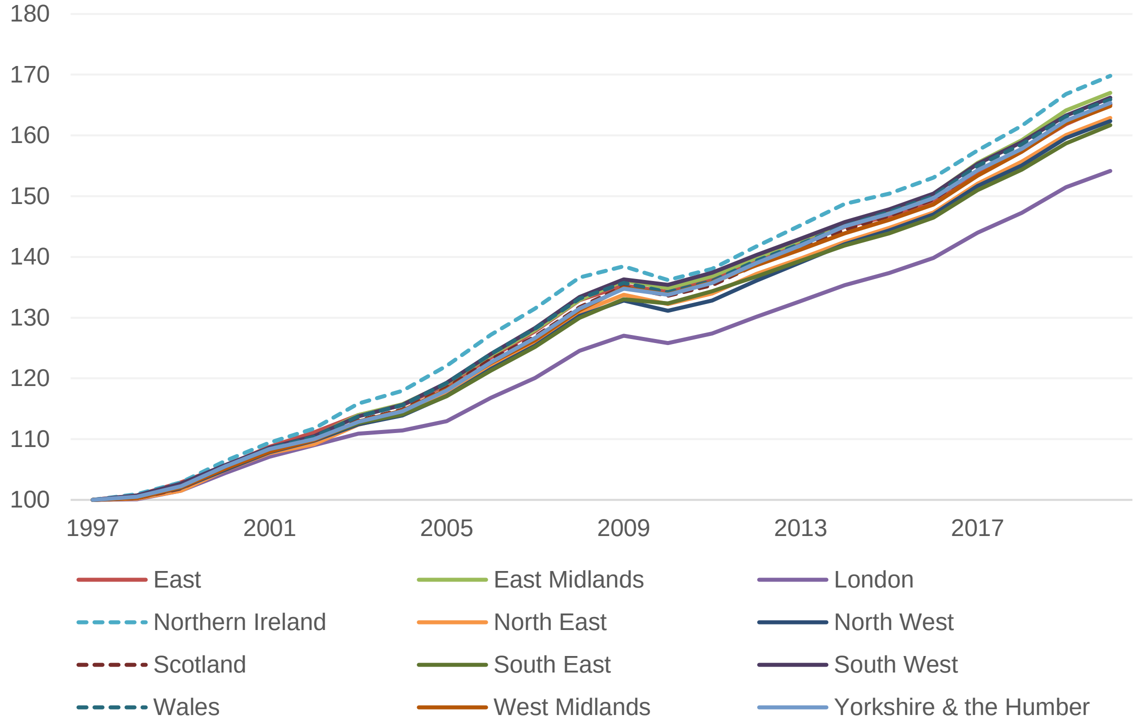
Some notable differences include:

- Total investment – London sees slower deflator growth due principally to a larger share of intangibles, and a relatively slower growing deflator for intangibles. All other ITL1 regions have similar growths, with Northern Ireland seeing slightly faster growth due to its relatively large share of buildings investment which has a fairly rapidly growing deflator.
- Buildings – All ITL1 regions are very similar.
- ICT equipment – All ITL1 regions are essentially identical.
- Transport equipment – London and Scotland are the two most different ITL1 regions here, with both seeing faster growth than other ITL1 regions, starting in 2013. The scale on the chart makes this appear more pronounced than it is – the difference in growth rates in 2013 from the other ITL1 regions is only around 2 percentage points for Scotland and 3 percentage points for London.
- Other tangibles – the North West is the ITL1 region which stands out, with slightly faster growth than the other ITL1 regions, starting in 2005. This is likely due to the treatment of BNFL (described above). Although we have tried to account for this in the calculation of deflators, it still shows up to a small degree in this series. It does not seem to have a material impact on the composite deflator for total investment.
- Intangibles – there is a reasonable amount of dispersion, with London seeing slower deflator growth than most other ITL1 regions starting in 2004, and the East and East Midlands seeing slightly faster growth throughout but especially from around 2013 onwards. In the case of London, this is likely due to the large share of intangible investment in the ICT services industry (section J), largely in software, which has a notably weak deflator around 2003-2005. For the East and East Midlands, this likely reflects relatively more investment in R&D in the manufacturing industry, which has a relatively strong deflator from 2013 onward. Thus, these differences principally reflect the composition of the intangible investment.

[31] Reflecting only the composition of ICT equipment into computer hardware and telecommunications equipment, which themselves have quite similar deflators. There is only one deflator for each of these two underlying assets across all industries.

## Figures A1 to A6 – Composite investment deflators, total by asset, 1997 to 2020, index 1997 = 100, ITL1 regions

### Figure A1 – Total investment




### Figure A2 – Buildings and structures

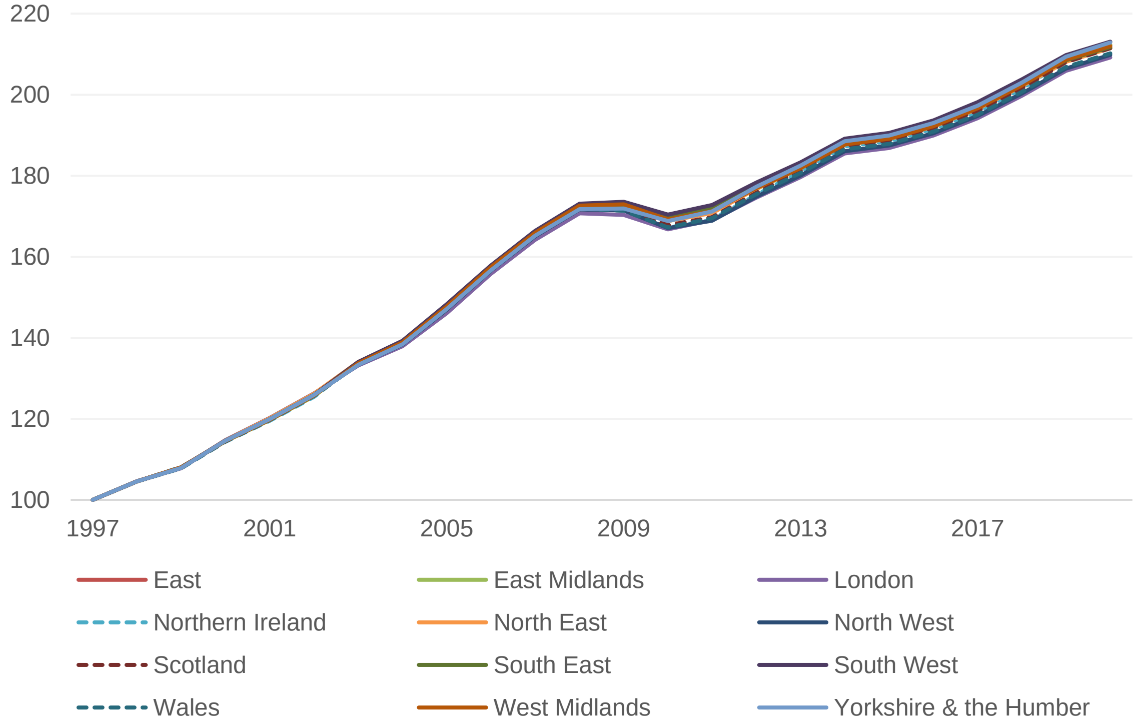


Figure A3 – ICT equipment

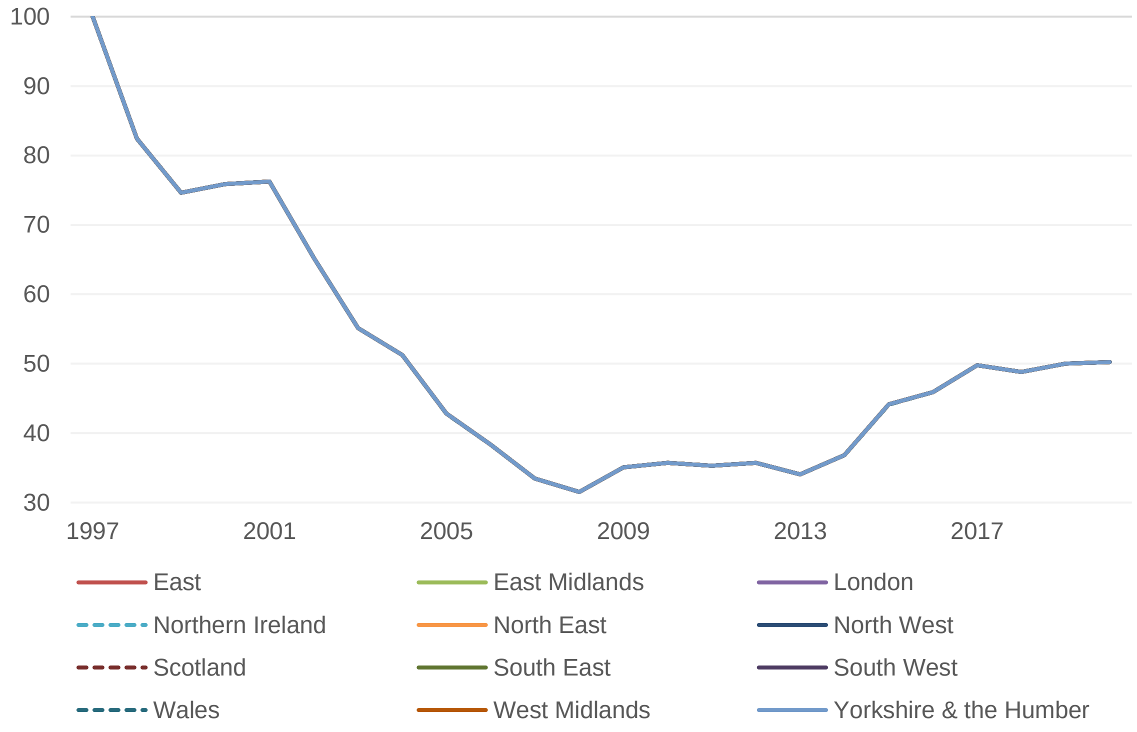



Figure A4 – Transport equipment

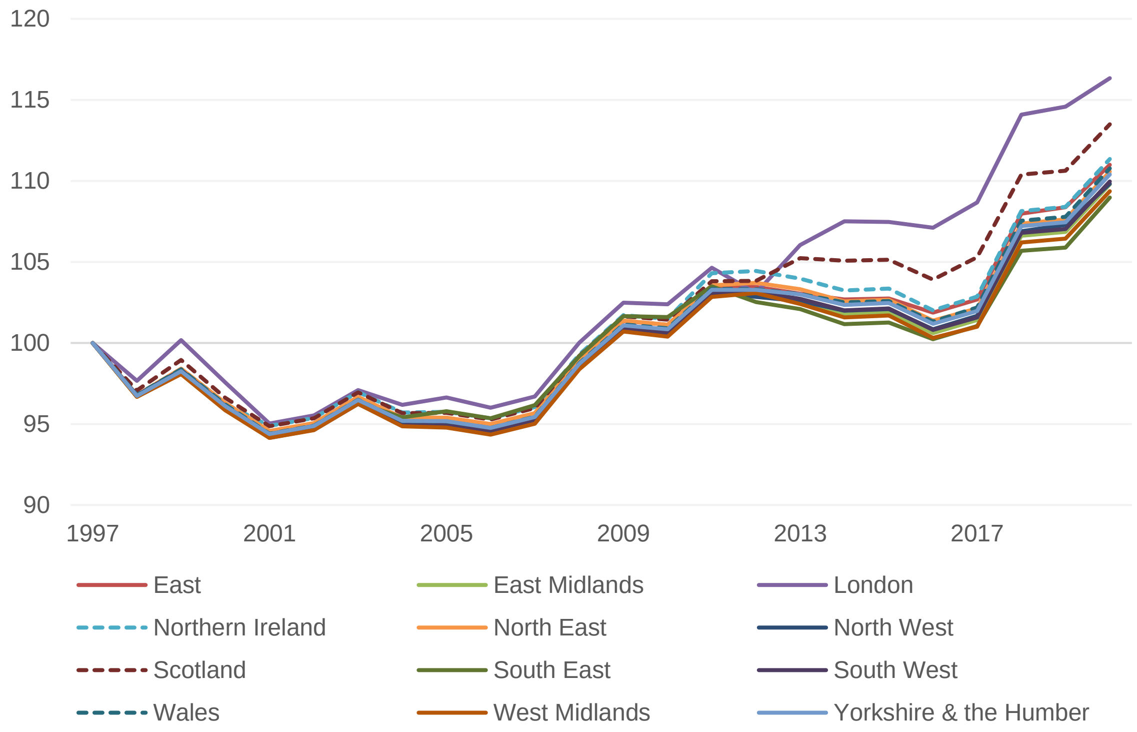


Figure A5 – Other tangible assets

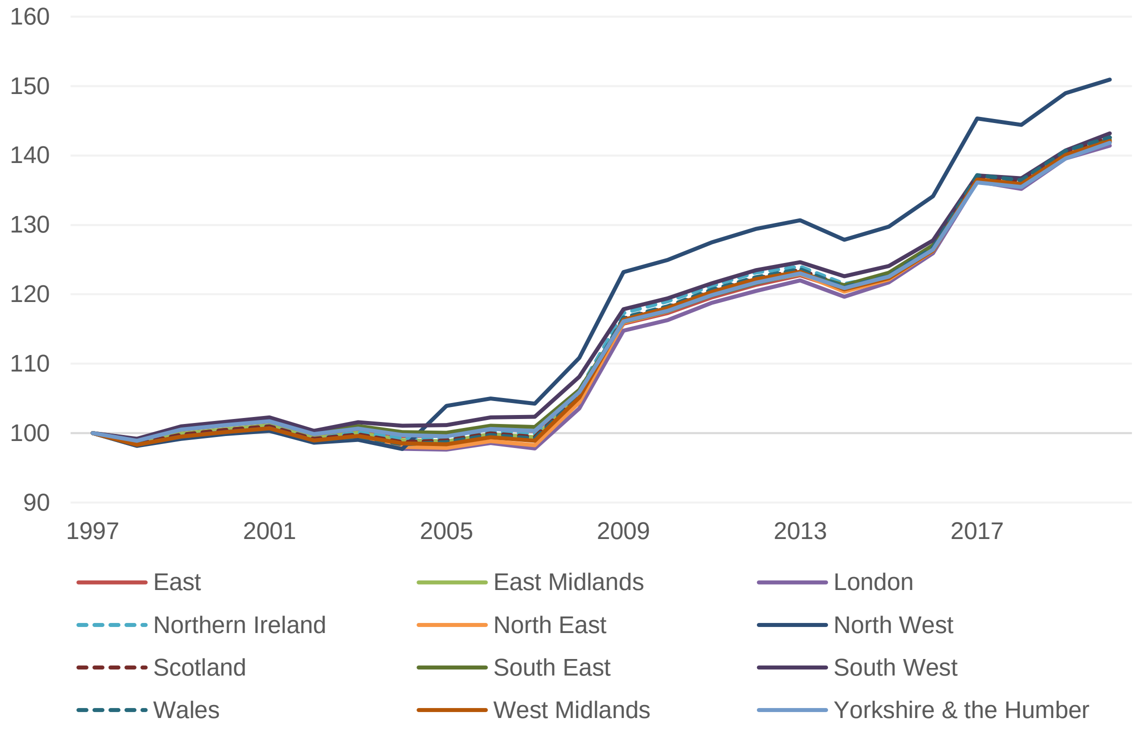
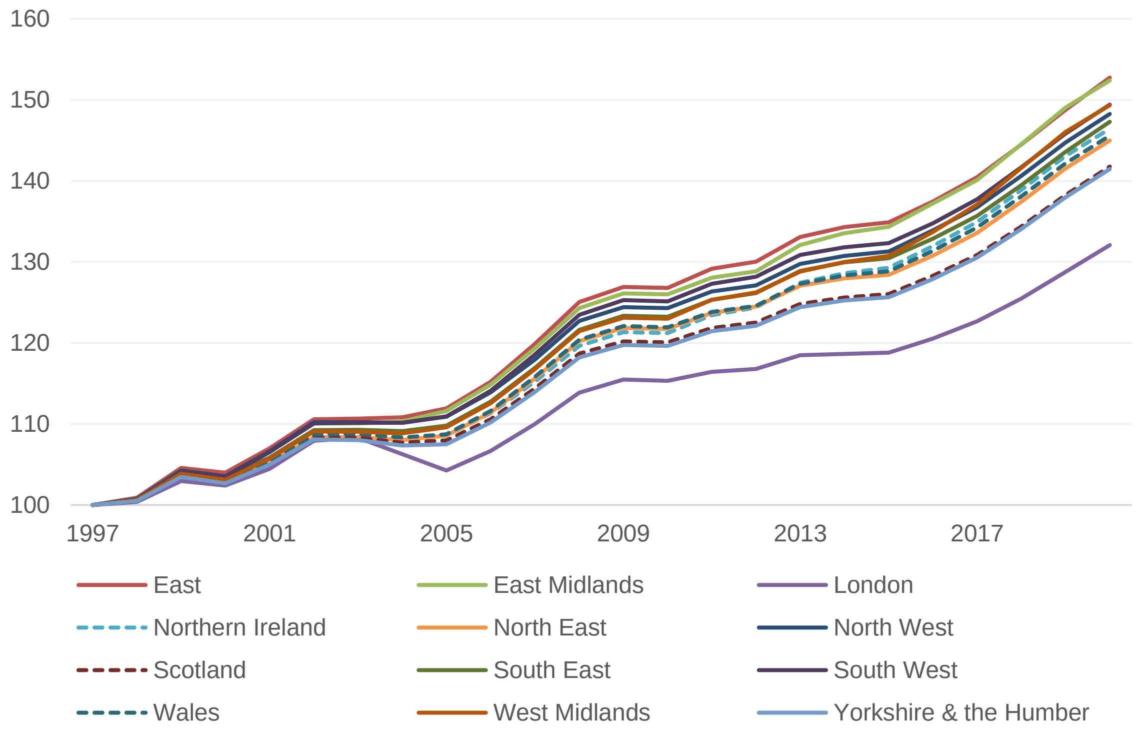



Figure A6 – Intangible assets



## Annex B – Additional maps

Figures B1 to B5 – Asset share of total investment, 1998 to 2019 average, ITL3 regions

Figure B1 – Buildings and structures

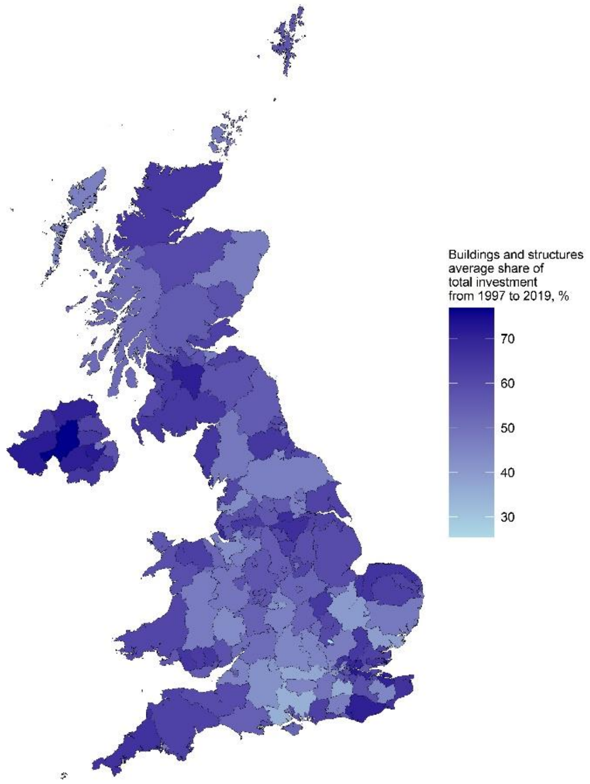



Figure B2 – ICT equipment

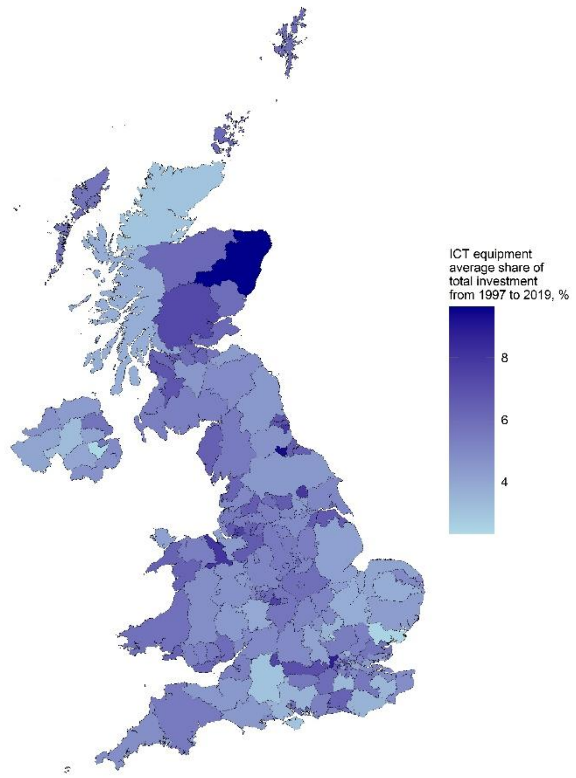



Figure B3 – Transport equipment

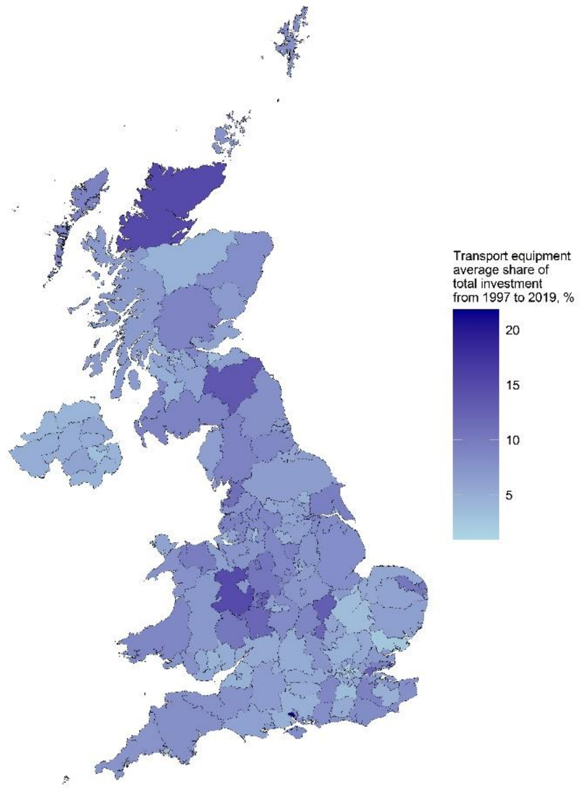



Figure B4 – Other tangible assets

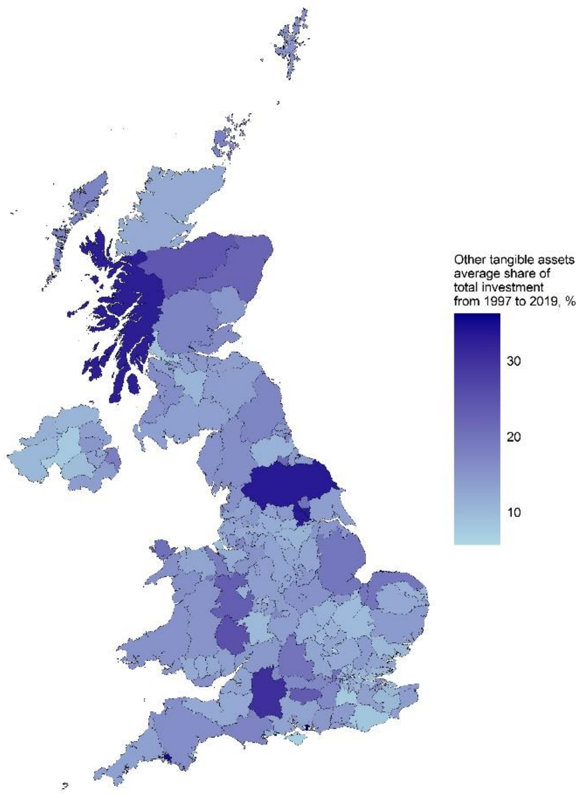
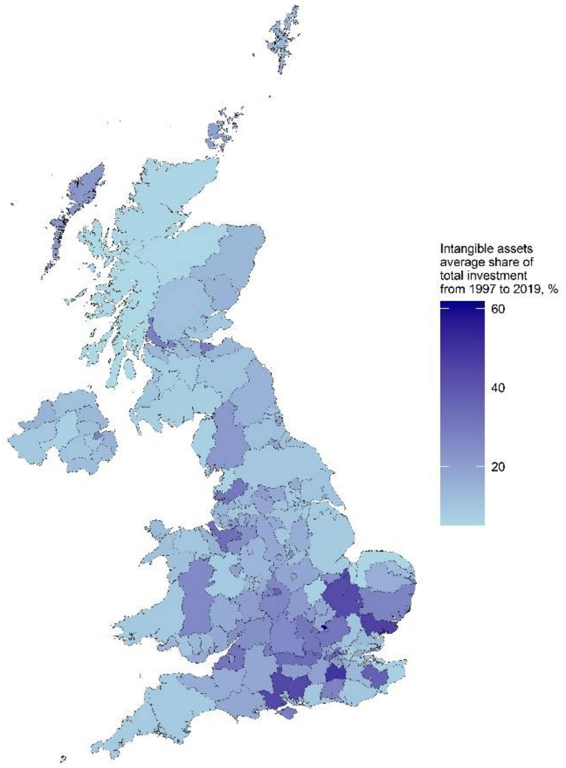


Figure B5 – Intangible assets




Figures B6 to B11 – Investment per hour worked, 2017 to 2019 average, ITL2 regions

Figure B6 – Total investment

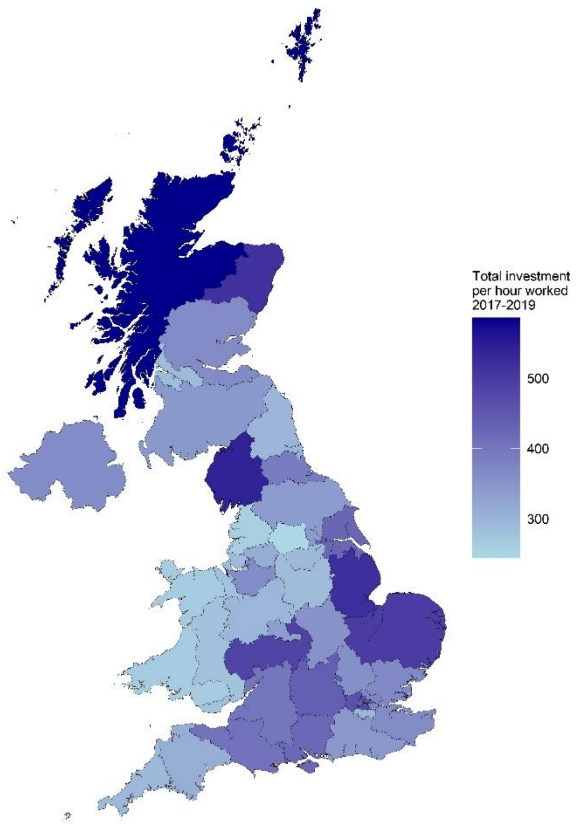



Figure B7 – Buildings and structures

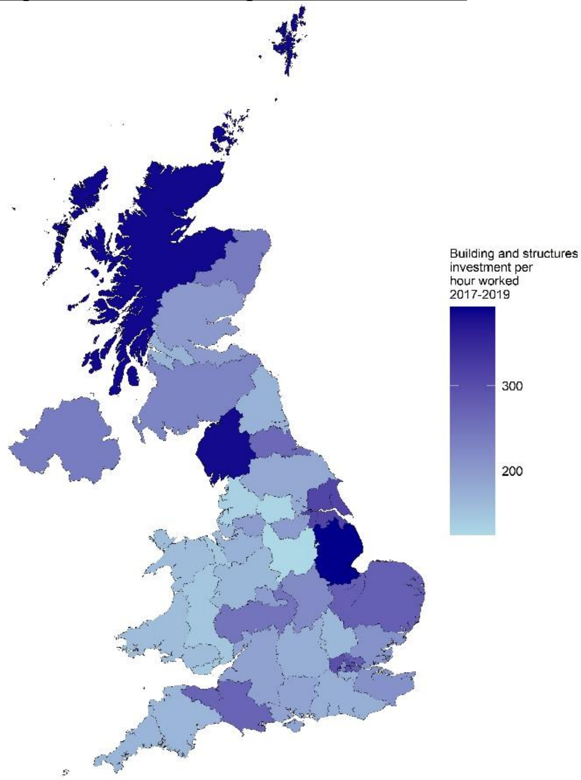


Figure B8 – ICT equipment

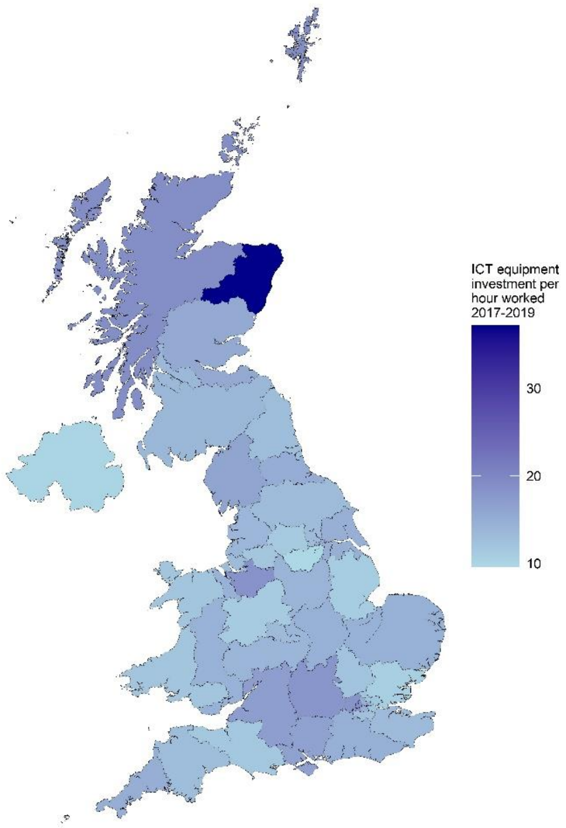



Figure B9 – Transport equipment

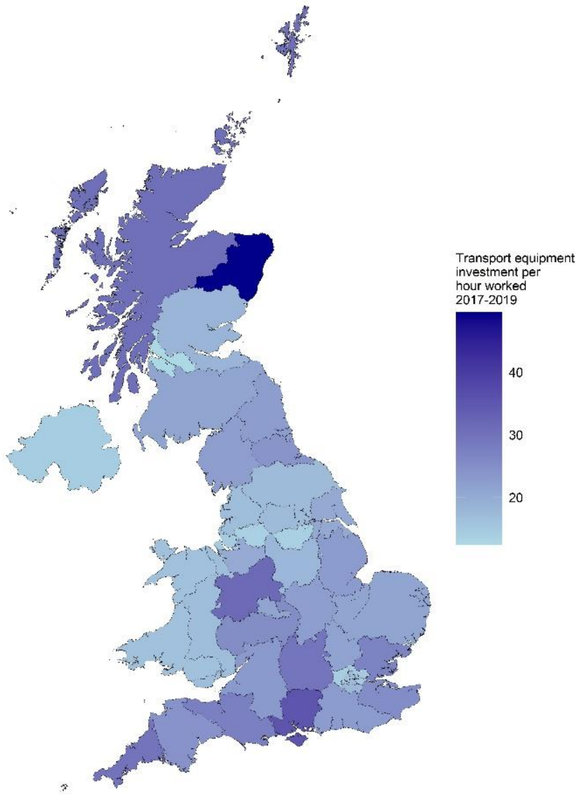



Figure B10 – Other tangible assets

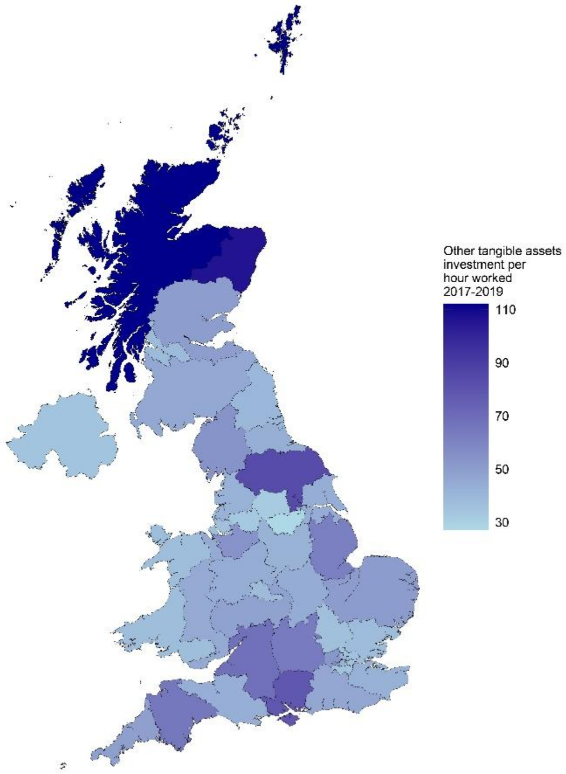
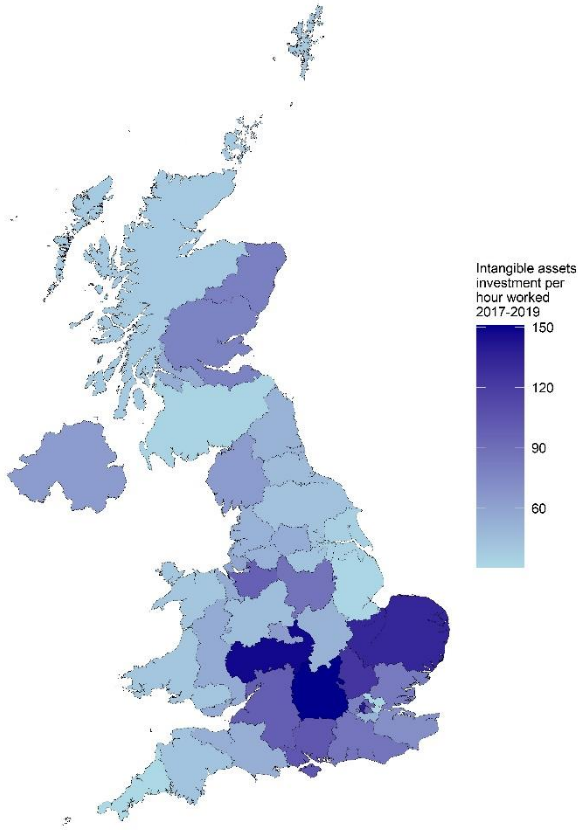



Figure B11 – Intangible assets



## Annex C – Additional analysis on the link between firm size composition and capital investment across regions

This Annex expands on the analysis in section 5.3, exploring the relationship between the composition of firms in a region and capital investment. To better account for the expected relationship between firm size and investment (that larger firms do more investment simply given their larger size), we now consider investment intensity measures (investment divided by GVA, or by hours worked). Since we are normalising the level of investment, we also normalise the number of firms, by looking at the proportion of firms in each region of each size; for instance, the share of total firms in a region that are size 0 to 4 employment.

We run a series of simple linear regressions on investment intensity (by asset), where the only explanatory variable is the proportion of firms[32] of each size in a region. With two[33] levels of geography (ITL2 and ITL3), six asset types (including total investment), two denominators (GVA and hours worked), and nine size bands, this entails 108 regressions.[34]

We summarise the results in Table C1, which shows the direction and statistical significance of the coefficients on firm size proportion, but not the actual coefficient, in order to aid interpretation. Three levels of statistical significance are highlighted: 10% (in the lightest colours, with only a + or - symbol), 5% (in the second darkest colours, with a * alongside the + or - symbol), and 1% (in the darkest colours, with two *s alongside the + or – symbol). Coefficients insignificant at the 10% level are in yellow with a +/- symbol.

There is some inconsistency between the measures using hours worked as a normaliser for investment, and the measures using GVA. Our preference is for the hours worked based measures, although we cannot be sure which is best. Measures using the ITL2 breakdown are rarely significant, likely due to the small number of data points (only 40).

Drawing mostly from the upper panel of Table C1 (reflecting the hours worked based measures), some intuitive patterns emerge. Investment intensity in buildings, intangibles and total investment is higher in regions with a larger proportion of very small businesses, which might be associated with start-ups. These very small firms, some of which will also be young, may benefit from initial or seed funding and make initial capital investments at the start of their life, especially in a building. As the firm grows, it has less need to invest further in buildings, since the asset life on buildings is long and the firm can continue to use it.

Regions with a relatively large proportion of medium-sized businesses see less investment overall but possibly more investment in more specialised assets, such as transport equipment, ICT equipment and other tangible assets (including specialised machinery and equipment for manufacturing, agriculture, and so on, and also general-purpose machinery such as office furniture).

[32] Data on "firms" is based on enterprises on the Inter-Departmental Business Register (IDBR), which includes public sector organisations, non-profit institutions (e.g., charities), public corporations, partnerships, and sole proprietors, as well as registered companies. To be included on the IDBR the unit must either be registered for VAT (requiring an annual turnover of over £85,000) and/or pay staff via PAYE income tax – thus it excludes the smallest firms and most self-employed. The vast majority of enterprises on the IDBR are traditional businesses, and we use the term "firms" throughout.
[33] With only 12 ITL1 regions, we judged the regression coefficients to be unreliable, so focus just on ITL2 and ITL3 breakdowns.
[34] We also conducted regressions with industry controls at the industry section level (letter-level) of SIC 2007. As hours worked estimates are not available by industry at ITL2 and ITL3 level, this was possible just for investment/GVA measures. The results were more consistent with those in the first panel of Table C1, than the second panel of Table C1. This is one reason why we prefer the results in the first panel of Table C1.

Finally, regions with a relatively large share of large businesses appear to invest more intensively in intangible assets. This could relate to difficulties in gaining finance for intangible investment, which is likely to be a particular issue for smaller businesses with little traditional collateral or reputation. Table C1 shows that regions with a relatively larger share of smaller businesses (although not the very smallest) may see less intangible investment. Larger businesses also tend to have better management practices (ONS, 2021), which might be associated with relatively more intangible investment.

As in previous sections, this analysis does not control for a range of other important factors and should therefore not be interpreted as causal. However, it offers some indication of how the composition of firms in a region might affect capital investment in that region.

<u>Table C1 – Direction and statistical significance of regression coefficients on the share of firms by firm size on investment intensity measures (investment divided by hours worked, and by GVA), ITL2 and ITL3 measures, 2016 to 2019 averages, UK</u>

| | Total investment | | Buildings and structures | | ICT equipment | | Transport equipment | | Other tangible assets | | Intangible assets | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ITL2 | ITL3 | ITL2 | ITL3 | ITL2 | ITL3 | ITL2 | ITL3 | ITL2 | ITL3 | ITL2 | ITL3 |
| **Investment / Hours worked** | | | | | | | | | | | | |
| 0 to 4 | +/- | +** | +/- | +** | +/- | +/- | +/- | +/- | +/- | +/- | + | +* |
| 5 to 9 | +/- | -** | +/- | -** | +/- | - | +/- | +/- | +/- | +/- | -* | -** |
| 10 to 19 | +/- | -** | +/- | -** | +/- | +/- | +/- | +/- | +/- | +/- | +/- | - |
| 20 to 49 | +/- | -** | +/- | -** | +/- | +/- | +/- | +/- | +/- | +/- | +/- | +/- |
| 50 to 99 | +/- | -* | +/- | -* | +/- | +/- | +/- | +/- | +/- | +/- | +/- | +/- |
| 100 to 249 | +/- | +/- | +/- | -* | +/- | +/- | +/- | +/- | +/- | +/- | + | +/- |
| 250 to 499 | +/- | +/- | +/- | -* | +/- | +/- | +/- | +/- | +/- | +/- | +** | + |
| 500 to 999 | +/- | +/- | -** | - | +/- | +* | +/- | +/- | +/- | +/- | +** | +** |
| 1000 plus | +/- | +/- | -* | - | +/- | +* | +/- | +/- | +/- | +/- | +** | +** |
| **Investment / GVA** | | | | | | | | | | | | |
| 0 to 4 | +/- | +/- | +/- | +/- | +/- | -* | -* | +/- | +/- | -* | +/- | +/- |
| 5 to 9 | + | +/- | + | +/- | +/- | +* | +* | +/- | + | +** | +/- | - |
| 10 to 19 | +/- | +/- | +/- | +/- | +/- | +** | +* | +/- | + | +* | +/- | +/- |
| 20 to 49 | +/- | +/- | +/- | +/- | +/- | +** | + | +/- | +/- | +/- | +/- | +/- |
| 50 to 99 | +/- | -* | +/- | -* | +/- | +/- | +/- | +/- | +/- | +/- | +/- | +/- |
| 100 to 249 | +/- | -* | +/- | -** | +/- | +/- | +/- | +/- | +/- | +/- | +/- | +/- |
| 250 to 499 | +/- | -* | - | -** | +/- | +/- | +/- | +/- | +/- | -* | +* | +/- |
| 500 to 999 | -* | -* | -** | -** | +/- | +/- | +/- | - | +/- | -* | +** | +* |
| 1000 plus | -** | -* | -** | -** | +/- | +/- | -* | - | -* | - | + | +* |

*Notes: Three levels of statistical significance are highlighted: 10% (in the lightest colours, with only a + or - symbol), 5% (in the second darkest colours, with a * alongside the + or - symbol), and 1% (in the darkest colours, with two *s alongside the + or – symbol). Coefficients insignificant at the 10% level are in yellow with a +/- symbol.*