Investigating the factors driving Scotland's productivity gap with international countries

Report for the Scottish Government

Ana Rincon-Aznar, Larissa da Silva Marioni, Francesco Venturini, Catherine Robinson

Disclaimer: The information and views set out in this report are those of the author(s) and not necessarily those of the Scottish Government.

Acknowledgments: We are grateful to Ben Gardiner from Cambridge Econometrics for proving capital stocks data and invaluable comments; we are grateful to Andrea Scanu at University of Cagliari for his research assistance.

Table of Contents

Abstract

Much as in the rest of the UK, productivity growth in Scotland has remained stagnant since the financial crisis (McLaren, 2018). The average labour productivity growth rate for Scotland during the period 2009-2017 was just over 1 per cent and appears to be stagnating in the international productivity rankings. While previous studies have investigated what might explain the productivity gap between Scotland relative to other areas of the UK, there is no comprehensive analysis of the productivity performance that illustrates Scotland's position in the regional European landscape. We aim to get a better understanding of what are the potential factors that might explain the productivity gap between Scotland and other well-performing European and UK regions. While this analysis is of high-policy relevance to the broad levelling-up agenda, which seeks to reduce economic and social disparities amongst the UK regions, does not consider in detail distributional issues.

Our comparative analysis focuses on a group of regions that are of similar level of economic development to that of Scotland, but that have excelled in terms of labour productivity growth. We examine the role played by capital investment, labour quality and Total Factor Productivity (TFP) as well as innovation and foreign direct investments (FDI) in explaining productivity differences. We focus on the post financial-crisis period covering the years from 2009 to 2017.

We find that Scotland has slightly outperformed many regions in the UK in terms of labour productivity, in particular thanks to a greater capital accumulation. However, and confirming empirically the ideas put forward by other studies, we find that the Scotland's underperformance relative to EU benchmark regions is largely explained by worse TFP and innovation, while to a lesser extent capital. On the innovation side, however, we find that Scotland does relatively well for its ability to translate the R&D effort into significant and economically important TFP gains.

Scotland has also been outstanding in attracting FDI, but this does not seem to be translating into higher TFP growth. We also present new evidence highlighting the diminished contribution from labour quality to labour productivity growth. This is the result of increased polarisation of workforce with greater role of graduates and a reduced importance of intermediate qualifications.

1 Key Findings

- Scotland's labour productivity fell sharply in the aftermath of the financial crisis, as in the UK and most developed countries. Since then growth has remained low, with a rate of labour productivity growth of just above 1 per cent per annum during the period 2009-2017.
- In this study we adopt a comparative approach, by illustrating what explains the existing productivity gaps between Scotland and other regions in the UK and in the European landscape. To this aim, we have compiled a new database that enables us to characterise all NUTS1 in Europe in terms of productivity and several economic and socio-demographic dimensions.
- Our analysis focuses on productivity gaps relative to a set of EU regions, which we consider the most suitable 'benchmark'. A distinctive feature of these comparison regions is that while they have exhibited a significant improvement in standards of living, Scotland has fallen behind.
- Scotland has a lower unemployment rate compared to other EU regions in the benchmark group. Scotland has also a well-educated population at the levels of the most developed regions in Europe.
- Scotland's capital per unit of labour is lower than the majority of regions in Belgium, Germany, the Netherlands, north of France, Ireland and Nordic countries. It is though higher than in most of the UK.
- During the period analysed here, about 40 per cent of labour productivity growth can be attributed to capital accumulation, and about 60 per cent of all labour productivity growth was due to TFP improvements. In contrast, the effect of improvements in labour quality (proxied by certified skills) was almost negligible.
- We find that Scotland has slightly outperformed many regions in the UK in terms of labour productivity, in particular thanks to this greater capital accumulation. However, and confirming empirically the ideas put forward by other studies, we find that the Scotland's underperformance relative to EU benchmark regions is largely explained by worse TFP and innovation, while to a lesser extent capital. In absolute terms the rate of TFP growth is lower than in many UK and benchmark regions.
- Skill shortages, usually measured by surveys of firms' perceptions, can have sizeable adverse impacts on productivity growth. From an employer's perspective, we observe that Scotland has a lower proportion of high-skills vacancies compared to the UK as a whole.
- Amongst the reasons given for 'hard-to-fill' vacancies stand out the 'poor terms and conditions (e.g. pay) offered for post' and the 'competition from other employers'.
- We find that job applicants in Scotland present smaller gaps in 'complex analytical and digital skills' compared to the whole of the UK, but more in 'communicating in a foreign language'.
- Gaps in 'management and leadership skills' were reported to be higher in Scotland compared to the other UK regions. This finding is in line with the results from the UK Labour Force Survey, showing that in recent years the share of managers attending

training or education has fallen in Scotland, alongside the UK as a whole. The share of managers with graduate qualifications has been stagnant but has picked up in the last year. More data will be needed however to understand whether this represents a change on trend or it is rather a reflection of short-lived changes in the workforce as a result of the Covid-19 breakout in 2020.

- In innovation effort, we find that Scotland falls on the right-hand tail of the distribution of the percentage of R&D over regional GDP compared to the benchmark region (with a share of 1.5% over GDP). Again, this is due to the low investment in the business sector with a contribution of only 0.6% of GDP.
- In terms of innovation output, Scotland's total number of patents per million inhabitants is 49. This is below all the EU regions in the comparison group. The relative low propensity to patent in Scotland can be traced back to the business sector.
- In contrast, Scotland's public research institutions (the higher education sector and government) perform well in relation to the reference regions. Relative to UK regions, Scotland is in the middle of the ranking of patenting performance.
- While Scotland has invested less in innovation than other comparable regions in the EU, it has a more positive innovation outcome in terms of patents per amount spent in R&D, relative to other UK regions, behind only the South East and London.
- In terms of Foreign Direct Investment, Scotland has by far the greatest level of activity in FDI investment, compared to regions in the comparison group. The positive association with measures such as employment, capital formation and GVA/GDP are indicative of a scale effect in attracting FDI. But we do not find evidence that regions with higher inflows of FDI also experience higher rates of TFP growth. These gains may materialise over time but cannot be seen within the short timeframe of few years of our analysis.
- We have investigated econometrically how TFP growth in Scotland systematically differs from that of other regions, looking in particular at the role played by knowledge factors which the literature has identified as key drivers of productivity growth.
- The results show a direct impact of R&D intensity on TFP growth. In the case of Scotland this is statistically significant and economically more important than the average in our sample of regions. The value of our estimated coefficient implies that 1 per cent increase in the share of R&D expenses on GDP should raise the rate of TFP growth by 1.3%, which is a sizeable effect, well above that found in the referenced literature. However, this R&D intensity does not seem to accelerate the process of technological transfers from the frontier.
- A different story emerges for human capital; while this factor is not found to have a direct positive effect on TFP growth, it does seem to stimulate Scotland's absorption of forefront knowledge.

2 Introduction

It is well-established in the economic literature that productivity is a key determinant of long-run economic growth and international competitiveness, necessary to sustain increases in living standards. As with the rest of the UK, productivity growth in Scotland has remained stagnant since the financial crisis (McLaren, 2018), and appears to be worsening in the international productivity rankings. To tackle the productivity problem, the Scottish Government created the Enterprise and Skills Board in 2017, with the aim to align and co-ordinate the activities of Scottish firms and skills' agencies and thus create the right conditions for an inclusive and sustainable growth path (Enterprise and Skills Board, 2018).

In the years leading up to the financial crisis, Scotland ranked 16th (out of 37) among OECD countries in terms of level of productivity[1] and while maintaining its productivity rank until 2017 (Scottish Government, 2018a), the gap between Scotland and the bottom of the top quartile of OECD countries has recently widened. A critical objective of the government is to project Scotland into the top quartile of OECD countries of productivity performance. As discussed in Kelly et al. (2018), a move to the top quartile in terms of productivity would mean aligning its productivity to the level of Denmark (which is 20 per cent above Scotland's current position). Within the UK, Scotland ranks 4th in terms of productivity per worker (in 2017)[2], behind London, the South East and East of England (Scottish Government, 2018b).

According to economic growth theory, the rate of labour productivity growth can be traced back to growth in three factors, namely physical capital, human capital, and Total Factor Productivity (TFP). TFP growth is a proxy measure for efficiency and technological change, likely to be influenced by a number of other factors such as a country's rate of innovation, the level of trade openness and engagement in international markets, and the quality of a country's institutions (Acemoglu et al. 2005; Griffith, et al., 2006). Empirical studies have indeed established that differences in TFP can explain a large part of the aggregate productivity and output differences amongst developed countries (OECD, 2003; O'Mahony and Timmer, 2009).

Previous works have investigated the nature and drivers of the productivity gap in Scotland using both national (including analysis of firm-level data) and international data sources (e.g. Scottish Government, 2016; Harris and Moffat, 2017; Kelly et al., 2018; McLaren, 2018). However, less research has investigated the sources of cross-country productivity growth at a sub-national level. Kelly et al. (2018) compare the Scottish productivity with that of other OECD countries. They find that lower capital intensity and TFP were the main reasons behind Scotland's relative under-performance, compared to other similar-sized economies. These results suggest that improvements in business environment, management quality and R&D are factors that could contribute to reducing the total factor productivity gap, in particular. Scotland fares better in terms of skills, with a highly educated workforce, above the levels on average of most developed countries, and that of the UK as a whole (Aitken et al. 2019).

[1] Measured as GDP per hour worked.
[2] Measured as Gross Value Added (GVA) per hour worked.

This report is structured as follows. Section 3 provides an initial overview of data sources and approaches adopted in this study and describes the main data considerations and limitations. Section 4 presents the approach to select a suitable benchmark for Scotland and investigates sources of differences in labour productivity levels across regions. Section 5 deepens the analysis to labour productivity growth performance and presents new evidence on drivers. Section 6 illustrates trends in demand for skills in Scotland and other UK regions. Section 7 reviews evidence of organisational and managerial practices and workplace performance and presents some illustrative findings for Scotland. Section 8 goes on to present the results of the econometric exercise on determinants of total factor productivity growth adopting a 'distance-to-frontier' approach. Section 9 concludes and Section 10 outlines avenues for future research.

3 Data description and empirical approaches

In this report, we set out to investigate causes underlying the productivity gap between Scotland and a selection of other advanced economies during the period 2009-2017. The work adopts a comparative perspective focusing on Scotland vis-à-vis a set of European regions, that are chosen as suitable benchmark. The main unit of this analysis are the EU NUTS1 regions, for which we have gathered a rich database of official data outputs, inputs, as well as a number of other economic and socio-demographic characteristics. We focus on the post-financial crisis period, that is 2009 to 2017, which allow us to provide a robust and recent picture of productivity performance and productivity gaps. We have compiled available data from the year 2000, but have focused on the post-financial crisis period as we aim to provide the most recent picture of productivity performance and productivity differences between Scotland and relevant comparators.

We are able to position Scotland in the European productivity map and relate to regions of similar level of economic development. With this approach, we aim to learn valuable lessons from well-performing regions and highlight strengths and weaknesses of Scotland's productivity performance. An alternative to this regional comparative exercise would be to focus solely on country-level comparisons, but this limits the range of countries with which we can establish meaningful comparisons. While firm-level data allow us to identify detailed factors influencing firm's behaviour, they are more suited for a UK-based analysis[3].

[3] International firm-level data exists but are limited in their content and coverage. BvD Orbis database is an all-European commercial data source, focused on collecting financial information but crucially, it lacks national representativeness.

In constructing our comprehensive regional database, we combine a rich range of datasets from sources such as Eurostat, EU KLEMS[4], the UK Labour Force Survey (UKLFS), the OECD EPO Reg Pat database (release January 2020) and FDI Markets. We merge all datasets using the harmonised NUTS1 codes, which are our main geographical unit of analysis[5]. In the Appendix we describe in further detail the main datasets used and data construction tasks that underlie our empirical exercise.

Firstly, we investigate differences in levels of productivity between Scotland and close comparators, implementing a *levels accounting* framework. We show what are the main factors explaining long-standing differences between Scotland and pertinent European regions. Second, we employ a dynamic *growth accounting* approach to map the sources of regional productivity growth in the period since the financial crisis. We aim to understand better what are the elements mostly limiting Scotland's productivity resurgence, which can be important forces elsewhere. While this type of framework does not allow us to address causality, it is a powerful accounting tool and has been employed extensively in the empirical literature to explain cross-country and cross-industry productivity differences[6]. Growth accounting is a widely used empirical tool to map the sources of growth across geographical and industrial units, despite criticism by new growth theorists questioning the restrictiveness of some of the methodological assumptions. Both the levels and growth accounting exercises allow us to pin down what are the main contributing factors to labour productivity cross-differences, disentangling the effect of capital investment, human capital or Total Factor Productivity (TFP).

A critical issue is the measuring of labour quality and skills in the above framework. Following previous cross-country empirical studies[7] we use changes in the employment shares of groups with different educational attainment to measures changes in labour quality. We draw from Eurostat data, which reports workforce shares according to three educational categories, classified as high, medium and low level, following the International Standard Classification (ISCED11). These are computed from micro data extracted from the national releases of the Labour Force Survey. We then use average wages by the same education group as a proxy for worker productivity, when computing the contribution of labour inputs to labour productivity. Due to small sample sizes, we are not able to consider employment shifts by other productivity-determinant characteristics such as age and gender. A potential limitation of this approach is that we are unable to incorporate formally qualification mismatches, beyond those implied by the wages paid.

---

[4] For a summary overview of the methodology and construction of the cross—country cross-industry EU KLEMS database, see Jäger (2018) and O'Mahony and Timmer (2009). For more details and analysis using these data, see van Ark and Jäger (2017).

[5] A complication we have to deal with was the change of NUTS classification in 2013, for which we had to use concordance tables.

[6] This is standard empirical methodology, based on the classical assumptions of constant returns to scale and competitive factor markets, and absence of externalities (Hulten et al. 2001; Greenwood and Jovanovic 2001).

[7] See O'Mahony and Timmer and Rincon-Aznar et al. (2015)

In addition to a formal analysis of level and productivity growth gaps, we explore results from the UK government's Employer Skills Survey (ESS) for 2017 which helps us characterise the nature of skills gaps, as perceived by employers, for the four nations of the UK. The ESS is one of the very few nationally-representative employer surveys in the UK, which is administered at the workplace level. The survey is conducted every two years with a UK sample size of around 90,000 workplaces. There are a number of international initiatives looking at skills surveys, but as yet there is not a comparable EU wide survey, with or without the UK, that can be used alongside the disaggregated results from the UK presented here.

Another key element in the measuring of labour productivity is that of capital. We draw from estimates from Ben Gardiner and colleagues at Cambridge Econometrics. The authors provide us with capital stock estimates for the NUTS1 and NUTS2 regions for the EU27. The latest data are available until 2016, so the analyses that require of the use of capital stocks are limited to 2016. The authors use data sourced from EUROSTAT to estimate their measures of regional capital, as measures of regional capital that are consistent with the National Accounts are not currently publicly available for the UK.

Further data sources employed in this study are the EPO patents database and FDI Markets. The former enables us to illustrate Scotland's position in terms of innovation, by focusing on the number of patents obtained by institutional sectors. The latter is a comprehensive record of FDI transactions globally, and it remains the most comparable international source of sub national data on FDI flows.

Drawing from the full database of EU regions, in the final section we estimate a model to investigate econometrically how TFP growth of Scotland has systematically differed from that of other regions. This type of model allows us to go beyond a pure accounting exercise and use the cross-region variation in TFP growth to understand its determinants. We employ panel data techniques that enable us to control for a range of observable factors and account for unobservable characteristics of the regions.

In particular, we stress the role played by knowledge factors, such as R&D expenditure and human capital, measured by the percentage of population with tertiary education. Within this modelling framework we are able to account for the potential to catch up to the technological frontier and that of technology transfers from the most advances to the laggard regions. A limitation is that we are not able to include further factors that would have an effect on TFP performance according to the literature. For instance, we are not able to explicitly look at the role played by managerial practices, workplace performance or organisational practices. This is because of the lack of harmonised regional data covering these aspects. These data do exist at a European country-level but are usually affected by low sample size problems.[8]

[8] For instance, the European Workings Conditions Survey (EWCS).

4 Productivity levels

4.1 Constructing a benchmark for Scotland

In this section we compute the GDP per capita for all EU regions expressed in purchasing power parities (PPP). We then rank all NUTS1 European regions according to their GDP per capita, and classify into the four different quartiles of GDP per capita, both in 2009 (start of sample period) and 2017 (end of sample period). Table A1 to Table A4 in the Appendix show the classification of all the NUTS1 regions in each of the four quartiles of the GDP per capita distribution.

Table A1 reveals which regions have the highest average GDP per capita (Euro PPP). These are Luxembourg (LU0), Brussels region (BE1), Hamburg (DE6), London (UKI), Île-de-France (FR1), and West Netherlands (NL3) in both 2009 and 2017. Thus, we see consistency in regional ranking. Ireland (IE0) appears in the top quartile in 2017 and is the region with the fifth highest GDP per capita in Europe. Scotland's GDP per capita, lies in the second quartile of the GDP per capita distribution in EU, at 25,200 Euro in 2009 and 29,200 in 2017.[9]

To identify a set of regions for comparison purposes - the 'EU benchmark regions' - we focus on those regions that were in the same (2nd highest) quartile of the GDP per capita distribution as Scotland in 2009, but that have seen a significant improvement in their GDP per capita during the period 2009 to 2017. Some of these regions have gone up in the GDP per capita ranking, to the extent that they moved into the top quartile of NUTS1 regions, while Scotland has seen its position stagnate. Scotland is the region with the 41st highest GDP per capita in Europe in 2017 (40th in 2009). It is interesting to note that five of out of these nine regions are located in Germany. This set of regions, hereinafter are denoted as the 'EU benchmark', are presented in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Table 1: GDP per capita for Scotland and EU benchmark regions

NUTS1	Region	2017 GDP per capita PPS (Euro)	Average GDP growth per capita 2009-2017
DE3	Berlin	36,300	1.57
BE2	Vlaams Gewest	36,000	1.39
AT2	Südösterreich	33,900	1.21
DE9	Niedersachsen	33,700	2.14
SE2	Södra Sverige	33,600	1.05
DEC	Saarland	33,200	1.32
DEB	Rheinland-Pfalz	32,800	1.75

[9] We express GDP per capita in Euros to facilitate comparability.

DEF	Schleswig-Holstein	30,200	1.33
UKH	East of England	29,500	1.07
UKM	Scotland	29,200	0.49

Source: Eurostat, own calculations.

Fehler! Verweisquelle konnte nicht gefunden werden. and 3 present a set of indicators variables for UK and EU benchmark regions that describe the structural characteristics of these economies. Scotland has a well-educated workforce, with one of the most educated populations. In 2009, 38.5% of the Scottish population held a tertiary degree. This is at a similar level to Berlin (DE3) and the Belgium region of Vlaams Gewest (BE2) (with a 38.5% and 38.3%, respectively). These two regions have higher GDP per capita and labour productivity levels than Scotland, in terms of both GVA per hour or GVA per person employed. By 2017, Scotland was the region with the highest proportion of population with tertiary education (48.6%), and this has increased by more than 10 percentage points compared to 2009.

Scotland's unemployment rate was 6.9% in 2009, which is the same level as the German region of Niedersachsen (DE9). Although unemployment rates dropped in both regions in 2017, the level in Scotland is marginally higher than in Niedersachsen (4.1% and 3.8% respectively). The share of employment in manufacturing in Scotland was 8.3% in 2009 and 8.1% in 2017, which is noticeably below that of most of the EU benchmark regions, where it ranges between 12% and 21%. These findings are indicative of significant structural differences across the regions.

Compared to the rest of the UK, Scotland's share of the population with tertiary education is only outperformed by London throughout the whole period. Scotland's unemployment rate was relatively low in 2009 compared to the other UK regions. Despite the fall in unemployment rate in all regions by 2017, Scotland's unemployment rate was the same as the North West (4.1%). Scotland's share of employment in manufacturing is at a similar level to the South East but behind London. Further, Scotland's exports as a share of GDP was among the lowest levels in the UK in 2009, but increased significantly by 2017.

In addition to the regions that conform to our primary benchmark we extend the analysis to an alternative set of regions that can serve as a secondary comparison group. These are regions with higher GDP per capita levels relative to Scotland at the beginning of the sample period, which continued to grow vigorously in subsequent years. We select those regions who were in the first or second highest quartile of the GDP per capita distribution in 2009, and where the average growth in GDP per capita during the period 2009 to 2017 was at least 1 standard deviation higher than the mean average growth of the 2nd quartile (where Scotland was in the GDP per capita distribution). This set of regions are listed in detail are presented in the Appendix Table A5. They were in Ireland, France, Germany, Spain or the Netherlands. Note that two of those regions are also part of our primary benchmark group: Niedersachsen (DE9) and Rheinland-Pfalz (DEB).

Table 2: Descriptive statistics – EU Benchmark regions

		2009						
Nuts1	**Region**	**GDP per capita PPS**	**Labour Productivity (GVA/Hours)**	**Labour Productivity (GVA/person employed in thousand)**	**Share of population with tertiary education**	**Unemployment rate (%)**	**Share in manufacturing (%)**	**Population**
AT2	Südösterreich	27000	33.38	57.02	17.41	4.90	16.90	1,764,257
BE2	Vlaams Gewest	28700	45.66	71.20	38.34	4.90	17.20	6,208,877
DE3	Berlin	28300	36.56	53.37	38.48	13.70	8.70	3,431,675
DE9	Niedersachsen	25100	36.66	50.71	22.92	6.90	19.60	7,947,244
DEB	Rheinland-Pfalz	25200	37.19	51.15	24.06	6.00	20.80	4,028,351
DEC	Saarland	26400	36.69	49.82	20.89	8.40	19.40	1,030,324
DEF	Schleswig-Holstein	24000	35.49	49.75	23.18	7.30	13.90	2,834,260
SE2	Södra Sverige	27400	34.82	56.59	31.68	8.50	14.90	4,026,590
UKH	East of England	24300	31.68	51.19	30.57	6.20	9.80	5,730,000
UKM	**Scotland**	**25200**	**31.40**	**51.44**	**38.51**	**6.90**	**8.30**	**5,216,921**
		2017						
Nuts1	**Region**	**GDP per capita PPS**	**Labour Productivity (GVA/Hours)**	**Labour Productivity (GVA/person employed in thousand)**	**Share of population with tertiary education**	**Unemployment rate**	**Share in manufacturing**	**Population**
AT2	Südösterreich	33900	36.96	60.50	31.49	4.60	17.50	1,798,375
BE2	Vlaams Gewest	36000	47.59	76.07	45.57	4.40	14.50	6,526,061
DE3	Berlin	36300	40.16	56.91	42.64	7.00	7.50	3,574,830
DE9	Niedersachsen	33700	40.88	56.38	24.02	3.80	18.60	7,945,685
DEB	Rheinland-Pfalz	32800	41.55	56.56	26.32	3.30	19.30	4,066,053
DEC	Saarland	33200	39.17	53.01	23.61	4.50	21.00	996,651
DEF	Schleswig-Holstein	30200	38.30	53.27	23.64	3.60	12.10	2,881,926
SE2	Södra Sverige	33600	43.50	71.06	39.69	6.70	12.30	4,322,801
UKH	East of England	29500	33.53	55.67	39.02	3.90	9.10	6,148,608
UKM	**Scotland**	**29200**	**33.66**	**55.88**	**48.61**	**4.10**	**8.10**	**5,414,723**

Tε *Source: Eurostat, own calculations*

NUTS1	Region	GDP per capita PPS (Euro)	Labour Productivity – in Euro (GVA/hour)	Labour Productivity (GVA/employment)	Share of population with tertiary education	Unemployment rate (%)	Share in manufacturing (%)	Exports/GDP (%)*
		2009						
UKC	North East	20,400	28.5	45,800	30.3	9.2	10.3	21.6
UKD	North West	23,200	30.5	49,300	33.3	8.3	11.1	17.3
UKE	Yorkshire and The Humber	21,900	28.8	46,500	32.2	8.5	11.5	12.1
UKF	East Midlands	21,400	28.3	46,200	30.3	7.1	13.7	18.1
UKG	West Midlands	21,000	27.8	45,700	30.7	9.7	13.3	13.8
UKH	East of England	24,300	31.7	51,200	30.6	6.2	9.8	17.2
UKI	London	45,300	43.9	76,800	47.5	9.0	3.6	7.2
UKJ	South East	28,900	35.9	57,900	36.2	5.8	8.0	18.4
UKK	South West	23,700	29.8	47,300	33.4	6.1	10.4	10.0
UKL	Wales	18,800	26.8	42,900	35.2	8.1	11.2	21.2
UKM	**Scotland**	**25,200**	**31.4**	**51,400**	**38.5**	**6.9**	**8.3**	**12.2**
UKN	Northern Ireland	20,900	26.8	46,200	32.8	6.4	11.1	16.1
		2017						
NUTS1	**Region**	**GDP per capita PPS (Euro)**	**Labour Productivity – in Euro (GVA/hour)**	**Labour Productivity (GVA/ employment)**	**Share of population with tertiary education**	**Unemployment rate (%)**	**Share in manufacturing (%)**	**Exports/GDP (%)***
UKC	North East	23,000	30.8	50,000	36.6	5.6	10.5	24.3
UKD	North West	28,000	32.6	53,700	39.4	4.1	10.6	16.2
UKE	Yorkshire and The Humber	25,200	30.2	49,000	38.2	4.8	11.7	14.0
UKF	East Midlands	25,400	29.8	49,400	37.2	4.0	14.0	19.4
UKG	West Midlands	26,600	31.1	52,000	36.6	5.5	12.4	24.6
UKH	East of England	29,500	33.5	55,700	39.0	3.9	9.1	18.2
UKI	London	56,500	46.4	82,700	59.5	5.3	3.3	8.3
UKJ	South East	34,200	37.9	62,100	45.2	3.2	8.1	16.7
UKK	South West	28,000	32.1	51,600	43.0	3.6	8.9	15.0
UKL	Wales	23,100	29.4	48,200	39.0	4.5	10.4	26.2
UKM	**Scotland**	**29,200**	**33.7**	**55,900**	**48.6**	**4.1**	**8.1**	**20.7**
UKN	Northern Ireland	25,800	30.7	53,600	39.8	4.6	10.0	20.6

Source: Eurostat, ONS, own calculations.

4.2 Labour productivity

We measure the level of labour productivity as GVA per hour worked (in 2010 prices).), BE1 (Brussels), FR1 (Île-de-France), DK0 (Denmark), SE1 (Östra Sverige), NL3 (West-Nederland), DE6 (Hamburg), UKI (London), and BE2 (Vlaams Gewest).

Figure *1* illustrates broad differences in the levels of labour productivity for the NUTS1 regions in Europe in 2016.[10] The figure shows that Scotland's labour productivity is below a significant number of regions in Northern Europe, in particular those located in Luxembourg, Ireland, France, Germany, Belgium, the Netherlands and in the Nordic countries. The NUTS1 regions with highest levels of labour productivity on average are Luxembourg (LU0), Ireland (IE0), BE1 (Brussels), FR1 (Île-de-France), DK0 (Denmark), SE1 (Östra Sverige), NL3 (West-Nederland), DE6 (Hamburg), UKI (London), and BE2 (Vlaams Gewest).

Figure 1: Real GVA per hour worked (Euro, 2010 prices) – NUTS 1 regions

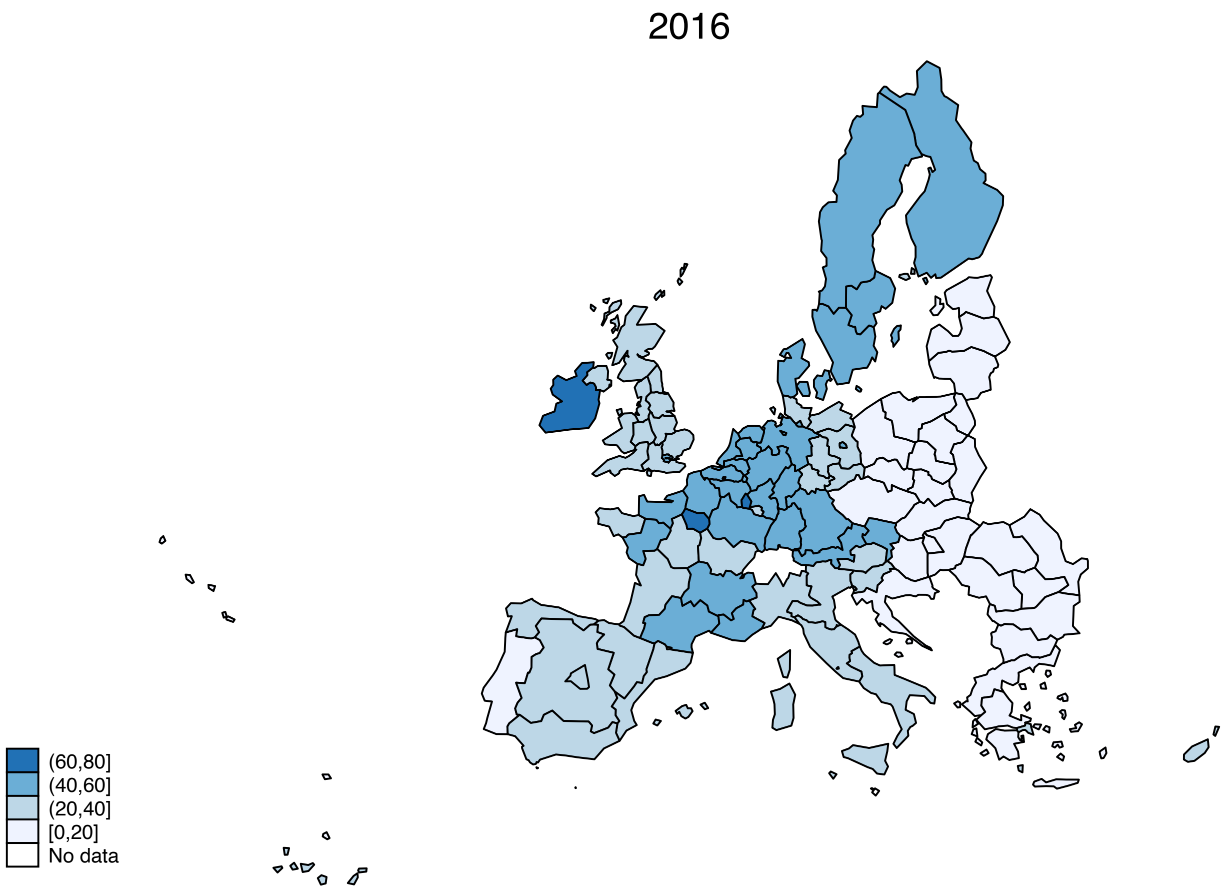
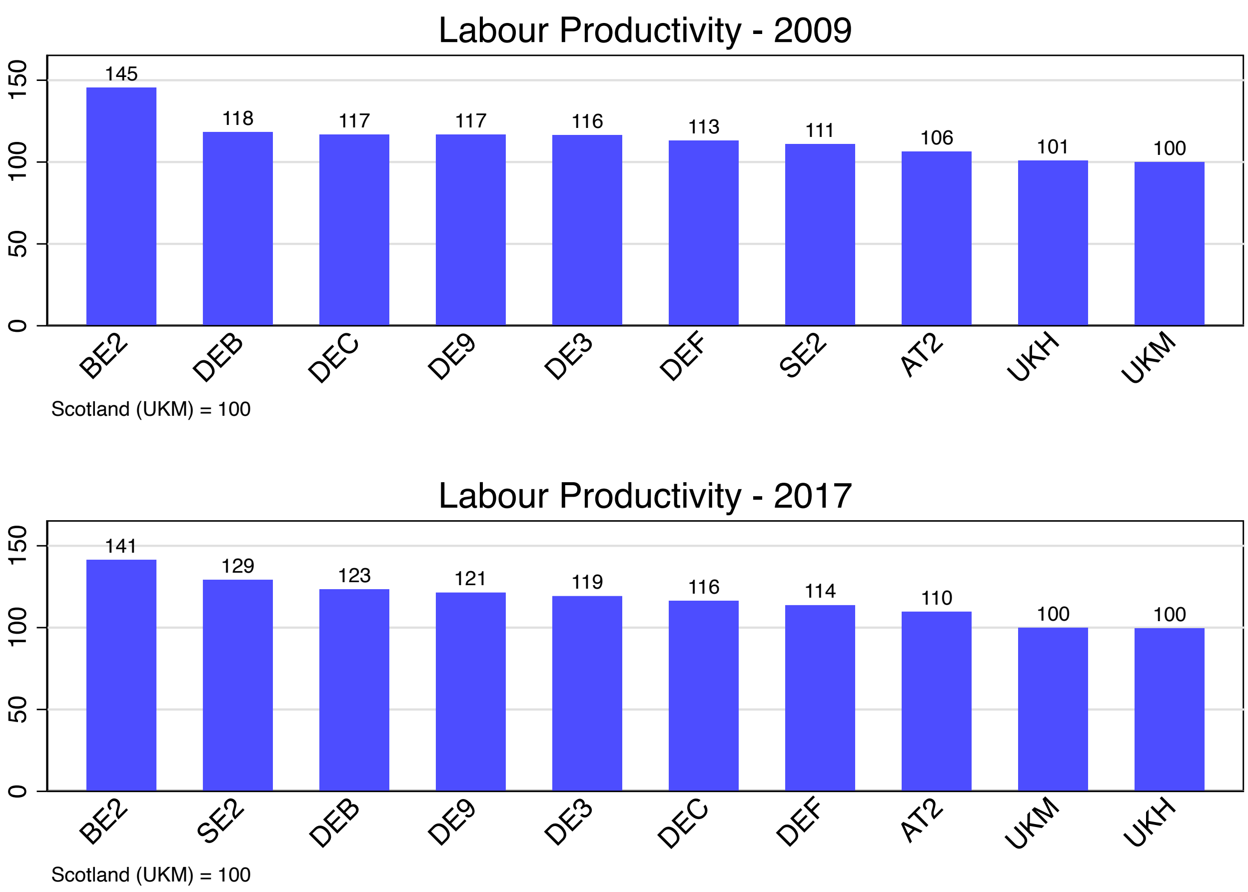


Figure 2 and Figure 3 show the labour productivity levels relative to Scotland for UK and EU benchmark regions (in 2009 and 2017).

[10] 2016 is the latest year with data available for most NUTS1 regions. 2017 data is available but not consistently across all EU regions.

Scotland's labour productivity level was lower than all the EU benchmark regions (Figure 2). The Belgium region of Vlaams Gewest (BE2) presents the highest levels of labour productivity among these regions, being 45% and 41% higher than Scotland in 2009 and in 2017, respectively. Scotland and East of England are the regions with lowest levels of productivity compared to the other EU regions.

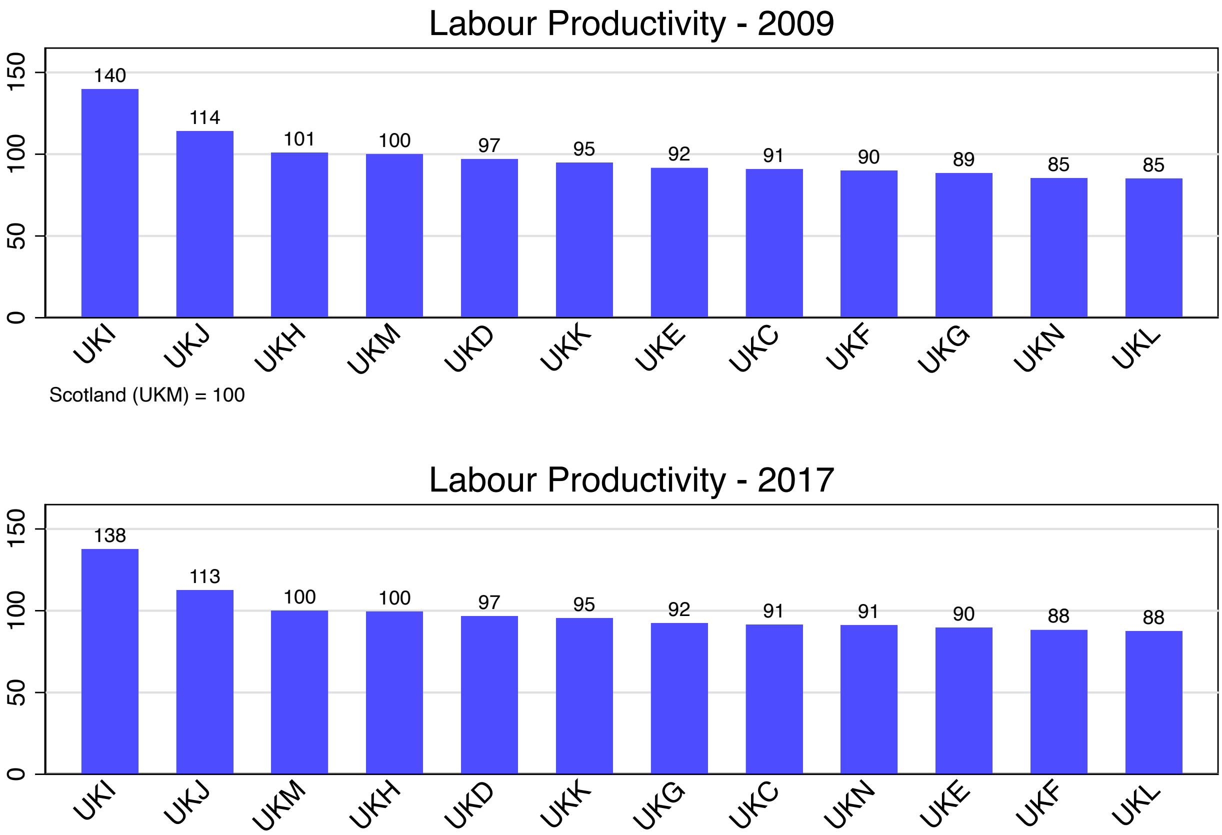
Figure 2: Relative labour productivity – Scotland and EU benchmark regions



Source: Eurostat, own calculations. Note: Labour productivity is measured as real GVA per hour worked at 2010 prices.

Within the UK, Figure 3 shows that Scotland's labour productivity level was only behind London (UKI) and the South East (UKJ) and was similar to the East of England (UKH), both in 2009 and 2017. The labour productivity gap between Scotland and these better-performing regions has not widened during the period analysed. London's labour productivity was 40% higher than Scotland in 2009 and only slightly lower (38%) in 2017.

Figure 3: Relative labour productivity (real GVA per hour worked, at 2010 prices, UK regions)



UKI: London; UKJ: South East; UKM: Scotland; UKH: East of England; UKD: North West; UKK: South West; UKG: West Midlands; UKC North East UKN: Northern Ireland; UKE: Yorkshire and the Humber; UKF: East Midlands; UKL: Wales.

Source: Eurostat and own calculations.

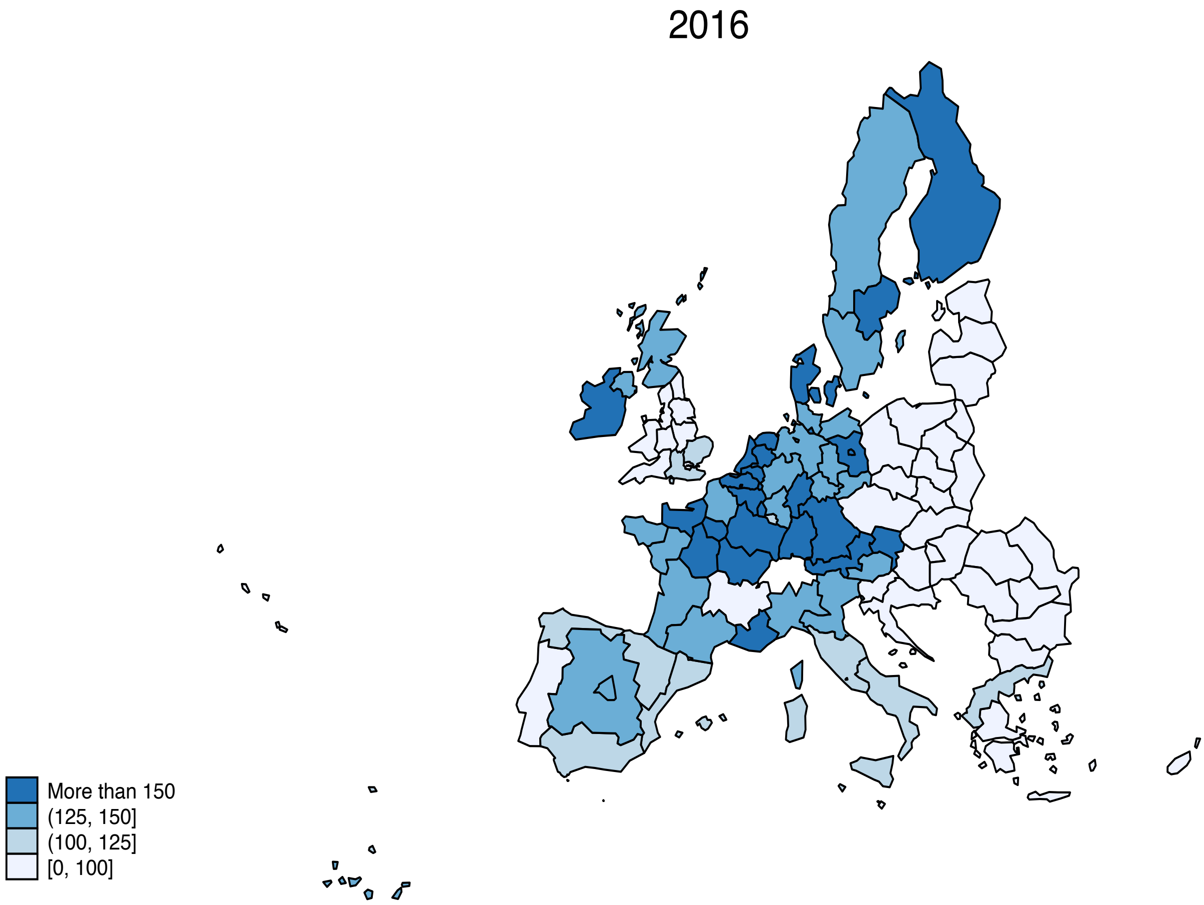
4.3 Capital intensity

In 2019, Cambridge Econometrics (CE) produced regional capital stock estimates across six sectors[11] at the NUTS2 level for the period 1995 - 2016 for the EU-28 Member States as part of a wider project to provide regional data with a long history freely available through the European Commission data portal.[12] We use these data to measure capital in our study and details of the methodology implemented, and final adjustments made to produce capital stock estimates for Scottish end EU regions, are provided in the Appendix.

[11] Agriculture, industry, construction, trade and ICT, financial and business services, non-market services.
[12] See https://ec.europa.eu/knowledge4policy/territorial/ardeco-database_en.

Using these capital stock data, Figure 4 illustrates difference in capital intensity across Europe regions. The regions with the greatest capital intensity include regions Île-de-France (FR1), Hamburg (DE6), Denmark (DK0), Brussels (BE1), Ostösterreich (AT1), Vlaams Gewest (BE2), Oost-Nederland (NL2), Manner-Suomi (FI1), Bayern (DE2).

Figure 4: Capital intensity – NUTS1



Source: Eurostat, Cambridge Econometrics, own calculations.
Note: Capital intensity is measured in Euro (per hour worked) in constant prices 2010.

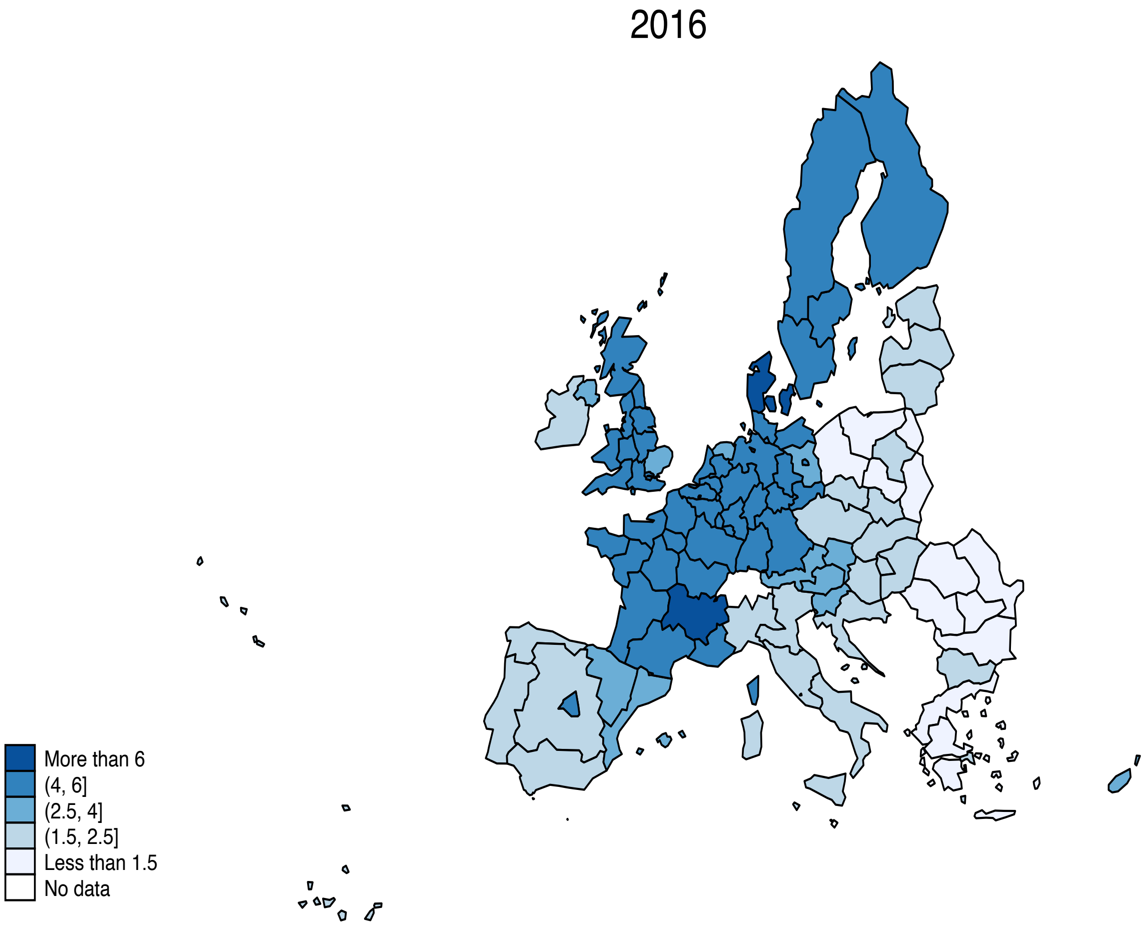
4.4 Total factor productivity

Figure 5 shows the TFP level[13] for NUTS1 regions in 2016. Scotland's TFP level is similar to a number of other UK regions, higher than Ireland and most of Eastern European, Italian, Spanish and Portuguese regions, but well below the regions with highest levels of TFP, and 47th overall.

---

[13] TFP was derived using conventional residual approach, as:
TFP = exp(ln Real GVA - (labour share * ln total hours worked) - (capital share * ln capital stock)

Figure 5: TFP level in 2016 – NUTS1

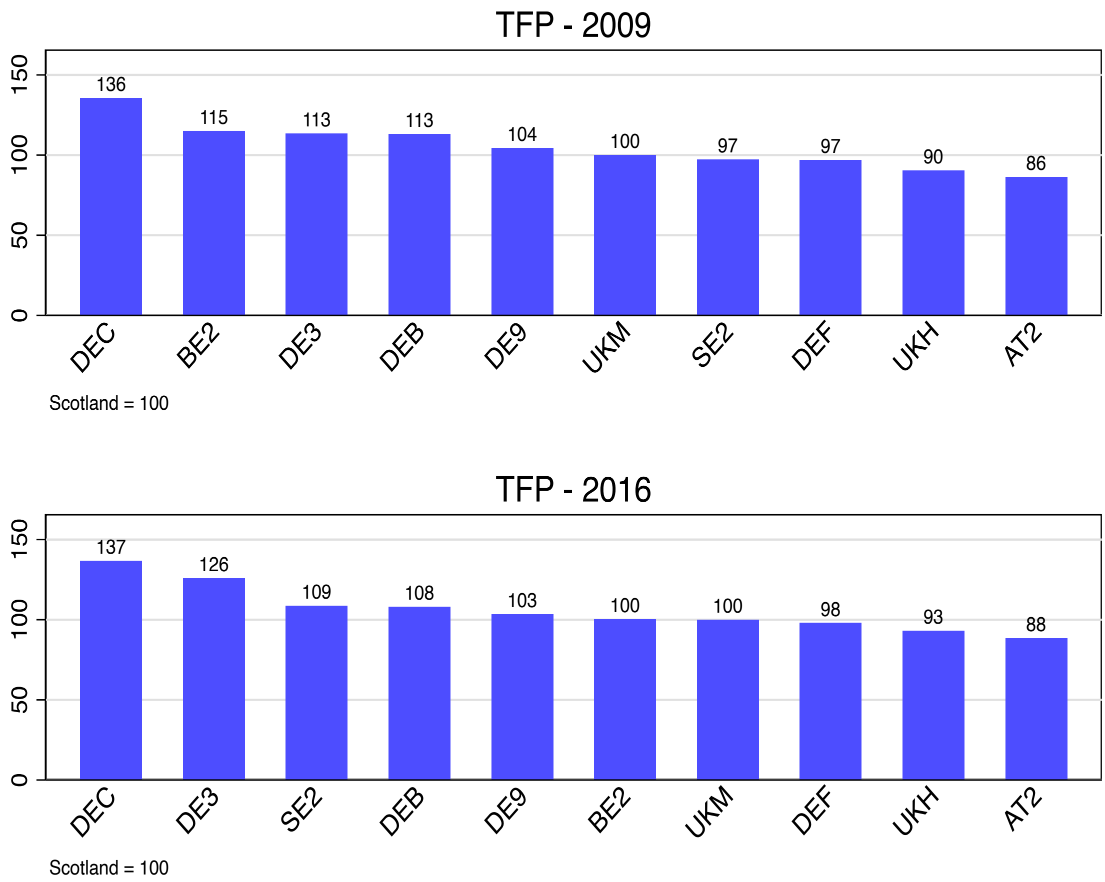


Source: Eurostat, Cambridge Econometrics, own calculations.

Figure 6 shows the TFP level relative to Scotland for the EU benchmark regions in 2009 and 2016. Among this group, the top performing regions in terms of TFP was Saarland (DEC) with levels just below 40% over those in Scotland (both in 2009 and 2016). Within the group, Berlin (DE3) was the third top performer in 2009 in terms of TFP and by 2016 has moved up in the rankings and is now second.

Other findings are worth drawing to the attention to. Scotland performance has improved in terms of TFP in relation to the Belgian region of Vlaams Gewest (BE2), which was the region with the second highest level of TFP in 2009. This region's TFP level was 15% higher than Scotland in 2009 but the gap has disappeared since then. In contrast, the Swedish region of Södra Sverige (SE2) exhibited a TFP level 3% lower than Scotland in 2009, but it increased subsequently and was 9% higher by 2016. Overall, TFP levels are more changeable over time, and we observed that the rankings are less persistent than with labour productivity measures.

Figure 6: Relative TFP level – Benchmark regions



Source: Eurostat, Cambridge Econometrics, own calculations. AT2: Südösterreich; DE3: Berlin; DE9: Niedersachsen; DEB: Rheinland-Pfalz; DEC: Saarland; DEF: Schleswig-Holstein; SE2: Södra Sverige; UKH: East of England; UKM: Scotland.

4.5 Levels accounting

In this section we breakdown the differences in the levels of productivity between Scotland and selected regions in the comparison group. We explore the extent to which different gaps (that is capital, labour quality and TFP gaps) explain the overall labour productivity gaps, computed on average for the period 2009-2016. We follow the methodology set out in Van Ark et al (2008), which we describe in more detail in the Appendix.

We compare Scotland and our selected EU regions in relation to a reference point. This is Vlaams Gewest in Belgium (BE2), which is the region with the highest average value of GVA per hour. All comparisons in this section are made with respect to this region.

Table 4 provides quantitative estimates of the labour productivity gaps between Scotland and the benchmark regions over the period 2009-2016. During this period, Scotland's labour productivity level was 75% of that of the Vlaams Gewest region (BE2), the productivity frontier among this group of regions (column 1). Scotland lags behind the productivity levels of most of these regions, with the exception of the East of England (UKH), which has levels of productivity similar to those of Scotland. Compared to the EU regions, Scotland's overall performance is similar to the Austrian region Südösterreich (AT2).

All German regions outperform the frontier in labour quality, while Scotland's relative labour quality levels is 95% of that in Vlaams Gewest (column 4). In terms of capital intensity, Scotland's level is 86% that in Vlaams Gewest, and is comparable to that in Berlin, (DE3), Saarland (DEC) and the East of England (0.80). The gaps in TFP (column 2) vary significantly across benchmark regions, ranging between 80 and 125% of that of the labour productivity frontier. Scotland's relative TFP is 95% of that the region Vlaams Gewest.

Table 4: Drivers of labour productivity across benchmark regions, 2009-2016, (BE2 = 1)

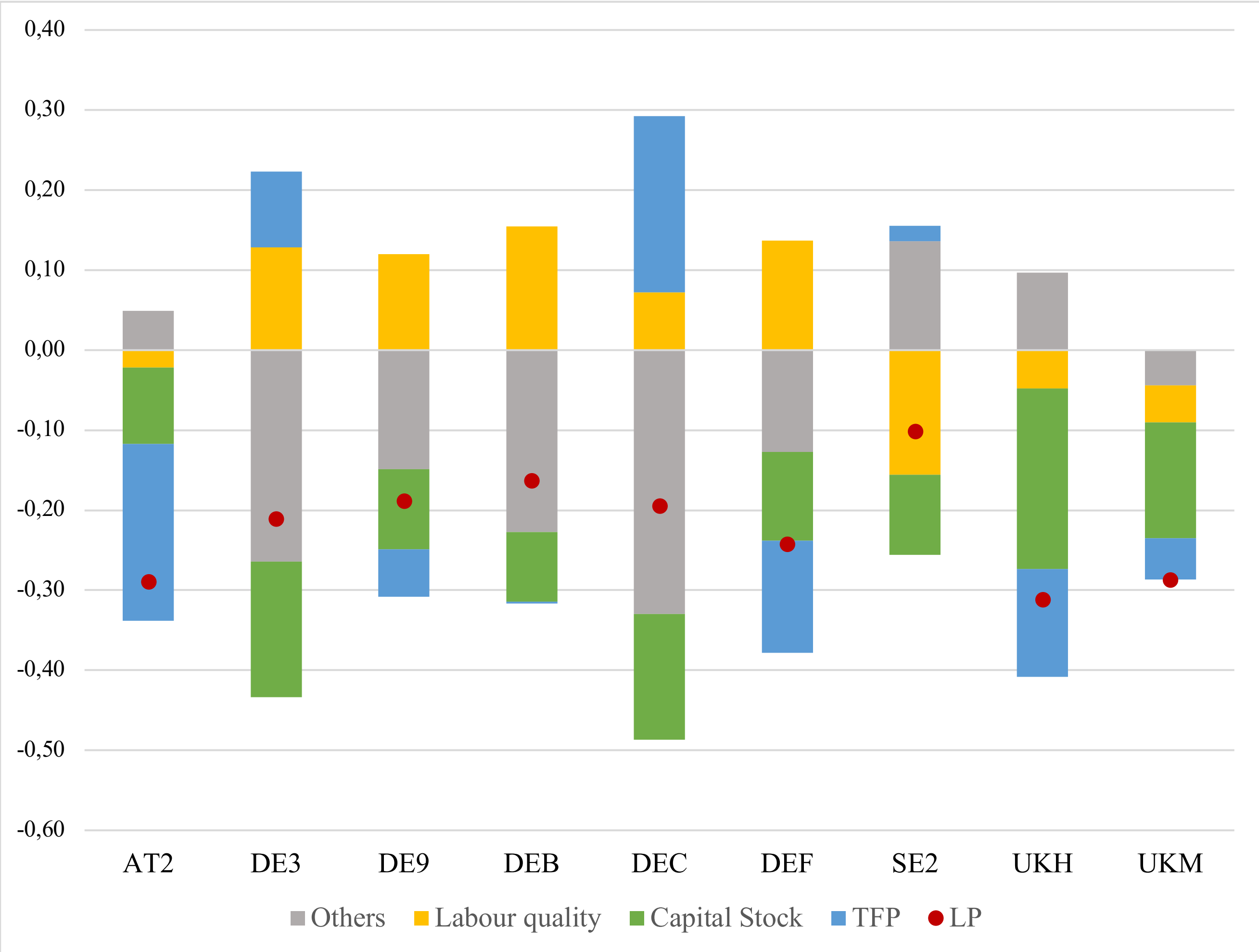
NUTS	**Region**	**(1) Relative Labour productivity**	**(2) Relative TFP**	**(3) Relative Capital Stock**	**(4) Relative Labour quality**	**(5) Relative Others**
AT2	Südösterreich	0.75	0.80	0.91	0.98	1.05
BE2	**Vlaams Gewest**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
DE3	Berlin	0.81	1.10	0.84	1.14	0.77
DE9	Niedersachsen	0.83	0.94	0.90	1.13	0.86
DEB	Rheinland-Pfalz	0.85	1.00	0.92	1.17	0.80
DEC	Saarland	0.82	1.25	0.86	1.07	0.72
DEF	Schleswig-Holstein	0.79	0.87	0.90	1.15	0.88
SE2	Södra Sverige	0.90	1.02	0.90	0.86	1.15
UKH	East of England	0.73	0.87	0.80	0.95	1.10
UKM	**Scotland**	**0.75**	**0.95**	**0.86**	**0.95**	**0.96**

Source: Eurostat data, own calculations. Note: relative others include omitted factors and measurement errors associated with the assumption of a Cobb Douglas technology, perfectly competitive markets and constant returns to scale. Figures in column (1) are the product of values in cols. (2)-(5), namely (1) = (2)(3)*(4)*(5).*

Figure 7 illustrates more intuitively the nature of the gaps in *levels of labour productivity* with the highest-productivity region, Vlaams Gewest (BE2). Note that the gap in labour productivity level is the sum of the gaps in all components: capital intensity, labour quality TFP, and a residual component reflecting omitted productivity determinants in empirical productivity models. Besides omitted factors, relative others also include measurement errors associated with the assumption of a Cobb-Douglas technology, perfectly competitive markets and constant returns to scale.

Measured in percentage terms Scotland's labour productivity gap with the region Vlaams Gewest was close to 30 per cent (28.7%). About half of this gap (14.5 p.p.) can be accounted for by differences in capital, while just below one fifth can be accounted for by differences in labour quality and TFP (4.6 p.p. and 5.2 p.p.). The labour productivity gap between Südösterreich and Vlaams Gewest is similar to that in Scotland (around 28%), however, less is explained by differences in labour quality. The figure shows that Scotland presents productivity gaps in all capital, labour quality and TFP, relative to the best performing region. Other regions outperform the frontier in some of the factors, and mainly in terms of TFP and/or labour quality.

Figure 7. Breakdown of labour productivity gaps with Vlaams Gewest (BE2)

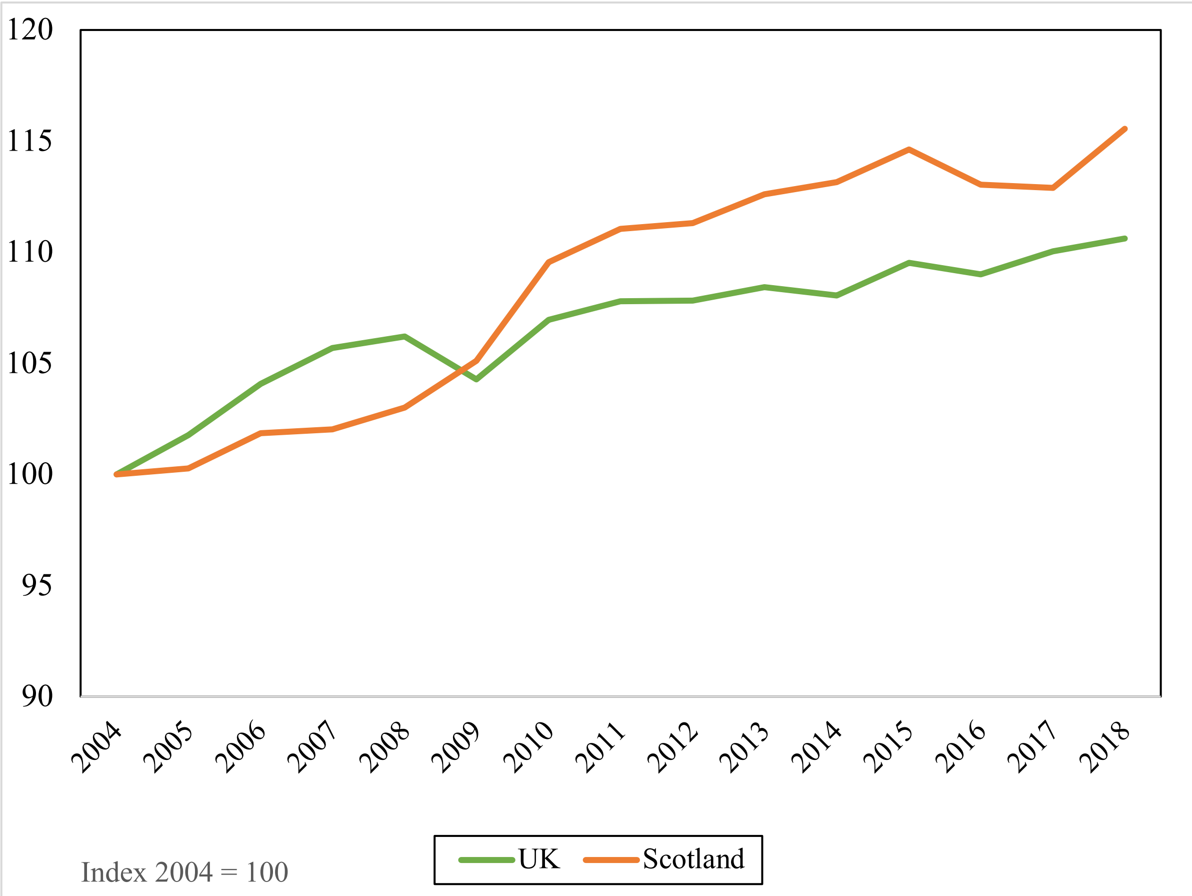


Source: Eurostat, Cambridge Econometrics, own calculations. Notes: others include omitted factors and measurement errors associated with the assumption of a Cobb Douglas technology. AT2: Südösterreich; DE3: Berlin; DE9: Niedersachsen; DEB: Rheinland-Pfalz; DEC: Saarland; DEF: Schleswig-Holstein; SE2: Södra Sverige; UKH: East of England; UKM: Scotland.

5 Productivity growth drivers: Growth accounting results

Figure 8 illustrates the evolution of labour productivity in Scotland and the whole of the UK from 2000 to 2017. Labour productivity grew steadily[14] from the early 2000s up to 2008-2009 period, when it fell sharply as a result of the financial crisis. Scotland's labour productivity growth rate was higher than that of the UK as a whole in the years leading up to the financial crisis. In the aftermath of the recession, Scotland's labour productivity level decreased sharply, and by 2009 was almost 15% lower than that in the mid-2000s. In subsequent years, Scotland's rate of labour productivity was higher than the UK's, signalling a stronger recovery. In 2016 and 2017, labour productivity fell again and recovered moderately in 2018.

Figure 8. Labour productivity growth in Scotland, 2000-2017.



Source: ONS data

In this section we compute the relative contributions of growth in inputs, and growth in efficiency or total factor productivity (TFP) to *labour productivity growth* during the period 2009-2017(6). Table 5 and Table 6 present the findings of the growth accounting analysis for Scotland, the UK and the EU benchmark regions, respectively. We implement a growth accounting methodology, which we explain more carefully in the Appendix.

[14] There was only a decline in 2003 of about 5% of productivity level in Scotland compared to the early 2000s.

Scotland's average labour growth rate during the period 2009-2017 was just over 1 per cent per annum (1.04%), as shown in Table 5. Scotland's labour productivity growth rate was 3rd largest of UK regions, behind Northern Ireland (1.2%), and the West Midlands (1.07%). We find that the capital contribution to Scotland's productivity growth (0.62 percentage points), was higher than in all other UK regions, and aligned with that of North East. In several regions the contribution of capital has been negative, which indicates de-investment. A large proportion of the labour productivity growth in Scotland was due to TFP growth (0.47 percentage points).

The contribution of labour quality to Scottish labour productivity growth was negligible and even slightly negative (-0.05 p.p.). Other regions in the UK also saw poor labour quality improvements, especially in London and the South East. Our measure of labour quality captures the impact of the compositional changes of employment by educational attainment. A caveat is that it does not aim to capture the very complex concept of "skill". As it is a degree-based indicator, it does not capture "on-the-job" training and other "soft-skills" which can be acquired through professional activity and on-the-job training activities. We thus recognise this is a partial adjustment for quality. Rincon-Aznar et al. (2015) have previously utilised this methodology to investigate the contribution of tertiary education to explain difference in labour productivity performance in the UK and a number of large EU countries in the post-financial crisis period.

Table 2: Breakdown of labour productivity growth 2009–2017 - UK regions

NUTS1	**Region**	**Growth in LP (%)**	**Contribution from (p.p.)**		
			Capital (1)	**Labour quality (2)**	**TFP (3)**
UKC	North East (UK)	0.72	0.45	0.16	0.10
UKD	North West (UK)	0.41	-0.23	0.10	0.55
UKE	Yorkshire and The Humber	0.09	-0.07	0.16	0.01
UKF	East Midlands (UK)	0.58	-0.13	0.11	0.61
UKG	West Midlands (UK)	1.07	-0.15	0.21	1.01
UKH	East of England	0.19	-0.22	0.19	0.21
UKI	London	0.75	-0.24	-0.48	1.46
UKJ	South East (UK)	0.12	-0.25	-0.01	0.38
UKK	South West (UK)	0.67	0.27	0.04	0.37
UKL	Wales	0.71	0.10	0.08	0.53
UKM	**Scotland**	**1.04**	**0.62**	**-0.05**	**0.47**
UKN	Northern Ireland (UK)	1.16	-0.19	0.13	1.22

Source: ONS, Cambridge Econometrics, EU KLEMS data, own calculations.

Table 6 shows the result of the growth accounting decomposition for the EU benchmark regions. The region of Södra Sverige in Sweden exhibited the greatest labour productivity growth rate, with a rate over 3 per cent per annum (on average). This was almost all due to total factor productivity gains.

During the period 2009-2016 Scotland under-performed relative to Südösterreich in Austria in terms of capital accumulation, and relative to others (Södra Sverige in Sweden and Berlin, Niedersachsen and Rheinland-Pfalz in Germany) in total factor productivity growth. If we consider all 83 NUTS1 regions, Scotland has ranked 45th in their total factor productivity growth. The highest average TFP growth was observed in Ireland and the regions of Thüringen, Sachsen Brandenburg and Mecklenburg-Vorpommern in Germany. These growth patterns may reflect a range of factors, for instance the fact that lagging regions may be experiencing a fast process of catching-up. We investigate this in more detail in Section 8.

A critical observation from Table 6 is the lack of contribution of labour quality in Scotland during this period, which is in contrast with the robust contributions seen across most of the benchmark regions. Similarly low impacts were also recorded for Berlin and the Niedersachsen regions in Germany. Interestingly, Berlin, like Scotland is characterised for having a highly educated population.

Table 6. Labour productivity growth, 2009–2016 – EU Benchmark regions

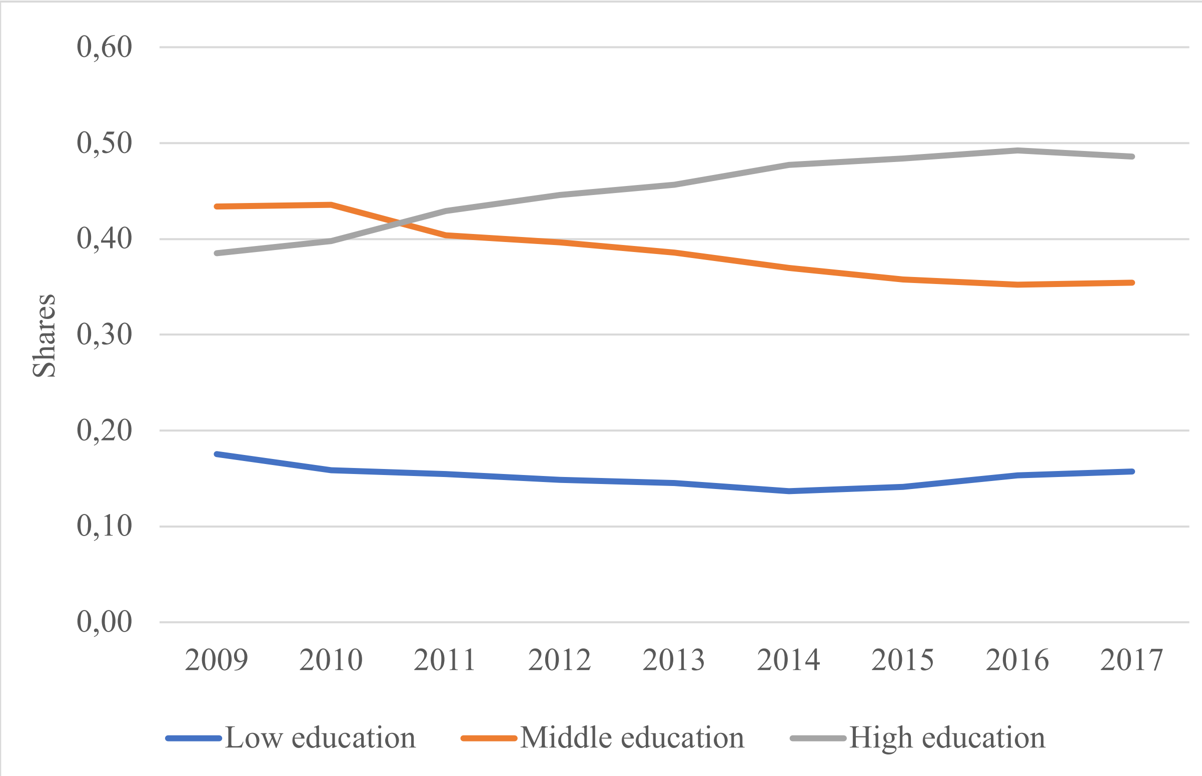
NUTS1	**Region**	**Growth in LP (%)**	**Contribution from (p.p.)**		
			Capital (1)	**Labour quality (2)**	**TFP (3)**
AT2	Südösterreich	1.15	0.71	0.29	0.15
BE2	Vlaams Gewest	0.60	0.54	0.15	-0.09
DE3	Berlin	1.30	0.27	0.05	0.98
DE9	Niedersachsen	1.46	0.36	0.09	1.01
DEB	Rheinland-Pfalz	1.54	0.59	0.17	0.78
DEC	Saarland	0.86	0.35	0.32	0.19
DEF	Schleswig-Holstein	0.85	0.61	0.12	0.12
SE2	Södra Sverige	3.29	0.06	0.33	2.90
UKH	East of England	0.19	-0.22	0.19	0.21
UKM	**Scotland**	**1.04**	**0.62**	**-0.05**	**0.47**

Source: Eurostat, ONS, Cambridge Econometrics, EU KLEMS data, own calculations.

A graphic exposition to Scotland's labour quality findings is shown in Figure 9. This shows a steady increase in the share of the workforce with a tertiary degree in Scotland, in detriment of those with middle-level qualification. While the percentages of the workforce with low skills declined for several years during the period of analysis, it has risen marginally since 2015.

Table A6 in the Appendix shows the result of the growth accounting decomposition for the 'alternative' set of regions considered and presented in table A5. Ireland exhibited the greatest labour productivity rate, with a 6.22% per annum on average. This was around 6 times the rate of Scotland (1.04%) and was mainly due to gains in TFP. Scotland slightly under-performed the Spanish regions of Madrid (ES1), Norest (ES2) and Este (ES5) in capital accumulation, but out-performed these regions in terms of TFP. Ireland (IE0), Denmark (DK0) and Este of Spain (ES5) excelled in terms of labour quality.

Figure 9. Evolution of workforce shares by educational group in Scotland, 2009-2017.



Source: Eurostat. ISCED education categories: Low education: Less than primary, primary and lower secondary education (levels 0-2), Medium education: Upper secondary and post-secondary non-tertiary education (levels 3 and 4) High education: Tertiary education (levels 5-8)

Country comparisons

In this subsection we compare Scotland's productivity with other countries beyond EU regions. Table 3 presents the labour productivity decomposition across a sample of countries for the period 2009-2016. Data are from the Conference Board, where we selected those economies that were in the top quartile of the GDP per capita distribution in 2009 (**Fehler! Verweisquelle konnte nicht gefunden werden.** in the appendix).[15] This database is a useful alternative source that allows a wide range of country coverage, which also draws from National Accounts data mainly.

[15] The Conference Board does not have data for regions but only for countries. Thus, for Scotland we use data from Eurostat.

Scotland's labour productivity growth rate ranked eleventh amongst a sample of 80 world countries[16]. Countries such as Ireland, Singapore, Hong Kong, Taiwan, Japan, Denmark, Australia, Germany, Sweden and Spain all saw higher growth in labour productivity relative to that of Scotland. Despite the modest performance, Scotland's labour productivity growth significantly above that in the UK's (1.04% and 0.50%, respectively), suggesting that whatever is suppressing UK productivity growth is less pronounced (or partially offset) in Scotland.

Table 3: Labour productivity growth accounting decomposition by country, 2009-2016

Country	**Growth in LP (%)**	**Contribution from (percentage points)**		
		Capital (1)	**Labour quality (2)**	**TFP (3)**
Ireland	4.07	2.80	0.25	1.03
Singapore	3.06	3.62	0.43	-0.99
Hong Kong	2.64	2.42	0.48	-0.26
Taiwan	1.74	1.64	0.37	-0.27
Denmark	1.50	0.82	0.24	0.43
Japan	1.50	0.67	0.29	0.54
Australia	1.32	1.84	0.36	-0.88
Germany	1.28	0.75	0.11	0.43
Sweden	1.26	1.34	0.18	-0.26
Spain	1.21	0.81	0.33	0.07
Scotland	**1.04**	**0.62**	**-0.05**	**0.47**
Finland	1.00	0.75	0.19	0.06
Canada	0.97	1.28	0.16	-0.47
United States	0.96	1.13	0.23	-0.41
Switzerland	0.88	1.04	0.29	-0.45
Austria	0.87	1.00	0.21	-0.33
France	0.83	0.81	0.32	-0.30
Iceland	0.78	0.51	0.27	0.01
Netherlands	0.75	0.82	0.07	-0.13
Belgium	0.68	1.04	0.22	-0.58
Luxembourg	0.61	2.52	0.14	-2.05
Norway	0.57	1.73	0.12	-1.28

[16] These are the countries from the Conference Board Database for which data allowed us to implement a growth accounting analysis.

United Kingdom	0.50	0.92	0.36	-0.78
Italy	0.47	0.25	0.12	0.10

Source: Conference Board and Eurostat, own calculations

6 Innovation

As proven by a large body of literature, innovation is fundamental to raising the rate of productivity growth and hence living standards (Aghion and Howitt, 1998). Several papers have illustrated that R&D-based innovation yields positive effects on the productivity of innovators by favouring the development of new products and new ways of production, which increase efficiency and allows improvements in competitiveness. Innovation activities are also considered important for "proximate" firms/industries/countries, through the realisation of knowledge spillovers (Ugur et al., 2016). R&D is also a fundamental source of absorptive capacities, allowing companies to benefit from the new knowledge created in neighbouring firms, industries or regions (O'Mahony and Vecchi, 2009). R&D activates technology transfers from the frontier, and this is particularly true for laggard firms (Griffith et al., 2004).

The percentage of innovation-active businesses in Scotland (UK CIS 2014-16 and 2016-18) is the lowest of UK nations, with England having the highest percentage (39%) and Scotland the lowest (33%). As with all other regions in the UK, this percentage has decreased from 2014-16 to 2016-18. Scotland experienced the largest decline, where the percentage of innovation active businesses decreased from 45% in 2014-16 to 33% in 2016-18.

Figure 10 illustrates the percentage share of R&D expenditure over regional GDP in the UK NUTS1 regions, as an average for the period 2009-2017. The total R&D expenditure comprises the R&D performed in three main institutional sectors: the business sector (firms), the government, and the higher education sector (universities) and private non-profit institutional sector.[17] The share of total R&D of GDP was 1.5 % in Scotland. This is below the UK average (1.7%). The UK regions with highest R&D intensity are the East of England (3.5%), and the South East (2.3%). Looking at the performance of the institutional sectors (Figure 17), Scotland holds the highest intensity of R&D performed by the higher education sector in the United Kingdom (0.7% of regional GDP). Comparisons with the European Benchmark Regions reveal that Scotland falls in the right-end of the distribution of total R&D expenditure on regional GDP, just above Saarland (DEC) and Schleswig-Holstein (DEF) (Figure 11).

[17] Data on the latter category tends to be available with less frequency at this level of regional disaggregation due to the concentration of private non-profit research institutions in few regions.

Figure 10: R&D expenditure in the UK regions (% over GDP), Average 2009-2017

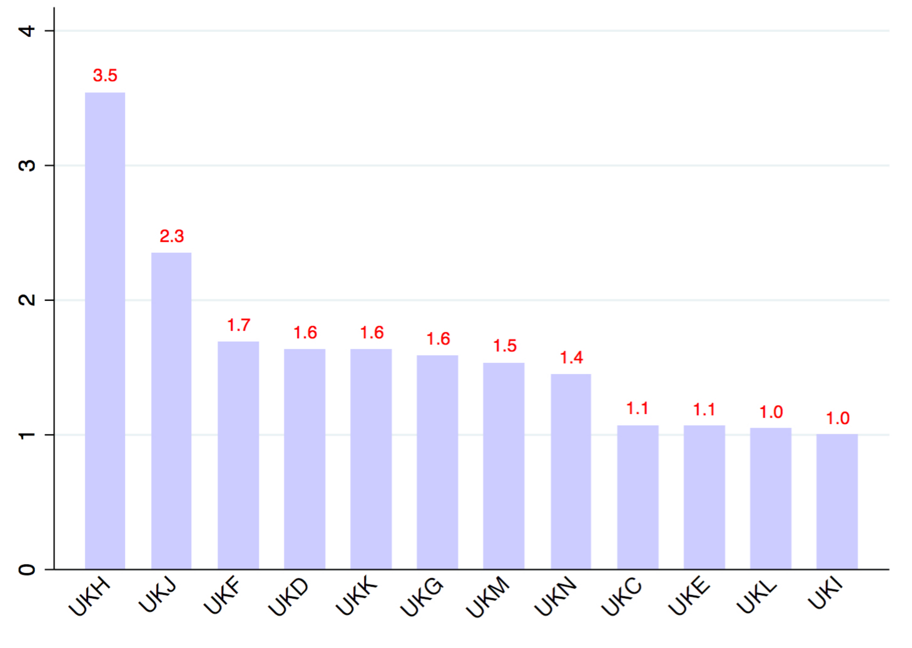
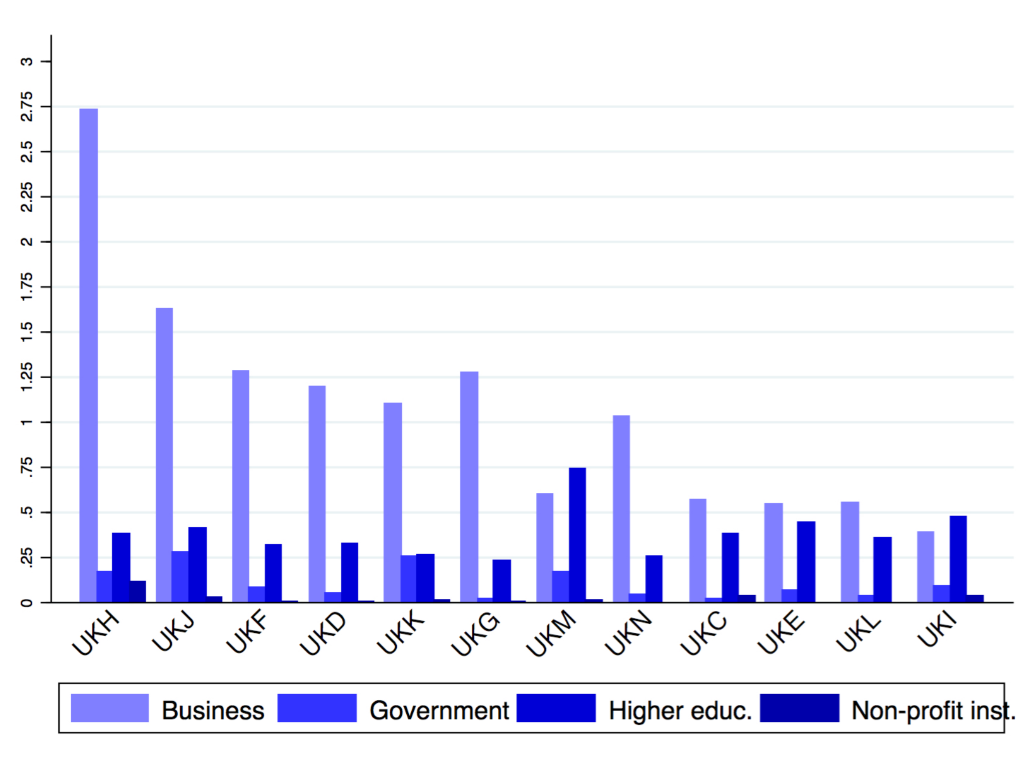


Figure 11. Breakdown of R&D expenditure by institutional sector in UK regions (% over GDP), Average 2009-2017



UKI: London; UKJ: South- East; UKM; Scotland; UKH: East of England; UKD: North West; UKK: South West; UKG: West Midlands; UKN: Northern Ireland; UKE: Yorkshire and the Humber; UKC North East; UKF: East Midlands; UKL: Wales
Source: Eurostat and own calculations.

Figure 12. R&D expenditure in the EU benchmark regions (% over GDP), Average 2009-2017)

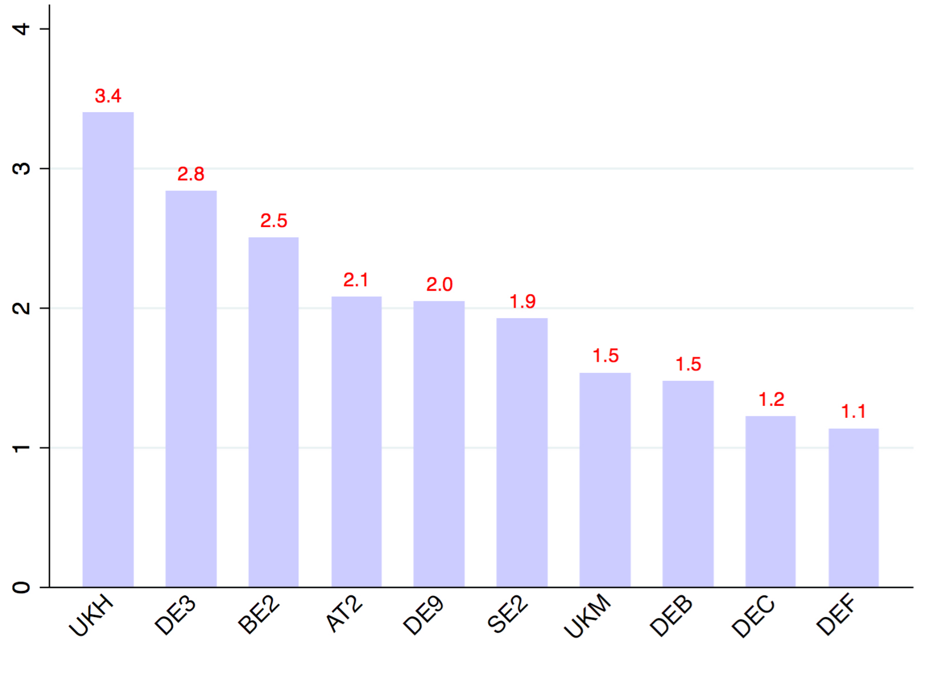
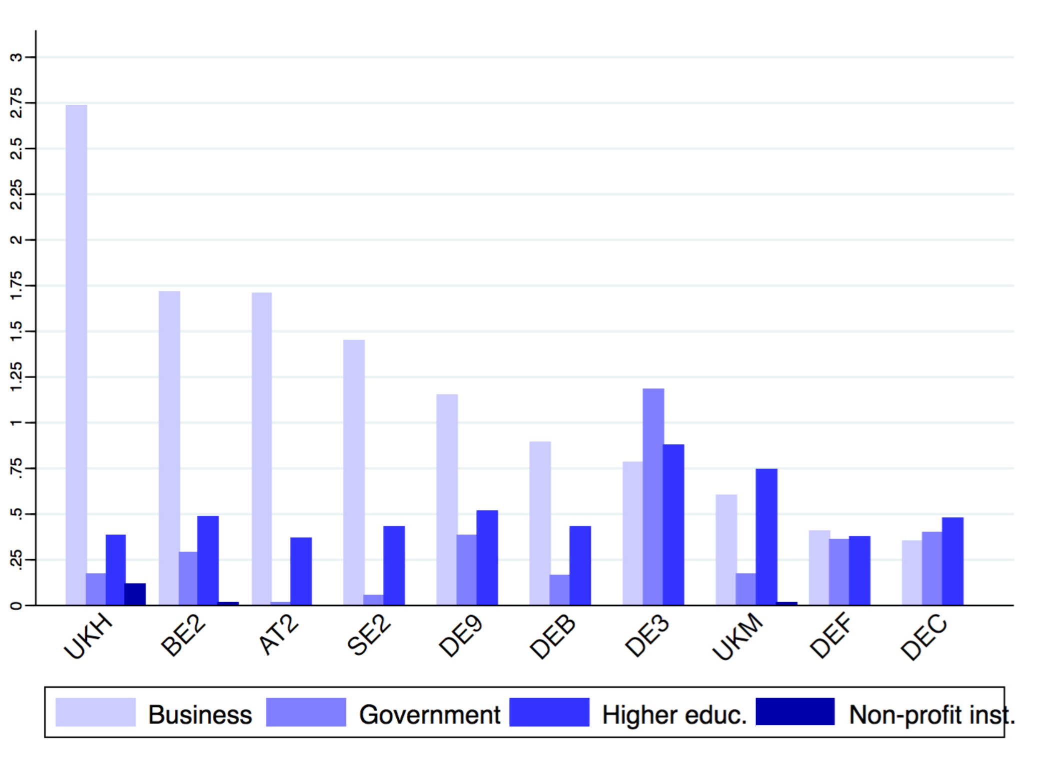


Figure 13. Breakdown of R&D expenditure by institutional sector in EU benchmark regions (% over GDP), ranked by business percentage. Average 2009-2017.



AT2: *Südösterreich;* ***UKH****: East of England;* ***DE3****: Berlin;* ***SE2****: Södra Sverige;* ***DE9****: Niedersachsen;* ***BE2****: Vlaams Gewest;* ***DEB****: Rheinland-Pfalz;* ***UKM:*** *Scotland;* ***DEC:*** *Saarland;* ***DEF:*** *Schleswig-Holstein.*

Source: Eurostat, own calculations.

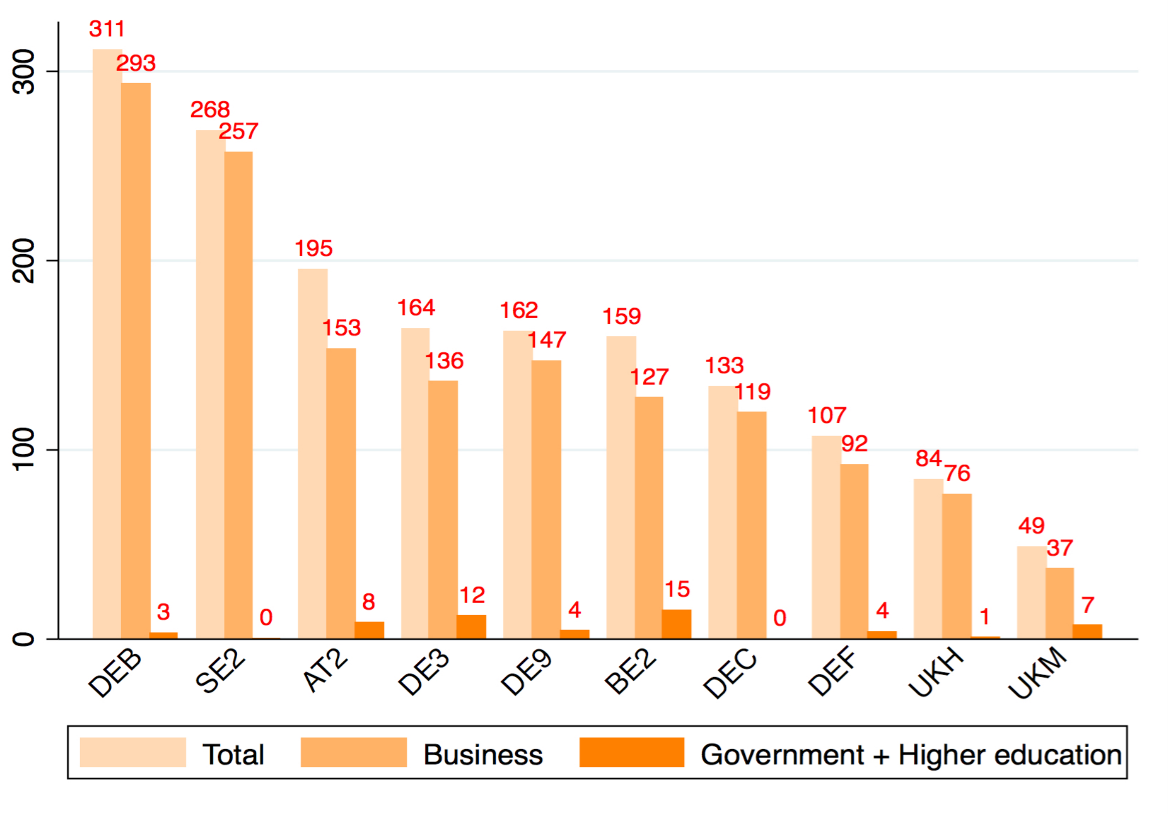
On average for the period 2009-2017 the share of total R&D expenditure over regional GDP is 1.5% in Scotland (Figure 13). This percentage falls on the right-hand tail of the distribution of the benchmark regions, alongside Saarland (DEC) and Schleswig-Holstein (DEF). Among top spenders, Südösterreich in Austria (AT2) stands out at a share of 4%.

Scotland is one of several UK regions whose business sector accounts for a markedly lower level of R&D investment as a share of GDP. This value is lower than the GDP percentage of the higher education sector's R&D expenditure (0.7%), for which Scotland is ahead of the benchmark group, just behind the region of Berlin, 0.9% (DE3).

Patents

Figure 14 and Figure 15 report the number of patents by millions of inhabitants of the region. We decompose the total number of patent applications by main institutional sectors: the business sector (firms), public research institutions (government, research centres and universities) and individual inventors (occasional inventors, self-employed, unincorporated companies, etc.). The difference between total and the sum of the other columns is due to individual inventors' patents. In essence, the column of individual inventors' patents is omitted as it is marginal compared to the figures of the other categories of applicants. Patent statistics are provided as average of the entire sample period 2009-17, in order to offer a better coverage of the regions' performance along this dimension of innovation.

Figure 14: Patents million inhabitants– Benchmark regions (average 2009-17)

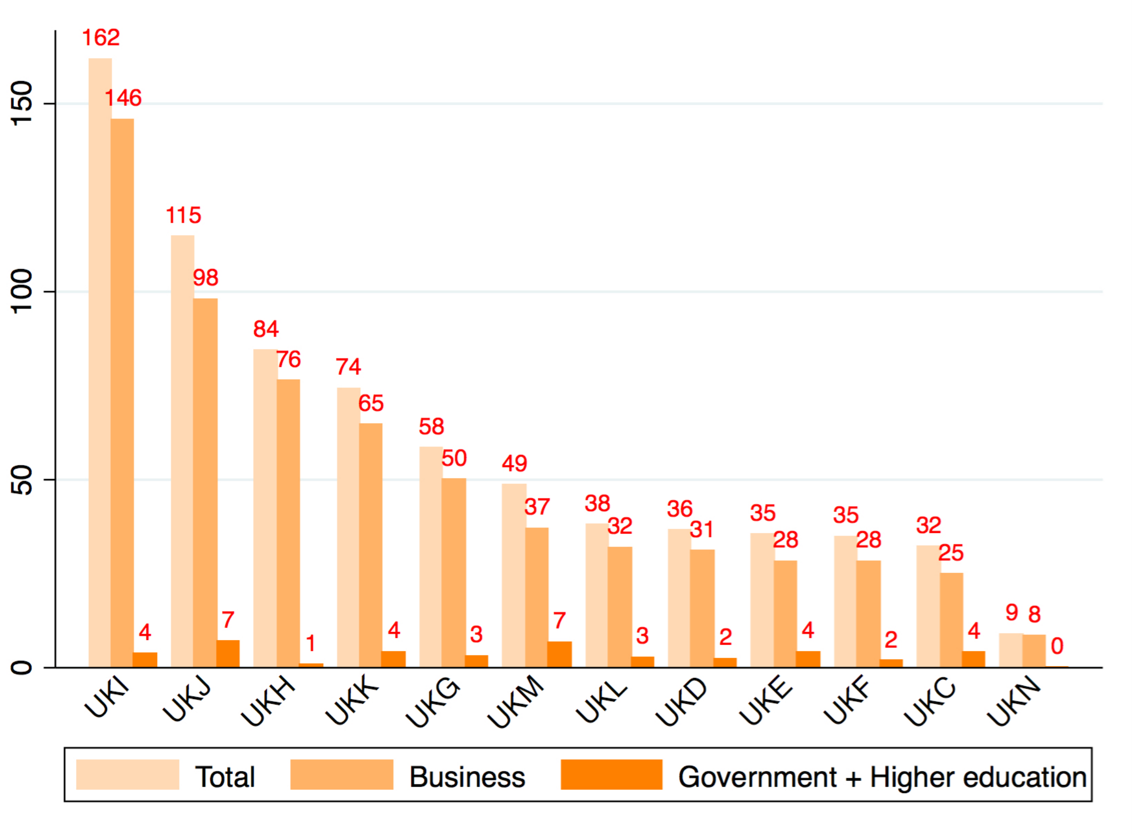


AT2: *Südösterreich;* ***UKH****: East of England;* ***DE3****: Berlin;* ***SE2****: Södra Sverige;* ***DE9****: Niedersachsen;* ***BE2****: Vlaams Gewest;* ***DEB****: Rheinland-Pfalz;* ***UKM:*** *Scotland;* ***DEC:*** *Saarland;* ***DEF:*** *Schleswig-Holstein.*
Source: *OECD EPO Regpat, own calculations.*

Scotland's total number of patents per million inhabitants is 49, a value around one sixth of Rheinland-Pfalz (DEB) and Södra Sverige (SE2) and well below the figures shown by all the regions in the comparator group. This lower overall patent performance of Scotland is characterised by a relative low propensity to patent in the business sector. Conversely, with 7 patent applications per million inhabitants between 2009 and 2017, Scotland's public research institutions (the higher education sector and government) perform well in relation to our comparators. From this dimension, Vlaams Gewest in Belgium (BE2) is on the lead with 15 patents per million inhabitants.

Scotland sits in the middle of the UK ranking of patents per million inhabitants, with West Midlands and Wales sitting on either side. The Scottish total is less than a third of the London figure and less than half that in SE England. The relatively high propensity to patent of public research institutions is shared by Scotland and South East England.

Figure 15. Patents per million inhabitants – UK regions (Average 2009-17)



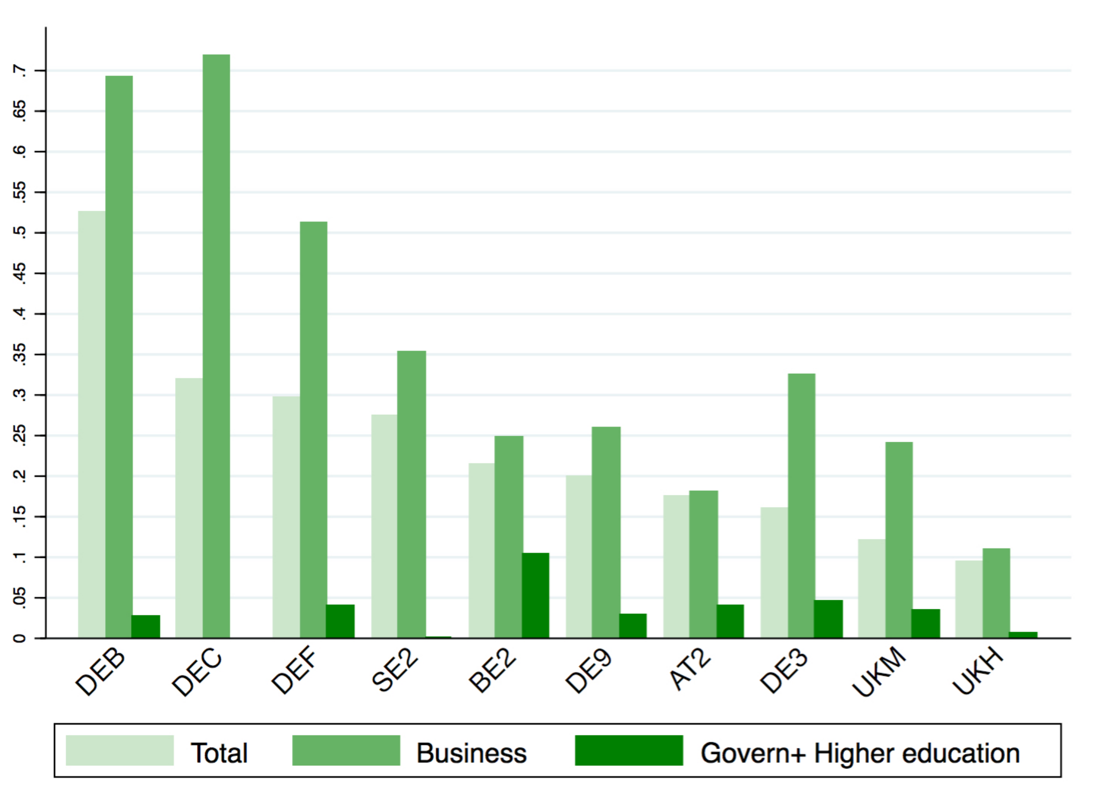
UKI: London; UKJ: South East; UKM; Scotland; UKH: East of England; UKD: North West; UKK: South West; UKG: West Midlands; UKN: Northern Ireland; UKE: Yorkshire and the Humber; UKF: East Midlands; UKC: North East UKL: Wales
Source: Eurostat and own calculations.

R&D productivity

As a measure of research productivity, Figure 16 and Figure 17 reports the number of patents per million of R&D expenditure (in PPS) broken down between business and all other categories. The graphs illustrate the total value of the indicator for each region; this is a combination of the other columns but is not fully additive because of the way of computation R&D expenditures (which are expressed at constant terms). The difference between total and the sum of the other columns is due to the patents applied by the residual category of individual inventors' (omitted for simplicity).

Figure 16. Patent per R&D expenditure – Benchmark regions

(per each million Euro PPP, Average % 2009-17)

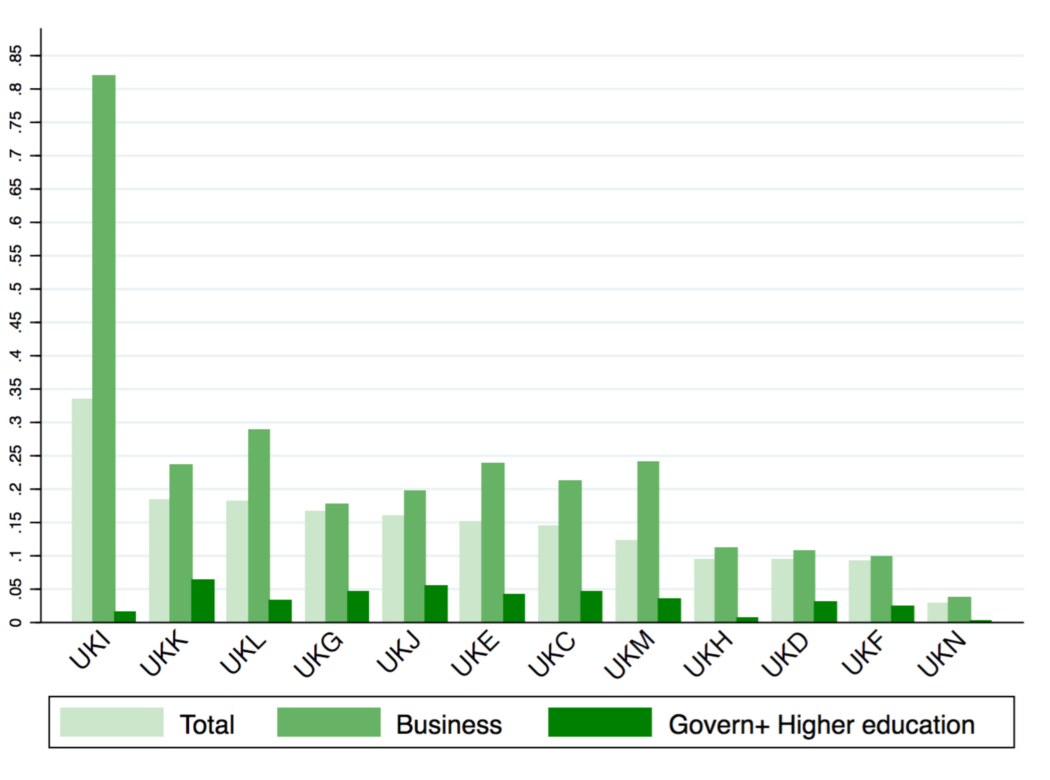


AT2: *Südösterreich;* ***UKH****: East of England;* ***DE3****: Berlin;* ***SE2****: Södra Sverige;* ***DE9****: Niedersachsen;* ***BE2****: Vlaams Gewest;* ***DEB****: Rheinland-Pfalz;* ***UKM:*** *Scotland;* ***DEC:*** *Saarland;* ***DEF:*** *Schleswig-Holstein.*

Source: *OECD EPO Regpat, own calculations.*

The comparison among UK regions (Figure 17) shows that Scotland's performance is broadly comparable to all other regions, excepting London's business sector; notably, Scottish private companies do however show a relatively high patent productivity per unit of research expenditure, just behind Wales (0.24 vs 0.29).

Figure 17. Number of patents per R&D expenditure – UK regions
(per each millions Euro PPP, Average % 2009-17)



***UKI**: London; **UKJ**: South East; **UKM**; Scotland; **UKH**: East of England; **UKD**: North West; **UKK**: South West; **UKG**: West Midlands; **UKN**: Northern Ireland; **UKE:** Yorkshire and the Humber; **UKF:** East Midlands; UKC North East; **UKL**: Wales*
Source: Eurostat and own calculations.

7 Foreign Direct Investment

7.1 The importance of FDI to economic prosperity

It is recognised that foreign firms bring with them new capacity in the form of technology and (in the case of greenfield sites) additional capital. As such, they are vital inward injections of resources to the macroeconomy. They are thought to be more capital intensive, paying higher wages and, on average, more productive than domestic (only) firms (in terms of both labour and total factor productivity). There is evidence to suggest that the source of FDI matters in realising the productivity benefits and that there is an additional class of FDI that is technology seeking rather than technology contributing (Driffield et al, 2010). That is, firms can also be seeking to learn by setting up overseas; where this is the case, there is no reason to expect them to be more productive.

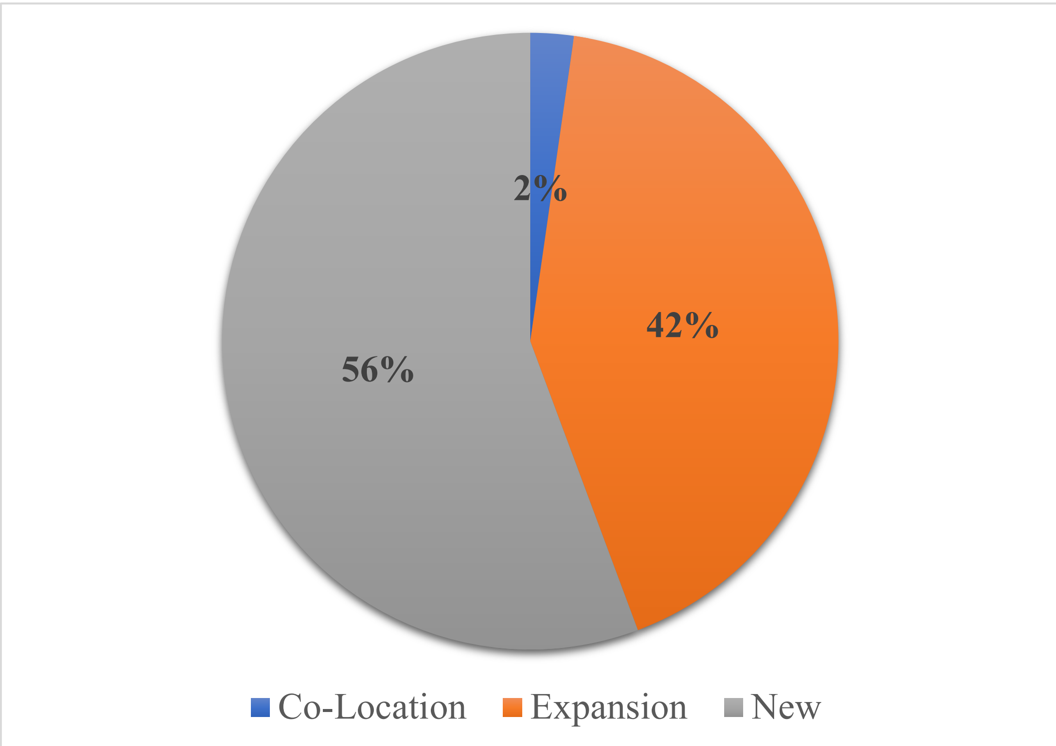
Scotland has a long and distinguished history of inward foreign direct investment. One of the earliest recorded incidences of FDI was from the US Singer Sewing Company into Glasgow (Dunning, 1988; Godley, 1999) around the 1860s. Glasgow was identified as the location because of its iron industry, relative abundance of cheap labour and its location on the Clyde enabled the shipping of goods to other parts of Europe. More generally, early FDI entrants were based in manufacturing and came largely from the US (where having a European base was considered advantageous) and Germany. Early entrants were primarily concerned with selling products to consumers in the UK but over time, the UK came to produce more intermediate goods.

Today, Scotland is still seen as a desirable location for FDI and is incredibly proactive its promotion as a first-choice destination for foreign investors. Most recently, a report by FDI Intelligence (2020) placed Scotland 10th overall in terms of a region for the future[18].

7.2 How are FDI projects distributed in Scotland?

Firstly, looking at the project level data (n=1,277 pooled over the period):

Figure 18. Type of FDI for Scotland, 2003-2017

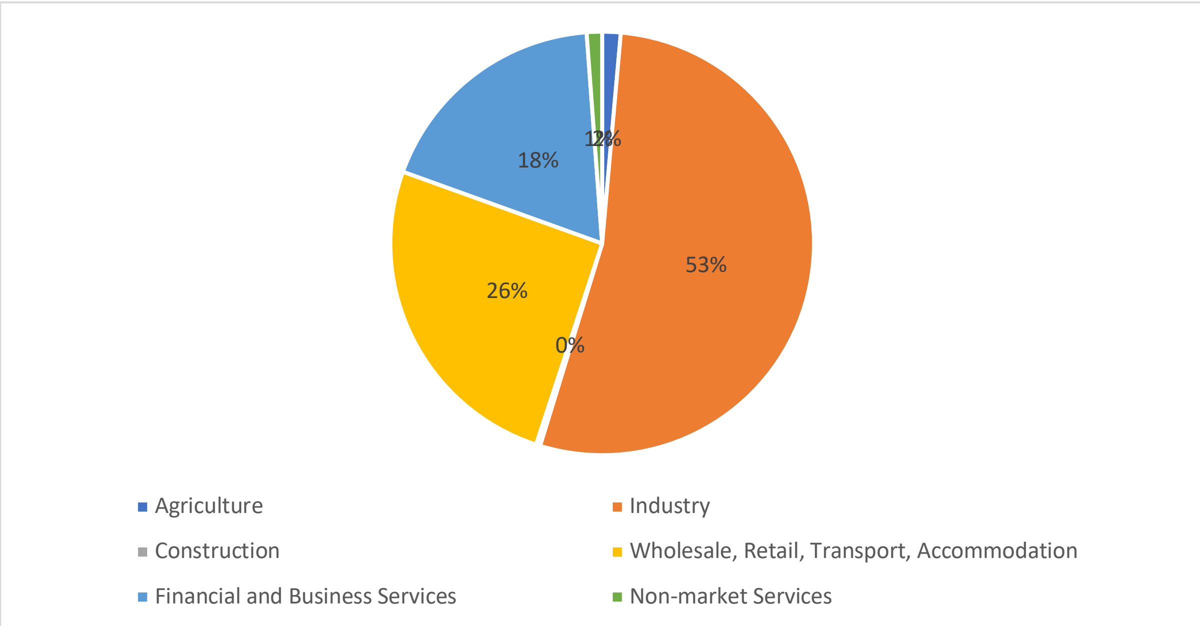


Source: FDI Markets, own calculations.

[18] This overall ranking is comprised of 3rd in terms of its FDI strategy for large European regions, 5th in Northern European regions and 8th in terms of economic potential and business friendliness. 10th in terms of human capital and lifestyle, which captures the quality of life for location and 1st in terms of connectivity. Glasgow has a strategic ambition to be the UK's best performing city for inward investment by 2023.

The majority of investment in Scotland was new, greenfield investment, followed by expansion of existing operations. Only 2% of projects commissioned over 2003-2017 were co-location activities. In terms of implications from this, new investment projects are likely to be more capital intensive and larger scale.

Figure 19. Sector distribution of Scottish FDI projects, 2003-2017



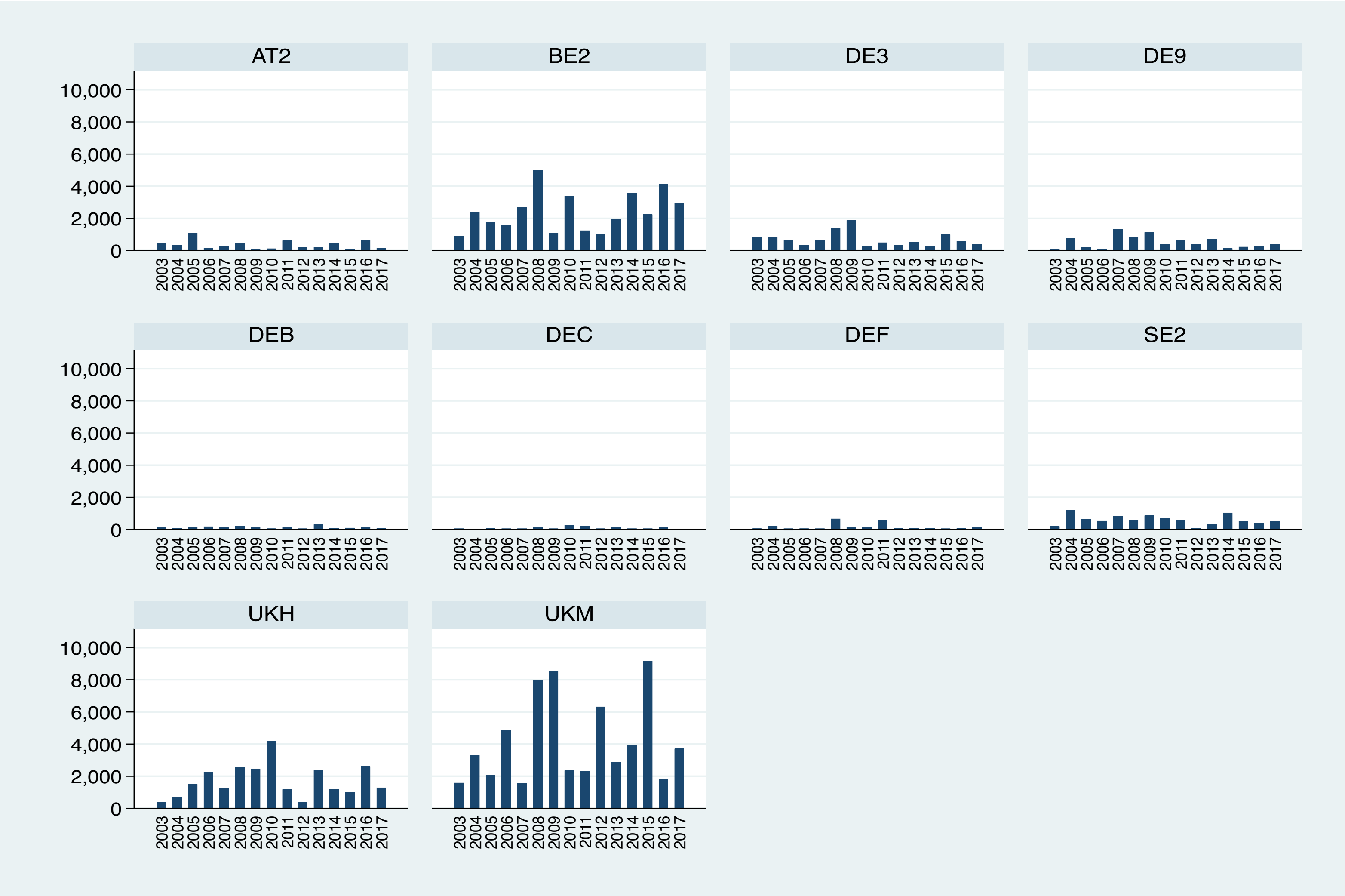
Source: FDIMarkets, own calculations.

Figure 19 shows that the majority of inward investment projects into Scotland are for industry (manufacturing), followed by distributive services (wholesale etc). Scotland has a significant financial and business services level of investment from overseas in terms of volume of projects. Combined, manufacturing and distributive services account for almost 80% of all FDI projects.

7.3 EU Benchmark comparisons

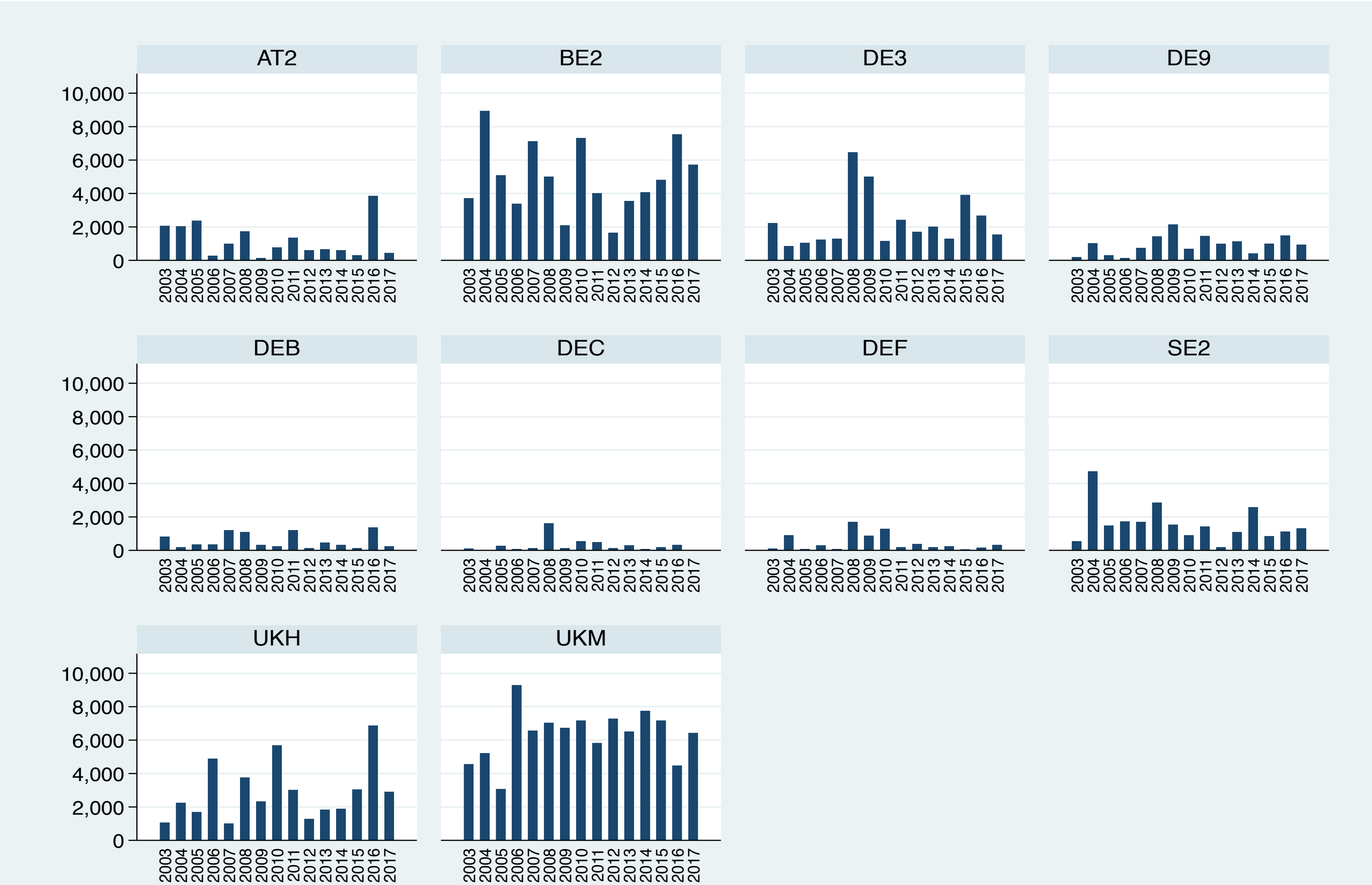
Taking Figures 20 and Figure 21 together it is evident that Scotland has by far the greatest level of activity in FDI investment, estimated to contribute significantly to job creation and capital investment. As there is considerable variation in the sizes of the NUTS1 regions, a more appropriate measure adjusts for this by measuring FDI investment relative to GVA. These data are presented in Table 9 below.

Figure 20. Inward real capital investment from FDI projects, 2003-2017



AT2: *Südösterreich;* ***UKH****: East of England;* ***DE3****: Berlin;* ***SE2****: Södra Sverige;* ***DE9****: Niedersachse;* ***BE2****: Vlaams Gewest;* ***DEB****: Rheinland-Pfalz;* ***UKM:*** *Scotland;* ***DEC:*** *Saarland;* ***DEF:*** *Schleswig-Holstein.*
Source: FDI Markets, own calculations

Figure 21. Jobs created by FDI projects by region, 2003-2017



***AT2:** Südösterreich; **UKH**: East of England; **DE3**: Berlin; **SE2**: Södra Sverige; **DE9**: Niedersachse; **BE2**: Vlaams Gewest; **DEB**: Rheinland-Pfalz; **UKM:** Scotland; **DEC:** Saarland; **DEF:** Schleswig-Holstein.*

Source: FDI Markets, own calculations

Table 9. Percentage of FDI investment flow as a proportion of GVA by NUTS 1 Benchmark group 2003-2017

year	UKM	UKH	SE2	DEF	DEC	DEB	DE9	DE3	BE2	AT2
2003	1.00	0.21	0.15	0.08	0.14	0.11	0.03	0.88	0.51	1.01
2004	1.96	0.36	0.91	0.28	0.00	0.73	0.39	0.91	1.30	0.70
2005	1.19	0.78	0.49	0.01	0.25	0.13	0.09	0.71	0.94	2.12
2006	2.70	1.16	0.37	0.07	0.12	0.17	0.03	0.35	0.81	0.31
2007	0.86	0.62	0.56	0.02	0.02	0.14	0.60	0.65	1.34	0.47
2008	5.03	1.49	0.43	0.89	0.45	0.18	0.37	1.36	2.45	0.81
2009	6.21	1.69	0.74	0.21	0.11	0.16	0.54	1.90	0.55	0.08
2010	1.65	2.73	0.50	0.23	0.96	0.04	0.17	0.25	1.66	0.23
2011	1.63	0.78	0.39	0.77	0.67	0.15	0.29	0.47	0.60	1.11
2012	4.09	0.23	0.06	0.08	0.02	0.21	0.17	0.32	0.47	0.35
2013	1.90	1.50	0.20	0.10	0.42	0.26	0.30	0.50	0.92	0.37
2014	2.38	0.67	0.67	0.11	0.16	0.07	0.05	0.23	1.65	0.82
2015	5.00	0.50	0.32	0.01	0.15	0.08	0.98	0.87	1.02	0.15
2016	1.13	1.42	0.23	0.09	0.43	0.14	0.12	0.49	1.84	1.12
2017	2.40	0.73	0.29	0.18	0.00	0.08	0.15	0.33	1.30	0.24

Source: FDIMarkets, own calculations.

There is, as expected, considerable volatility in FDI flows over time and across NUTS1 regions. 2008/09 sees the highest average level of FDI across the benchmark regions (with or without Scotland). This is particularly pronounced in the immediate aftermath of the financial crisis possibly reflecting exchange rate adjustments.

Scotland has significantly higher relative shares of FDI flows as a proportion of real GVA compared to all other regions in almost all years. The Vlaams Gewest region for Belgium is the next highest recipient of FDI over the period, relative to its GVA, followed by the East of England. Other regions see comparatively modest levels of FDI inflows.

Correlation between GVA and FDI inflows

The academic evidence on what attracts FDI to nations and regions is extensive. Dunning's early work on the OLI[19] paradigm highlighted the importance of ownership, locational and international advantages when firms choose their mode of entry to foreign

[19] Ownership, Location, Internalisation

markets (Dunning 1988). Lucas (1990) points out that flows of capital do not follow expected neoclassical patterns and rather than seeing a shift of resources from developed to less developed regions of the world, in fact, capital resources remain concentrated in richer parts of the world due to differences in - and spillovers from - human capital, as well as imperfect capital markets and factors surrounding institutional stability (Foad, 2012). Thus, we expect that regions with greater economic mass are more likely to have higher levels of FDI inflows and there is some evidence of this when we see the correlation between real GVA and FDI inflow.

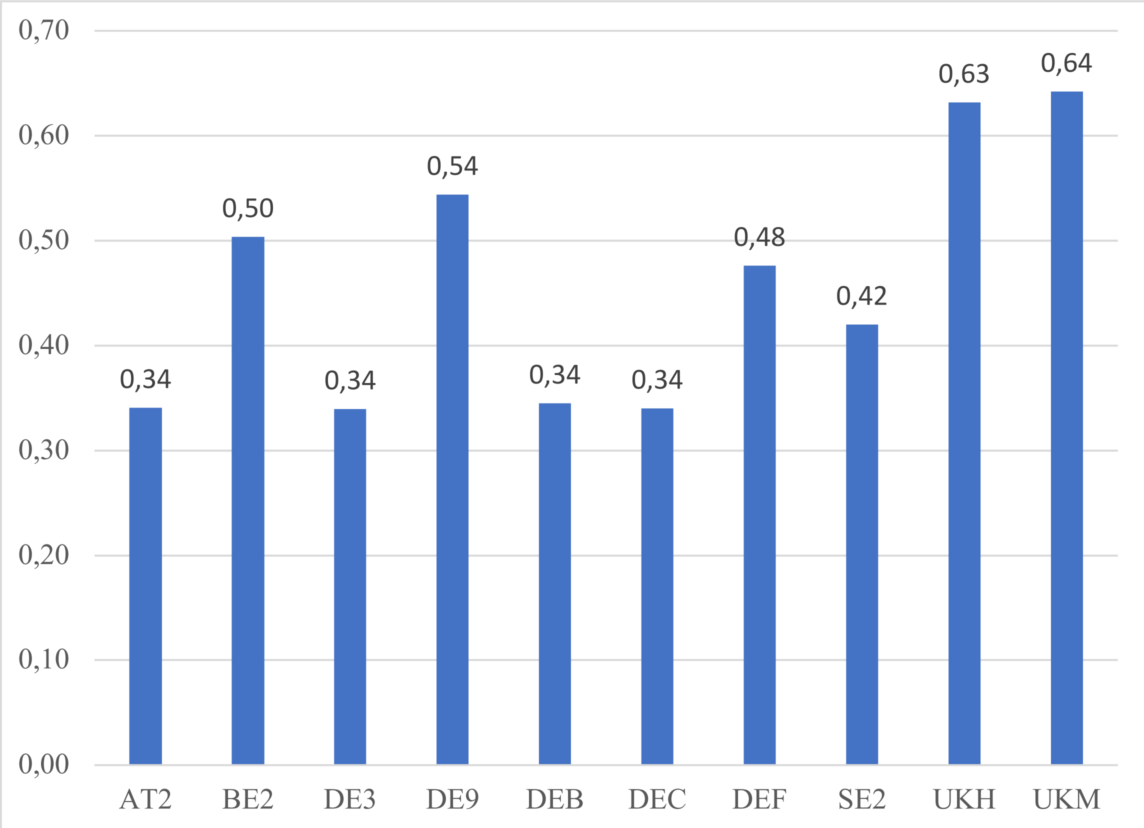
Table 10: Pairwise correlations across all benchmark NUTS1/year observations.

	FDI capital investment	*FDI jobs*
FDI capital investment	1	
FDI jobs	0.808*	1
RGVA	0.388*	0.428*
Employment	0.364*	0.372*
GFCF	0.396*	0.438*
TFP Growth (LQ_Adj)	0.006	0.017
GDP PPS	0.353*	0.386*

Source: FDIMarkets, own calculations. (indicates 5% level of significance)*

FDI inflows and jobs are as expected, highly correlated. TFP growth does not appear to be correlated with FDI. That is, we do not find evidence that regions that experience higher inflows of FDI experience higher TFP growth. These gains may materialise over time but cannot seen within the timeframe observed here. There has consistently been mixed empirical evidence in this regard (Gorg and Greenaway, 2004). Recent work by Bournakis et al (2019) suggests that the evidence on the extent to which FDI increases regional productivity is mixed, arguing that the inward investment is not always aligned with the needs of the host nation. The positive association with the other measures such as employment, capital formation and GVA/GDP are indicative of a scale effect in attracting FDI.

Figure 22. Average FDI spend per job created by region, 2003-2017 (millions of Euro per job created)



AT2: *Südösterreich;* ***UKH****: East of England;* ***DE3****: Berlin;* ***SE2****: Södra Sverige;* ***DE9****: Niedersachsen;* ***BE2****: Vlaams Gewest;* ***DEB****: Rheinland-Pfalz;* ***UKM:*** *Scotland;* ***DEC:*** *Saarland;* ***DEF:*** *Schleswig-Holstein.*
Source: FDI Markets, own calculations

From Figure 22 we note that FDI investment in Scotland and East of England is comparatively more capital intensive than in other regions. Comparisons with other EU Benchmark regions shows that Germany sees lower investment levels per job created in general, except for the Niedersachsen region.

In summary, FDI flows are high in Scotland, relative to the EU Benchmark Regions and we see clear correlation between jobs created and capital injected, as well as regional GVA. What is not clear is a positive relationship with FDI flows over the period and TFP growth. It may be that the time period is too short see the benefits. An alternative interpretation may be that FDI entering the UK does not bring benefits because it is seeking technology rather than bringing productivity advantages (Driffield and Love, 2005). In their detailed micro-econometric analysis, Harris and Moffatt (2017) find similar results for Scotland and FDI plants compared to the rest of the UK comparisons, which they attribute to negative non-place effects. These relate to the characteristics associated with the plants themselves such as the age and level of R&D investment by the FDI plants. Caution must be exercised, and we stress that we are focussing on FDI flows not levels of FDI stock in each of these regions.

8 Demand for skills: gaps and vacancies

Our measures of labour quality[20] described in section 5.1 capture the effect of changes in shares of hours worked by workers with different levels of qualifications. Rooted in the growth accounting literature we follow postulations of human capital theory in that the wages equal marginal productivity in competitive equilibrium.

From a demand perspective, however, it is possible that there are notable mismatches between the supply and demand for skills, which ultimately can depress productivity. Within this framework is thus possible to infer indirectly the impact of mismatch on productivity through its estimated effect on wages. For instance, a tertiary graduate who holds a job requiring only an upper secondary qualification will tend to earn less than if he were in a job requiring a tertiary qualification. Therefore, the effect that any hypothetical shift towards a higher proportion of graduates will have on aggregate productivity could be diminished if there is skill mismatch.

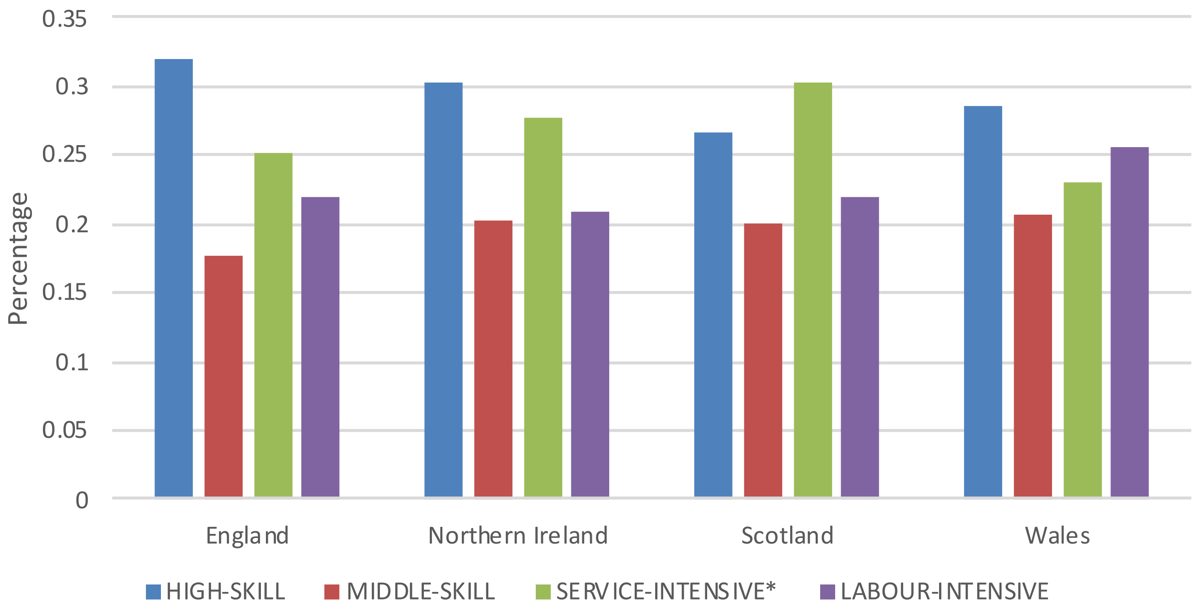
McGowan and Andrews (2015) explore the link between skill and qualification mismatch and labour productivity using cross-country industry data for 19 OECD countries, and data from the OECD Survey of Adult Skills (PIAAC). Drawing from workers' perception on the match between their jobs and education, they find that higher skill and qualification mismatch is associated with lower labour productivity.

It is crucial that education and the labour market are aligned on the types of skills and qualifications that are most essential for boosting productivity. While increases in the stock of highly educated workers significantly boosted labour productivity of major developed economies in early 2000s explaining up to 20 per cent of annual labour productivity growth rates, this slowed down after the financial crisis (see O'Mahony and Timmer, 2009).

In this section we look in detail at the results of the UK Employer Survey for 2017 (the latest available) to offer a more nuanced understanding of current labour market conditions. Figure 23 depicts the profile of vacancies occupation for the four nations of the UK in 2017. High-skill occupations represent 26.7% of all vacancies in Scotland. England presents the highest share of vacancies in high -skilled occupations (32%), followed by Northern Ireland (30.3%) and Wales (28.6%). Scotland shows the highest proportion of vacancies in service-intensive activities (30.2%) among the UK nations.

[20] Also referred to as labour composition.

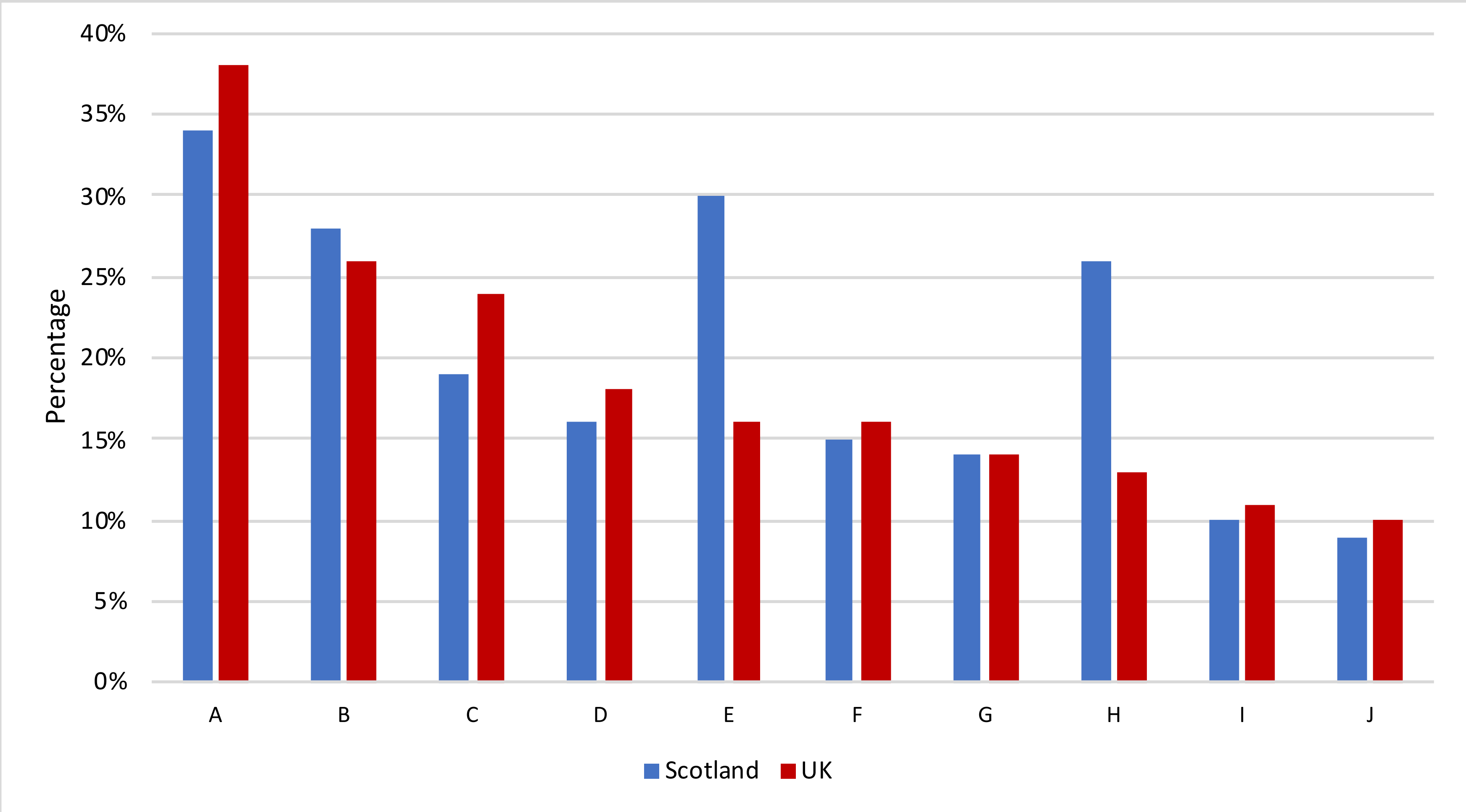
Figure 23. Profile of vacancies occupation – UK, 2017.



*Source: ESS, 2017. Note: * Include caring, leisure, sales and customer services, other services activities.*

Figure 24 shows the reasons, from an employer perspective, for the hard-to-fill vacancies in Scotland and the UK in 2017. Both in Scotland and in the UK, the main reason for hard-to-fill vacancies in businesses was the *'low number of applicants with the required skills'*, which are 34% and 38%, respectively. The *'low number of applicants generally'* was also reported as a common reason for these hard-to-fill vacancies (around 28% in Scotland and 26% in the UK). Note that '*poor terms and conditions offered for post'* and *'too much competition from other employers'* were much higher in Scotland (30% and 26%, respectively) compared to the UK (16% and 13%, respectively).

Figure 24. Reasons for hard-to-fill vacancies in Scotland and in the UK businesses – ESS 2017

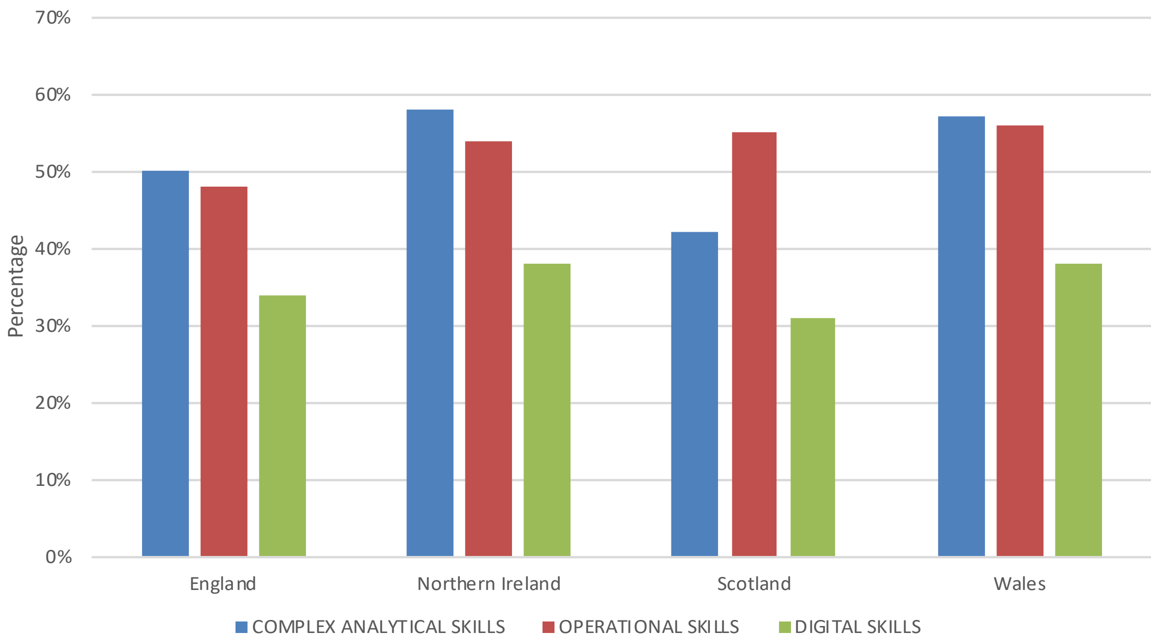


A *Low number of applicants with the required skills;* ***B*** *Low number of applicants generally;* ***C*** *Not enough people interested in doing this type of job;* ***D*** *Lack of work experience the company demands;* ***E*** *Poor terms and conditions (e.g. pay) offered for post;* ***F*** *Low number of applicants with the required attitude, motivation or personality;* ***G*** *Lack of qualifications the company demands;* ***H*** *Too much competition from other employers;* ***I*** *Remote location/poor public transport;* ***J*** *Job entails shift work/unsociable hours.*

Figure 25 presents the gaps in technical skills from applicants in the four nations of the UK in 2017. In Scotland the largest gap related to operational skills (55%), which was similar to Wales (56%) and Northern Ireland (54%). Note that the gap in complex analytical skills and digital skills in Scotland (42% and 31%, respectively) were smaller than that for the other three UK nations. These are the type skills that best complement the use of technology and can accelerate the development and the implementation of the most advanced digital technologies in businesses. Such skills are needed to develop new technologies as well as to embed them in production (OECD, 2018). Further research should shed light into which are the specific skills that will be necessary to improve labour productivity in an increasingly digitalised world, and which skills and occupations will be mostly redundant. The displacement of labour in automated tasks could be counteracted by an increase in the productivity in non-automated tasks due to the cost savings generated by automation. As argued by Acemoglu and Restrepo (2018), a critical factor in this adjustment process will be the potential mismatch between technology and skills, that is between the requirements of new technologies and tasks and the skills of the workforce. The scarcity of complementary skills thus could reduce the productivity gains from both automation and the introduction of new tasks.

In Figure 9 we highlighted the diminished role of intermediate technical skills in the Scottish workforce. From the demand side, Figure 25 illustrates the one factor to consider that may explain this result, that is, the difficulties of employers to recruit workers with the desired technical and operational skills. This result, taken together to the finding that applicants are deterred by the poor terms and conditions offered for the job vacancies (highlighted in figure 24), pointing to significant skill mismatch in expectations between employers and employees, which appears to be more accentuated in the case of Scotland.

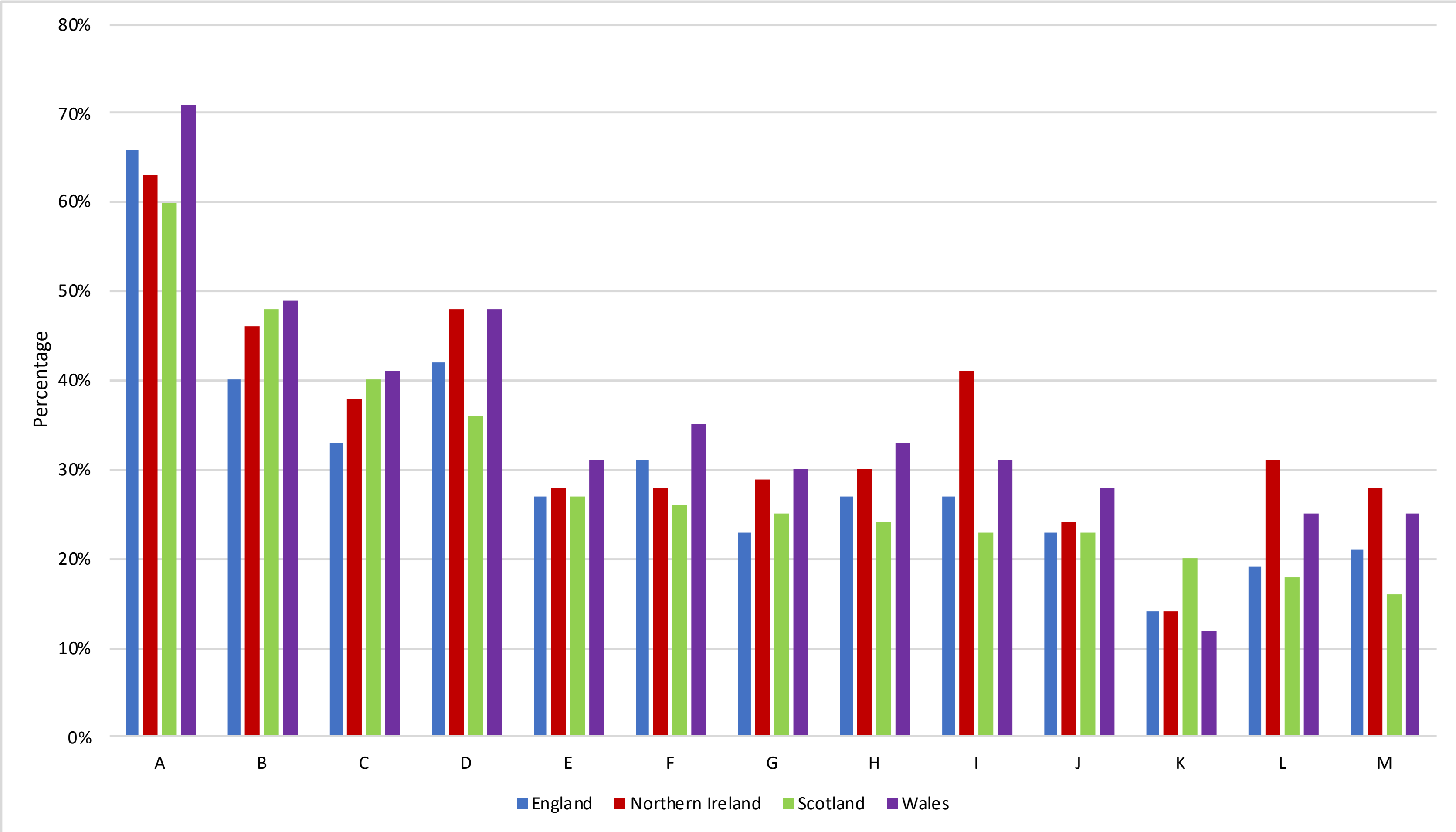
Figure 252. Gaps in technical skills of applicants - 2017



Source: ESS, 2017.

Figure 26 looks deeper into the type of technical skills that are lacking. For the four nations, the highest gap is related to *'specialist skills or knowledge to perform the role'*. Despite this, Scotland's gap in this particular skill (60%) was smaller than the other nations - it was 71% in Wales, 66%, in England and 63% in Northern Ireland. The gap in Scotland was also high in *'knowledge of products and services offered by your organisation and organisations like yours'* and in *'knowledge* of how your organisation works', 48% and 40%, respectively. In addition, note that Scotland's gap in *'communicating in a foreign language'* was 20% above that in England and Northern Ireland (where it was 14%) and that in Wales (12%).

Figure 26. Gaps in technical skills of applicants – disaggregated, ESS 2017



A Specialist skills or knowledge needed to perform the role; **B** Knowledge of products and services offered by your organisation and organisations like yours; **C** Knowledge of how your organisation works; **D** Solving complex problems requiring a solution specific to the situation; **E** Writing instructions, guidelines, manuals or reports; **F** Reading and understanding instructions, guidelines, manuals or reports; **G** Adapting to new equipment or materials; **H** Basic numerical skills and understanding; **I** More complex numerical or statistical skills and understanding; **J** Computer literacy / basic IT skills; **K** Communicating in a foreign language; **L** Manual dexterity; **M** Advanced or specialist IT skills.

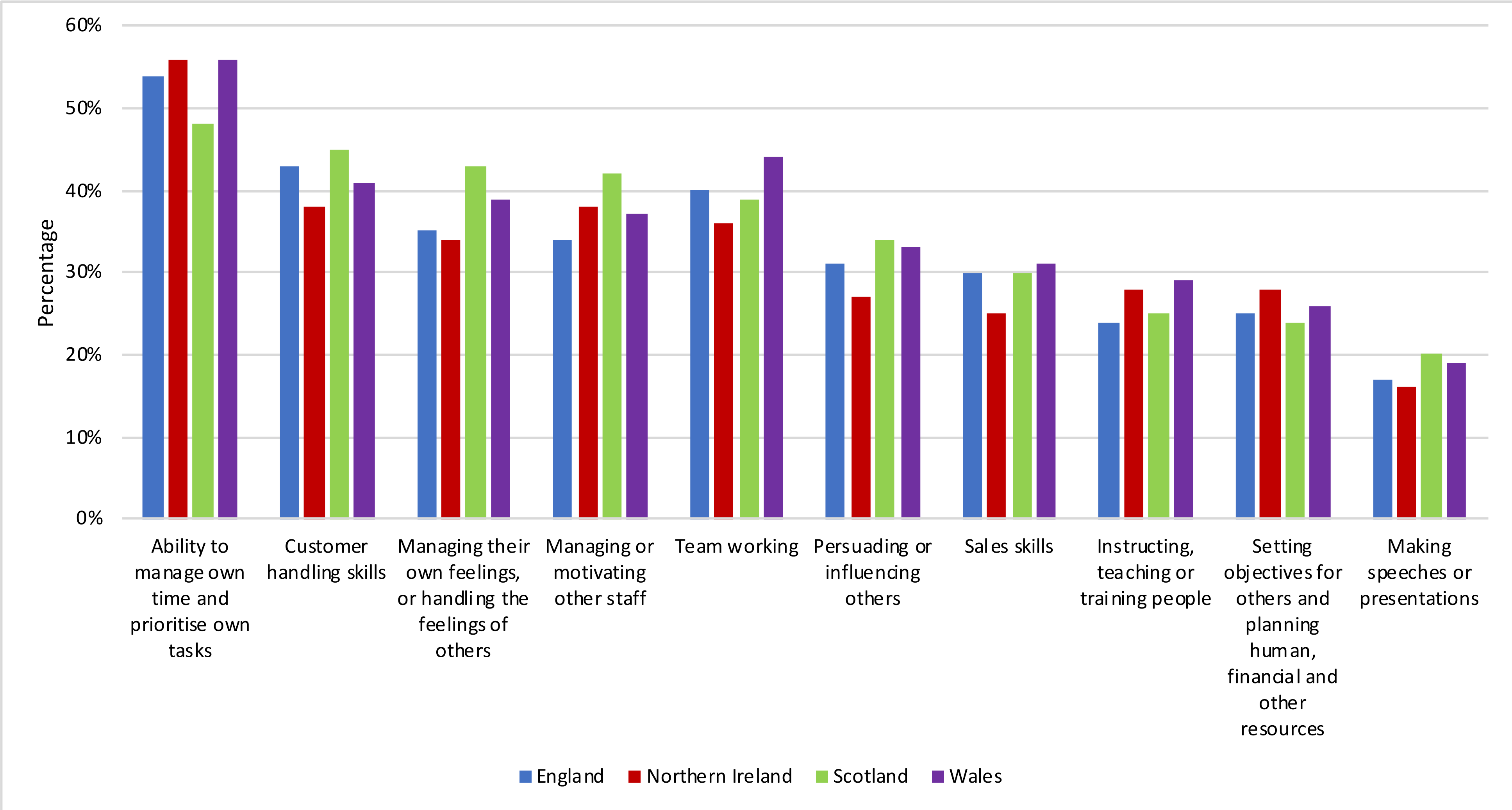
Figure 27 presents the results on soft-type skills gaps. The highest gap in Scotland was on *'self-management skills'* (58%), followed by *'management and leadership skills'* (53%) and *'sales and customers skills'* (51%). While the gap on 'self-management skills' was smaller in Scotland compared to the other three nations, the gap in 'management and leadership skills' and 'sales and customers skills' was greater in the Scotland case.

Figure 27. Gaps in soft skills of applicants - 2017

Source: ESS, 2017.

Lastly, Figure 28 shows the gaps in soft skills of applicants with greater detail. The largest gap in Scotland is related to the *'ability to manage own time and prioritise own tasks'* (48%). This was also the most prevalent in the other nations (56% in Wales and Northern Ireland and 54% in England). Other soft skills such as *'customers handling skills'*, *'managing their own feelings, or handling the feelings of others'* and *'managing or motivating other staff'* are perceived as dominant in Scotland (45%, 43% and 42%, respectively).

Figure 28. Gaps in soft skills from applicants – disaggregated results, 2017



Source: ESS, 2017.

9 Review on work organisation practices.

The literature on employment practices and workplace performance highlight what are the main practices that are expected to have a positive influence on productivity outcomes (Bloom and Van Reenen, 2010). First, the literature considers the role of work organisation practices, which give workers a greater level of autonomy, aid collaboration, and raise their skills; second, the performance or quality of management practices which seek to more closely manage workers' effort; and third, incentive pay schemes which seek to motivate workers through financial incentives.

Understanding where Scotland lies in a range of workplace performance measures can reveal a range of opportunities for promoting productivity growth. In this section we review what we have learnt from empirical contributions and illustrate recent developments on employment practices in Scotland and the UK regions.

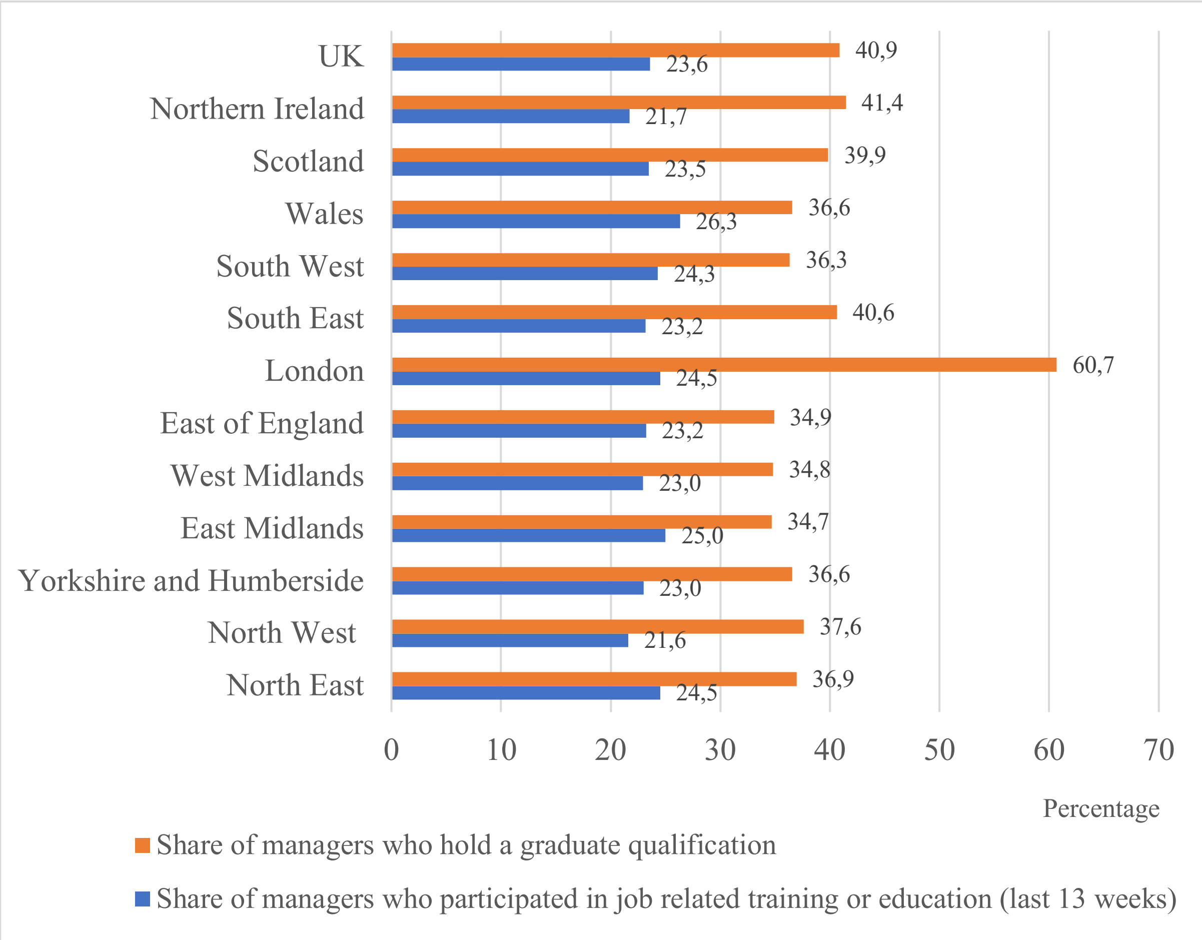
An increasingly influential literature shows that differences in management practices are responsible for a large fraction of TFP growth gap across countries (Bloom and Van Reenen 2007, Bloom et al. 2014). These studies are largely based on survey information collected worldwide and are aimed to measure management practices along three main dimensions: monitoring, targets, and incentives. From a policy perspective, a question then becomes what determines managerial quality.

Recent research (see Bloom et al., 2014) identifies four possible explanations: i) *competition*; ii) *regulations affecting product and labour markets*; iii) *ownership structure* (e.g. managerial quality is highest in MNEs and lowest in family managed firms); and iv) *education*. While improvements in the quality of management can lead to high productivity within firm, along with other within-firm factors (e.g. intangible assets), researchers are increasingly stressing other results such as those that link the efficiency of resource allocation within industries to aggregate performance (Bryson and Forth, 2015)

As highlighted by the literature, an important aspect of managerial quality is that of education of managers. Using data from the quarterly Labour Force Survey (LFS) for the period 2013-2020 we compare proxies for the quality of managerial practices in the UK Figure 29 shows that Scotland ranks close to the UK average in two types of indicators: the share of managers who hold a graduate qualification (39.9%), and the share of managers who actively participate in job related training or education (23.5%). Unsurprisingly, London has the highest proportion of managers with a university degree but the differences across regions on the proportion of managers participating in training activities is less significant. Compared to the

East of England, which is the other UK region in the benchmark regions, Scotland fares better particularly in terms of the share of managers who hold a graduate qualification.[21]

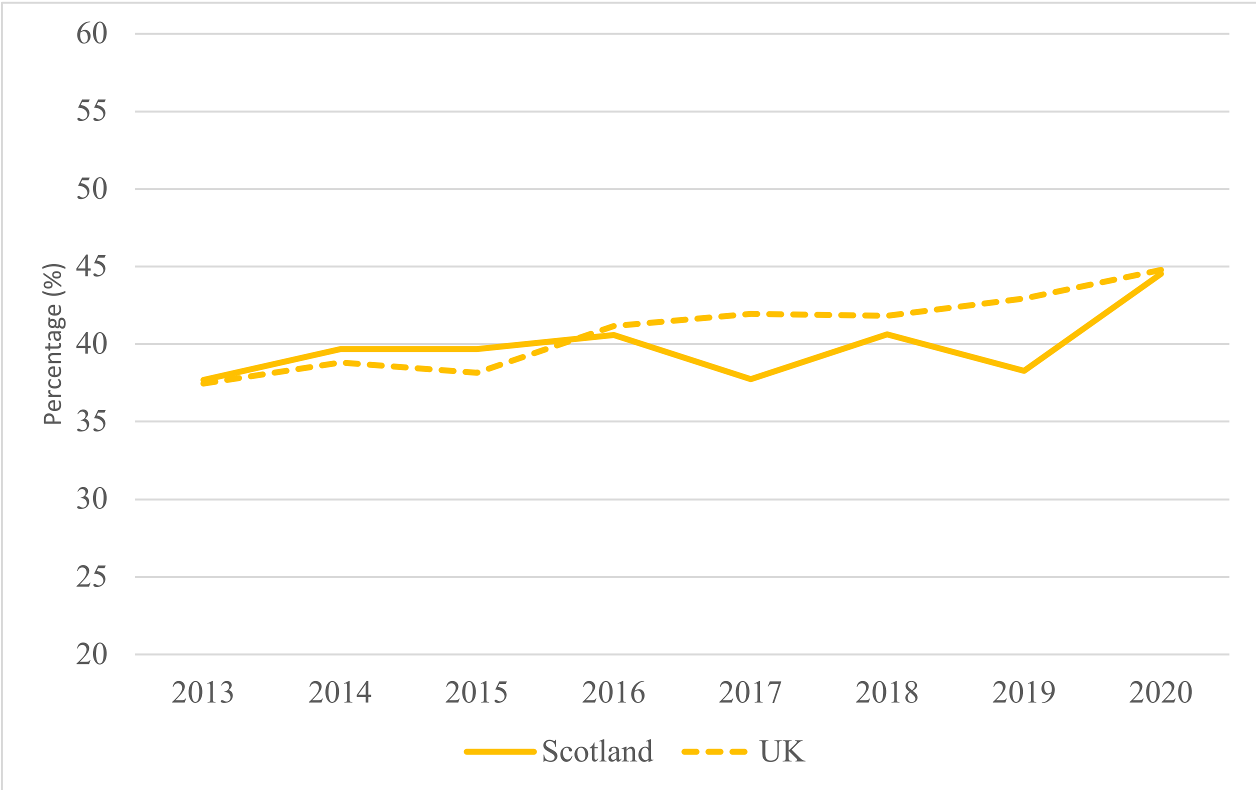
Figure 29. Participation of managers in higher-education or training activities, 2013-2020.



Source: UK LFS and own calculations. Note: qualification groups are defined based on the highest qualification that individuals have completed.

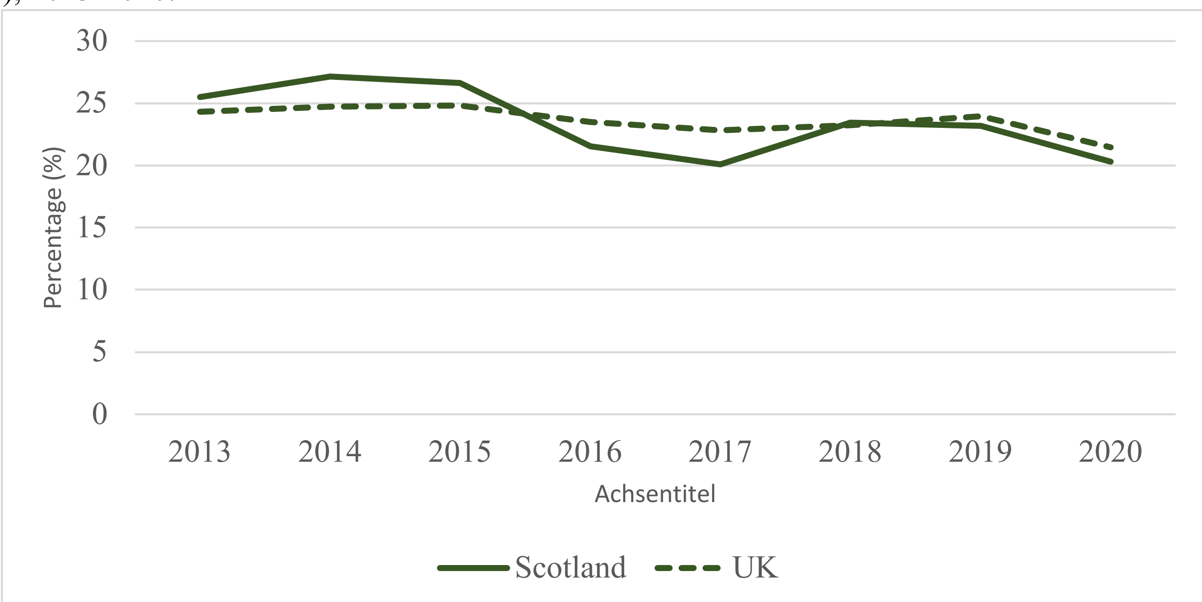
[21] A similar analysis could potentially be done for the EU benchmark regions, but this will require access to the micro data in the European Labour Force Survey, and obtaining such data is neither a simple or straightforward process and as such this analysis is limited to UK.

Figure 30. Share of managers with a graduate qualification, 2013- 2020.



Source: UKLFS

Figure 31. Share of managers who participated in job related training or education (last 13 weeks), 2013-2020.



Source: UKLFS

A strand of works has investigated the different ways in human resource management, employment relations and compensation systems impact upon organisational performance. Forth and McNab (2008) explore the role of unions and collective bargaining on pay and productivity. They find a positive association between workplace productivity and union recognition or incentive pay.

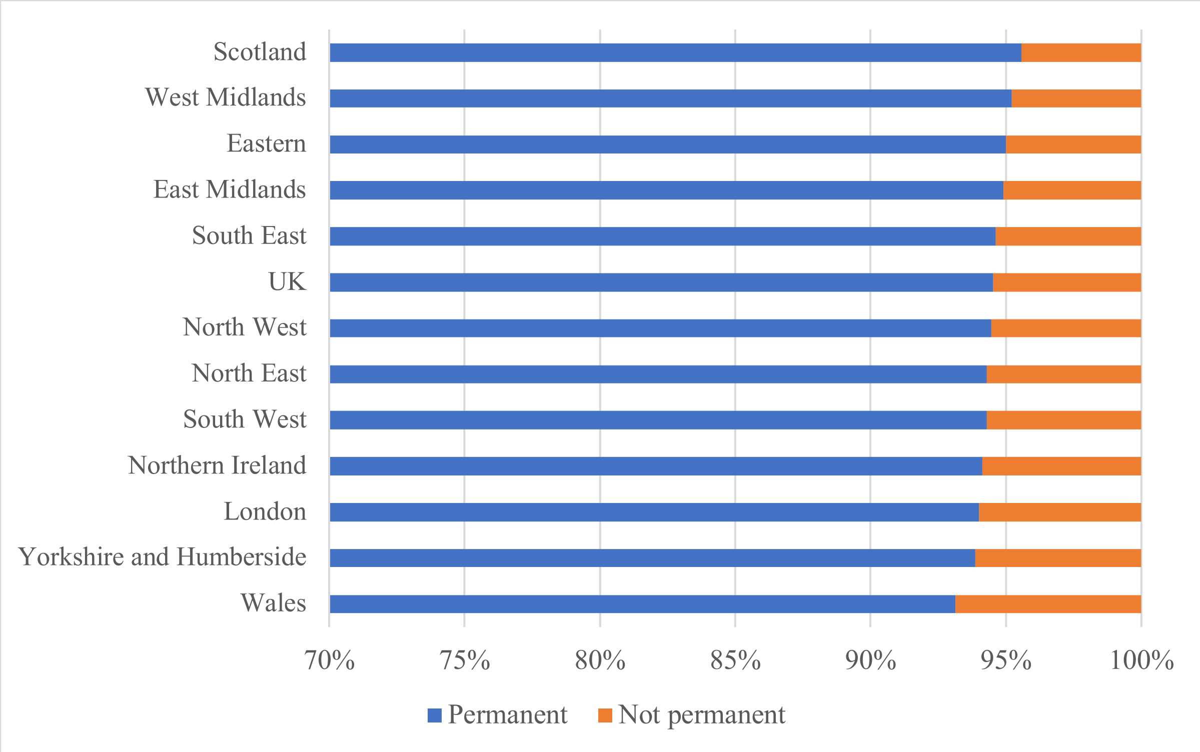
Drawing from WERS[22], Bryson and Forth (2015) undertake micro-analysis of workplace-level behaviour in the UK between 2004 and 2011, offering a workplace perspective of the UK's productivity puzzle. Specifically, they investigate whether the rate of growth of a range of employment practices might have slowed since the mid-2000s, in such a way as to have contributed to the general slowdown in productivity growth in the UK. The Workplace Employment Relations Surveys (WERS) have proven an important source of data on workplace practices as well as organisational performance, but the latest data is for 2011. This paper finds no evidence that workplaces have benefited from the flexible labour market arrangements but instead workplaces with increasing unionisation appeared to benefit in terms of improved workplace performance.

Several sources such as ASHE (employer-based) and LFS (employee-based) can offer information on job quality. Job quality can be influenced by non-economic aspects of jobs, and good working conditions influence workers quality of life and wellbeing, which can also be associated with firms' productivity and economic performance (Eurofound and International Labour Organization, 2019). Here we look at data from the quarterly Labour Force Survey (LFS) for the period 2013-2017 to investigate several aspects affecting quality of employment and other productivity-enhancing practices.

On working arrangements, Figure 32 shows the share of employees on permanent contracts, as an indicator of labour market security. With regards to productivity, the OECD (OECD, 2009) show that strict employment protection legislation that impedes the laying off of workers in permanent contracts may be detrimental for productivity. This is because restricts an efficient allocation of resources and may slow down technological change. Among the UK regions, Scotland presented the highest percentage of permanent contracts (95.5%) for the period 2013 to 2017, and around 1 percentage points higher than the UK as whole (94.5%).

[22] WERS is a national survey, which maps employment relations in workplaces across Britain. It collects data from managers, worker representatives and employees in 2,700 workplaces with 5+ employees. It was first undertaken in 1980, and then in the following years: 1984, 1990, 1998, 2004 and 2011. It provides linked employer-employee data since 2011.

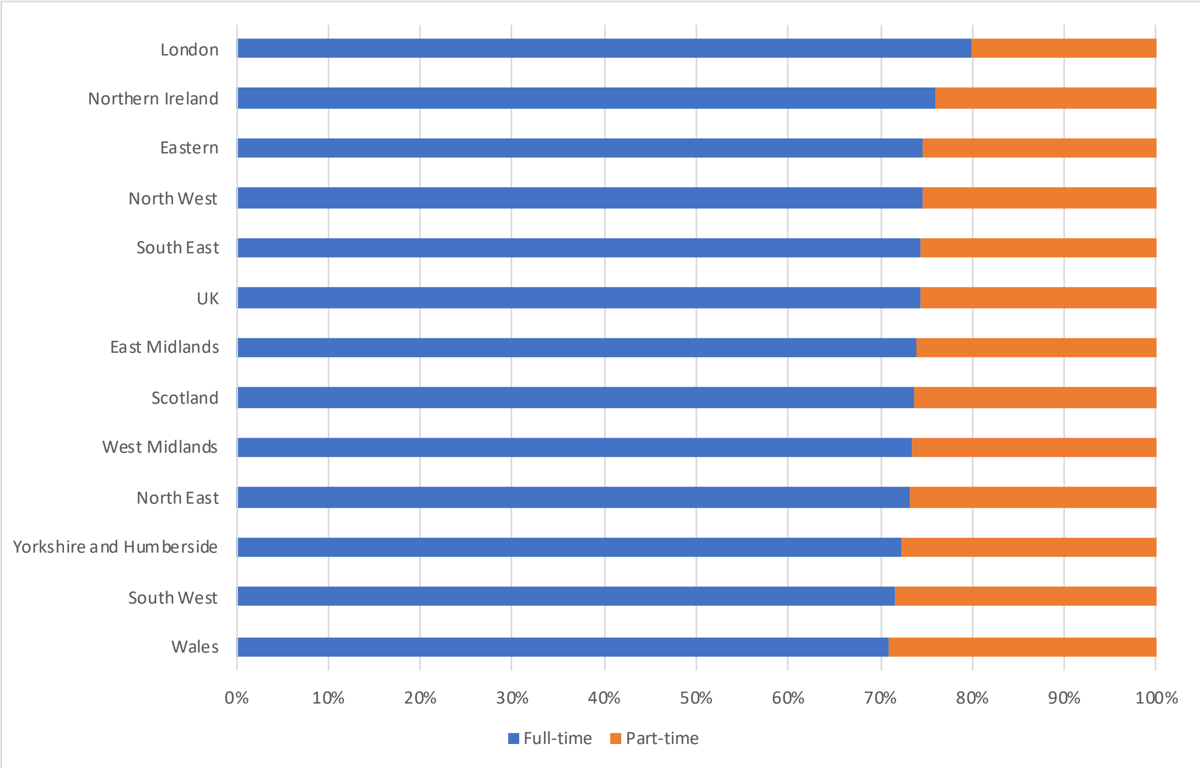
Figure 32: Job type, 2013-2017



Source: UK LFS and own calculations.

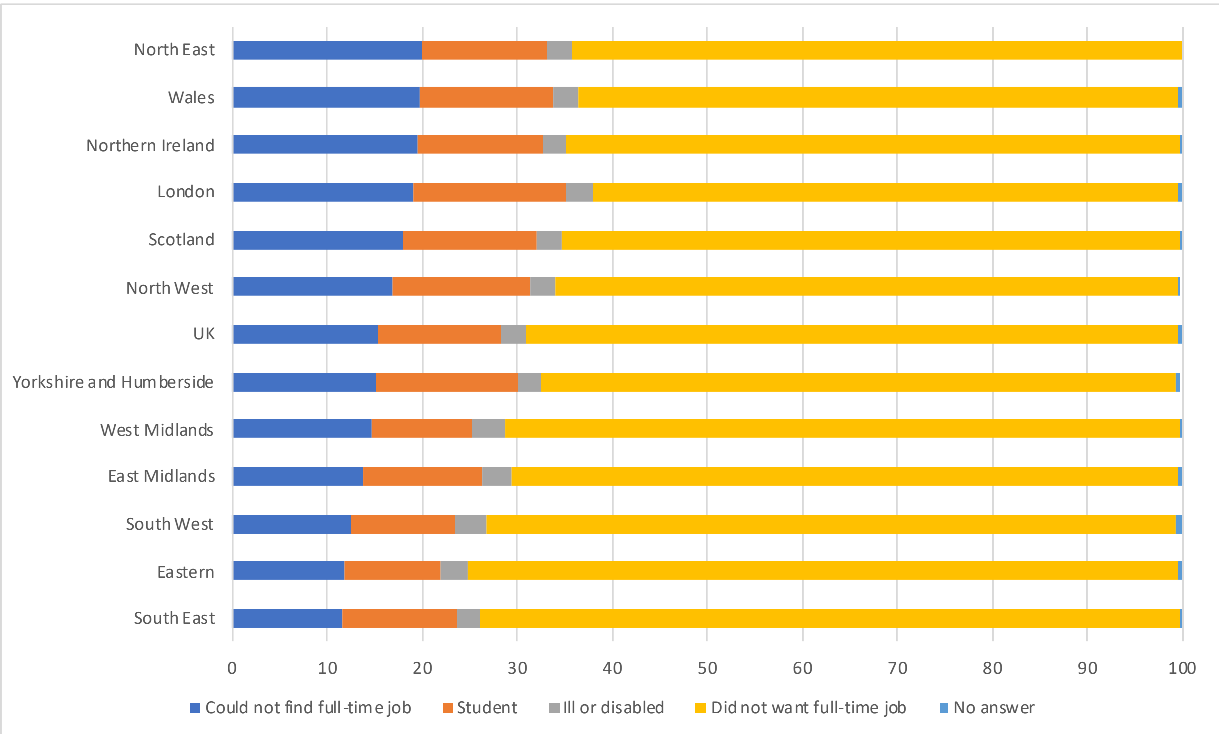
Another indicator we have looked at is the incidence of flexible working arrangements. Figure 33 presents the share of workers in full-time and part-time employment. An empirical question and an area for further research is whether it is beneficial or not for firm productivity. This is a question of high-relevant that will gain prominence in the post-pandemic work as workers request to maintain patterns of flexible working. For the period 2013-2017, 73.7% of workers in Scotland were in full-time employment, while the UK average was 74.3%. London has the highest share of workers in full-time employment over the period, around 80%.

Figure 33. Full-time vs; Part-time work, 2013-2017



Source: UK LFS and own calculations.

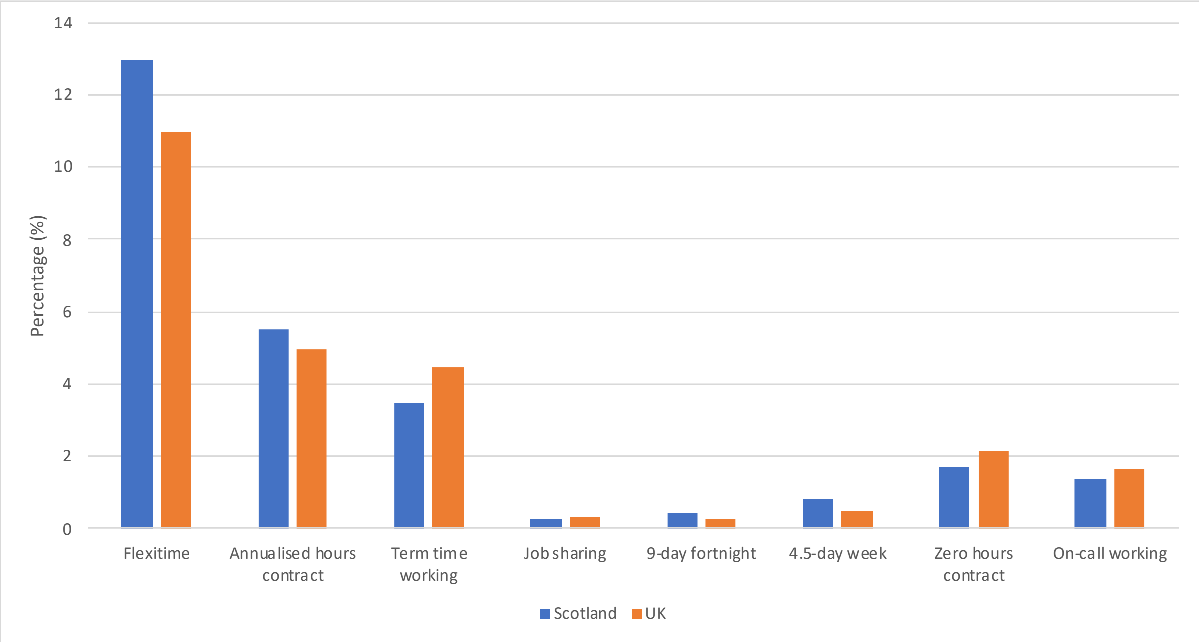
Figure 34. Reason for part-time job, 2013-2017



Source: UK LFS and own calculations.

Figure 35 shows more information on flexible working arrangements for Scotland and the UK. Scotland flexitime arrangements were 2 percentage points higher than the UK as a whole (13% and 11%, respectively). In addition, Scotland also reported a slightly higher percentage of annualised hours contract (5.5%) compared to the UK (around 5%). Conversely, the share of workers in term-time employment was smaller in Scotland (3.4%) than in the UK (4.5%).

Figure 45: Working arrangements, 2013-2017

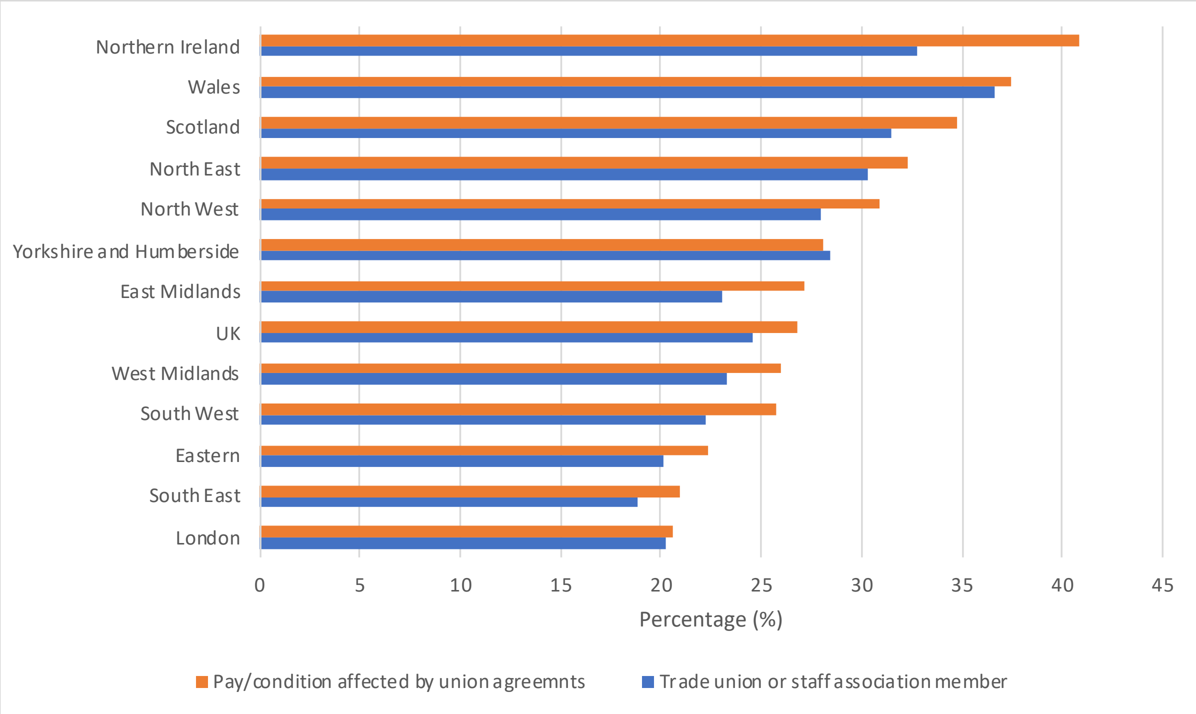


Source: UK LFS and own calculations.

Finally, we also look at the union membership and collective bargaining in the workplace (see Figures 36 and 37). Around 34.7% of workers in Scotland reported that their earnings and/or conditions were affected by union agreements. This level was almost 8 percentage points above that in the UK as whole (where 26.8% of workers reported being affect by union agreements). Scotland was only below Northern Ireland (40.9%) and Wales (37.4%). The share of workers that reported being union members was higher in Scotland (31.5%) than in the totality of the UK (24.6%).

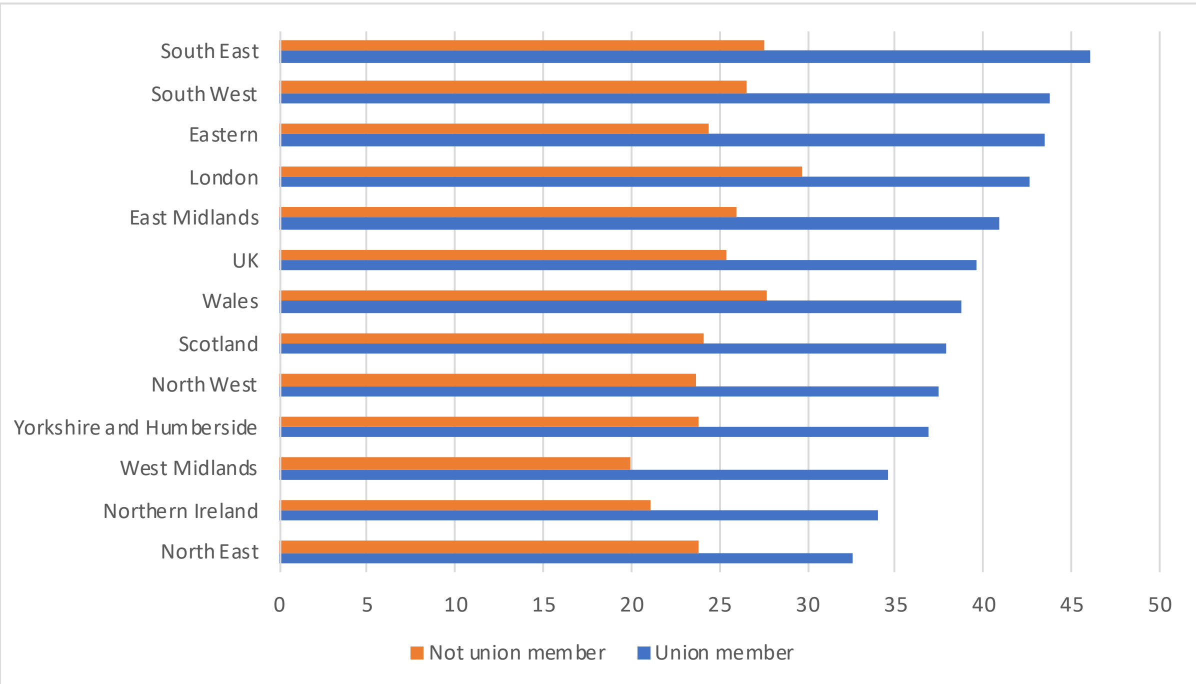
We then compare the participation rate in job- related training or education in the last 13 weeks for union members and non-members (Figure 37). In all regions in the UK, the participation rate in training is higher for union members compared to non-members. For instance, the participation rate is 37.9% for members and 24.4% for non-members in Scotland. These are below the UK rates, 39.7% and 25.4% for members and non-members, respectively.

Figure 36: Union presence, 2013-2017



Source: UK LFS and own calculations

Figure 37: Participation in job related training or education in the last 13 weeks by union membership, 2013-2017



Source: UK LFS and own calculations

In absence of constituent measures that capture directly the quality of management of Scotland businesses, we have looked at some proxies. Overall, we see that Scotland ranks close to the UK average in two types of indicators: the share of managers who hold a graduate qualification and the share of managers who actively participate in job related training or education. There are some other distinctive features of Scottish labour market that can also impact on workplace performance. We observe: a higher union presence, but less training activities among union members; and a higher incidence of flexible-time, on-call working and zero hours contracts.

10 The econometric determinants of TFP growth: A distance to frontier approach

In this section we investigate econometrically how TFP growth of Scotland has systematically differed from that of other regions, looking at the role played by knowledge factors (KF). The literature has identified several key drivers of productivity growth, namely the intensity of R&D investment over GDP (used as proxy of the region's innovative capabilities), and the share of population with tertiary education (used as a proxy for regional endowment of human capital).

We build on the analytical framework developed by Griffith et al. (2004) and Vandenbussche et al. (2006), which model TFP growth as follows:

$$\Delta \ln \mathrm{TFP}_{it} = \alpha_{0i} + \alpha_1 \Delta \ln \mathrm{TFP}_{Ft} + \alpha_2 \ln \mathrm{KF}_{it} + \alpha_3 \mathrm{GAP}_{it} + \alpha_4 \mathrm{GAP}_{it} \times \ln \mathrm{KF}_{it} + \alpha_5 \ln \mathrm{KF}_{it} \times \mathrm{UKM}_i + \alpha_6 \mathrm{GAP}_{it} \times \ln \mathrm{KF}_{it} \times \mathrm{UKM}_i + \mathrm{TD} + \epsilon_i \qquad (6)$$

where Δ is the first-difference operator; and *ln* denotes logs of the variables', *i* denotes regions (i = 1,.., 83) and *t* years (t=2009, …, 2016).

This specification rationalises the idea that productivity growth in a country (in this case adapted at the regional level) depends on:

- the endowment of own knowledge factors (KF = R&D expenditure on GDP or the population share of tertiary education),
- new technological opportunities enabled by outward shifts of the 'technological frontier', denoted by the term $\Delta \ln \mathrm{TFP}_{Ft}$, and
  technology transfers from the frontier to those regions behind the frontier denoted by the distance term $\mathrm{GAP}_{it} = \ln(\mathrm{TFP}_{Ft}/\mathrm{TFP}_{it})$.

In this formulation, the subscript *F* denotes the frontier, i.e. the region with the highest level of TFP in each sample year.

The technology transfers from the frontier can be facilitated by the region's absorptive capacity, usually proxied by their knowledge stock (see Cohen and Levinthal, 1989). As long as knowledge factors are relevant and facilitate the technology transfers for those far from the frontier, the coefficient is expected to be positive. This would be negative if the regions closer to the frontier are more capable to gain from spillovers from forefront areas than those regions lagging further behind.

Our regression model includes region-specific fixed effects to capture unobservable regional characteristics that do not change over time or change very slowly (such as institutional setting, natural factor endowments, demographic structure, etc.). We also include a set of time dummies (TD, i.e., binary indicators for each year covered by the analysis), aimed at capturing the effects of macroeconomic shocks affecting regions symmetrically. These shocks can reflect movements along the business cycles, the transmission of financial shocks etc.

Note that since all variables are expressed in natural logs, the estimated coefficients can be interpreted directly as elasticities. This implies for instance that any percentage point increase in a given explanatory variable (e.g. 1%, 10%) would lead to a corresponding % increase in TFP growth.

Our regression framework allows us to identify two types of effects for the knowledge factors (KF) considered here. The coefficient α_2 captures the direct effect on TFP growth, whilst α_4 identifies the indirect effect. This is assumed to vary with the distance to frontier (GAP). Our regression model is estimated on the subset of NUTS1 regions (83 regions) for which annual data are consistently available.[23]

The overall (marginal) effect of KF, for a region of our sample, would therefore be given by the following expression:

$$\frac{\partial \Delta \ln \ln \mathrm{TFP}}{\partial \ln \mathrm{KF}} = \alpha_2 + \alpha_4 \overline{\mathrm{GAP}}$$

where the bar denotes the sample mean of the distance to frontier (average productivity gap).

This modelling framework enables us to quantify the specific impact that these explanatory variables have for Scotland's productivity growth (and for other reference units such as the chosen benchmark regions).

This is accomplished by multiplying a binary indicator for UKM -- assuming the value 1 for Scotland and 0 otherwise-- with (i) the KF variables (taken alone), and with (ii) the interaction between the productivity gap term and the KF variables.

[23] France is omitted from the analysis as the new NUTS classification adopted for this country inhibits to go back in time in building TFP series.

On this basis, it captures the direct impact that Knowledge Factors have for Scotland in addition to that estimated for the overall sample. If it was not statistically significant, the impact of knowledge factors would not differ from that found for the sample mean. Similarly, if significant, would be indicative of a differential indirect effect of KF on Scotland's productivity growth with respect the rest of the sample.

Summing up, the overall (marginal) effect of KFs for Scotland are:

$$\left.\frac{\partial \Delta \ln \ln \mathrm{TFP}}{\partial \ln \mathrm{KF}}\right|_{\mathrm{UKM}=1} = (\alpha_2 + \alpha_5) + (\alpha_3 \overline{\mathrm{GAP}} + \alpha_6\ \mathrm{GAP}_{\mathrm{UKM}}) \tag{7}$$

where $\mathrm{GAP}_{\mathrm{UKM}}$ is Scotland's specific distance to frontier term.

Table 11. Productivity TFP growth estimates: distance to frontier, R&D intensity and tertiary education

Dep. Variable: TFP growth	(1)	(2)	(3)	(4)
Knowledge factor	**R&D expenses/GDP**		**Tertiary education**	
Knowledge	0.0120	0.00996	0.0265	0.0243
	(0.0539)	(0.0538)	(0.0456)	(0.0456)
TFP growth frontier	-1.000***	-0.983***	-0.982***	-0.976***
	(0.148)	(0.147)	(0.154)	(0.155)
Gap	0.358***	0.355***	0.282***	0.284***
	(0.0350)	(0.0350)	(0.0458)	(0.0462)
Gap x Knowledge	-0.0105	-0.0100	-0.0846**	-0.0815**
	(0.0250)	(0.0250)	(0.0401)	(0.0401)
Scotland x Knowledge		**1.328*** **		**-0.130*** **
		(0.113)		**(0.0452)**
Scotland x Gap x Knowledge		**-0.423*** **		**0.201*** **
		(0.0541)		**(0.0355)**
Observations	575	575	575	575
R-squared	0.229	0.235	0.240	0.241
No. Regions	83	83	83	83

*Notes: fixed effect OLS estimates of eq. (2). Robust standard errors in parentheses. ***, **, * significant at 1, 5 and 10% respectively.*

Table 11 reports the point estimates from an OLS regression of eq. (1). Regressions in columns (1)-(2) consider R&D intensity on total GDP as a knowledge factor, ($\ln KF$) in equation (6). Regressions in columns (3)-(4) use the share of population with tertiary education instead, as the knowledge factors. If we consider these factors alone, they do not seem to exert any direct impact on TFP growth. This is represented by the coefficients of the variable *knowledge* term in columns 1 to 4, which are not statistically significant. This result likely reflects the wide heterogeneity in the effects across regions and within regions at the level of NUTS1 aggregation.

The negative coefficient of frontier TFP growth (coefficients of the term TFP growth frontier in columns 1-4) indicates that there is no productivity convergence in Europe between forefront and the regions that lag behind in terms of productivity. These results suggest that the productivity advantage of the leaders widens over time. This process of divergence is well known and has been investigated both at the regional and firm level (see OECD 2018 and Andrews et al. 2019, respectively).

However, those regions further away from the frontier grow faster than those falling behind the leaders. This is indicated by the positive coefficient of the variable *Gap*. An additional percentage point gap is associated with a faster rate of TFP growth, and this is ranging between 0.28% and 0.36% per year.

We then look at the interaction *variable Gap x Knowledge,* which measures the extent to which the effect of the knowledge variable, that is R&D or human capital, will depend on the productivity distance to the frontier. This effect would add to the main (direct) impact of the knowledge factor. The coefficients for the interaction term in columns 1 and 2 are not statistically significant which indicate that there is no indirect effect of R&D intensity on TFP growth. That is, higher level of R&D spending does not help firms away from the frontier grow faster. Conversely, the story of human capital is more interesting. The negative and significant coefficient of this interaction variable in columns (3) and (4) indicate that regions further away from the frontier that counting with a relatively higher level of human capital perform worse in terms of TFP growth with respect to regions having a smaller gap to the frontier. These regions are not able to exploit human capital endowments to close the gap with leading regions, whilst regions falling close to the frontier have a greater attitude to return to educational investment and in part close the gap to the frontier by means of this type of knowledge factor.

Two further interaction terms in the equation (6) helps us to investigate whether these effects hold similarly in the case of Scotland, one of the regions behind the frontier. We can capture this through the terms $\ln KF * UKM$[24] and $\text{GAP} * \ln KF * UKM$

The pattern of results for Scotland appears somewhat different to what we have observed for the overall sample. For Scotland we find that there is a direct impact of R&D intensity on TFP growth (the term Knowledge in columns (1) and (2)), that is statistically significant and economically more important than that found on average in our sample of regions (1.328). The value of this coefficient implies that 1 percentage point increase in the share of R&D expenses over GDP raises the rate of TFP growth by 1.3%, which is a sizeable effect well above that found in the referenced literature. However, we find that in this case the intensity in R&D does not seem to activate technology transfers from the frontier to any non-frontier company, and the indirect effect of this type of knowledge factor turns out to be negative (-0.42).

A different story emerges for human capital (columns 3 and 4); while it is not found to have a positive (direct) effect on TFP growth (-0.13) it does seem to promote Scotland's absorption

[24] NUTS1 code for Scotland.

of forefront knowledge (0.20). This finding is very powerful as it reinforces the role that human capital plays as an important productivity-enabling factor.

Table 12. Marginal effects of knowledge factors

Code	Region	R&D exp/ GDP		Tertiary education	
	All EU regions	0.002		-0.055	
	Benchmark				
AT2	Südösterreich	0.068	***	0.020	
BE2	Vlaams Gewest	-0.042		-0.345	***
DE3	Berlin	0.474	***	0.278	
DE9	Niedersachsen	0.324	***	0.426	***
DEB	Rheinland-Pfalz	0.115	**	0.581	***
DEC	Saarland	0.197	***	0.296	***
DEF	Schleswig-Holstein	0.229	***	-0.041	
SE2	Södra Sverige	0.311	***	-0.440	***
UKH	East of England	0.149	***	0.001	
UKM	Scotland	0.921	***	0.009	

*Notes: Marginal effect of knowledge factor derived from estimates in Table and computed as of eq. (2). ***, **, * significant at 1, 5 and 10% respectively.*

Table 12 summarises the marginal effects of knowledge factors for Scotland (direct + indirect) and compares them with those identified for the EU benchmark regions, performing a regression analysis similar to that shown in Table 11. Overall, Scotland turns out to be the region with the highest total effect of R&D intensity (0.9), i.e. almost a threefold factor larger than that of the other regions. Conversely, the net effect of human capital is not statistically different from zero; however, this is a characteristic shared between Scotland and several of benchmark regions as only Vlaams Gewest (BE2), Niedersachsen (DE9), Rheinland-Pfalz (DEB), Saarland (DEC) and Södra Sverige (SE2) are found to gain productivity benefits from higher education.

11 Conclusions

In this paper we highlight the relative labour productivity performance of Scotland compared to most the UK and comparable EU regions, in the nine years following on from the financial crisis. Scotland performed well, with its productivity growth behind only London (UKI) and the South East (UKJ), and on a pair with the East of England. In comparison to EU other regions of similar levels of economic development we find that Scotland fared worse in terms of TFP growth and business innovation. Thus, the productivity puzzle that has blighted the UK for the past decade appears to be as evident in Scotland as in the UK as a whole, in comparison with European regions.

Overall, we see that Scotland has remained fairly constant in terms of our key metrics over the period of analysis, gaining in areas such as tertiary skills but losing ground in terms of intermediate skills and innovation. In terms of productivity rankings, it has remained relatively stagnant. In contrast, other regions, especially those in the EU Benchmark have pulled away. This may be partly explained by structural differences, where we see Scotland having a comparatively smaller share of manufacturing of most of high-performing regions in Central and Northern Europe.

As previous research has suggested, there are certain knowledge factors that accelerate the process of catching-up to the technological frontier. In particular we find that R&D is a factor that could contribute to reduce significantly total factor productivity gaps with leading European regions. This is consistent with plant level analyses conducted for Scotland, which find that plants that undertake R&D are generally more productivity. Our findings demonstrate that this effect is more important in the case of Scotland compared to other regions. R&D investment in Scotland remains below the UK average.

Our research finds evidence of the indirect channel by which R&D impacts on TFP growth. This is that of the development of absorptive capacity, which allow the identification, assimilation and exploitation of innovations by other firms as well as universities and research institutes. We find Scotland to be the region with the *highest total effect of R&D intensity on TFP growth relative to selected benchmark regions.*

Somewhat counterintuitively, we find that FDI continues to be a prominent source of employment and capital flows into Scotland, certainly compared to other EU Benchmark regions, however its contribution to TFP growth does not appear significant, at least in the short run. There is mixed evidence on the extent to which FDI increases regional productivity, as some argue that the inward investment may not always be aligned with the needs of the host nation.

Strikingly, we find that the contribution of labour quality to labour productivity growth has been almost negligible in recent years, but education and skills affect productivity directly and indirectly. Our econometric investigation confirms that while human capital in Scotland *does not seem to have a statistically significant effect on TFP growth, this factor appears to improve Scotland's ability to absorb technological knowledge from regions at the frontier. While higher levels of education and skills allow individuals to perform more complex tasks – the direct effect – it also enhances the absorption of knowledge – the indirect effect.*

Another key organisational factor is that of the quality of management and managerial practices, which has been demonstrated to have sizeable impacts on productivity. Other factors could be explored more systematically in this type of framework, including the influence of the business environment and the industrial relations systems. These extensions to the analysis are however less feasible at present due to the lack of comparable data at an international level.

12 Further research

Understanding the sources of the longstanding 'productivity gaps' of the UK relative to other developed countries remains at the centre of the policy agenda. In this work we offer a more granular approach by focusing on performance of Scotland in comparison to EU regions that are similar in make-up and levels of GDP per capita. The debate at the micro level is limited by the lack of harmonised international data that would allow us for instance to focus on the characteristics of companies identified as most important at the macro level. There are databases that allow cross-country firm-level analyses at the European level, such as ORBIS. They usually contain rich financial information but less detail on other types of company activities, and are not meant to be representative of the population of EU firms.

We have highlighted the diminished role of intermediate technical skills in the Scottish workforce, as well as the difficulties of employers to recruit workers with the desired technical and operational skills. This result, taken together to the finding that applicants are deterred by the poor terms and conditions offered for the job vacancies points to a significant skill mismatch in expectations between employers and employees. This appears to be more accentuated in Scotland.

We have seen that an optimal match between the skills demanded by firms and those acquired in education and on the job is an essential ingredient for promoting growth. Improvements on the measuring of labour quality should focus on the value and contribution of non-certified skills, training and vocational skill specifically, and on recognising the reinforcing effect of education and occupation on productivity. Further micro-level analyses should look further at the relationship between a wider range of skills and productivity, ideally drawing from matched employee-employer data.

Another area to investigate is the specific skills that will be necessary to improve labour productivity in an increasingly digitalised world, and which skills and occupations will be most rewarded by employers.

A source of better data, beyond that included in typical business surveys or financial accounts is that offered by workplace surveys, which can be used to look at a wider range of contextual information and topics affecting workplace performance. It is of prime importance to exploit further links to other databases to enable deeper analyses of the correlates of productivity. Another example are new surveys of managerial practices such as The Management and Expectations Survey (MES). Unfortunately, such surveys are rare at a wider international scale thus limiting the extent of international comparisons.

The research has illustrated that, in the area of innovation activities, Scotland performs relatively well given the scale of R&D of the higher education sector. In future decades this sector thus has the potential to play an important role in fostering Scottish competitiveness and contribute to mitigate the long-term effects of the pandemic.

Further research should look at how effectively the higher education sector disseminates technological knowledge and promote business-sector innovation. This could be investigated by looking at the technological collaborations, measured in terms of (co-)patenting activities, between academic and private companies' researchers. Of fundamental importance will be the identification of technological fields in these joint research initiatives that are particularly fruitful. This type of analysis could be expanded by looking at the breadth of business-section innovation opportunities enabled by university research, tracking citations by business-sector inventors to university patents.

As a second idea to follow-up would be to investigate which institutional sector contributes the most to spur TFP growth of the nation, and close (open) the gap with the frontier regions, through research activities. This would be helpful to understand whether public innovation policies, in the form of higher education sector or government R&D, may favour productivity upgrades in the business-sector.

Our research has shown weaknesses and strengths of Scotland's performance relative to a range of well-performing regions in Europe. While we find some interesting themes in the drivers of growth, but we also find that the picture is far from homogenous. A recommendation of further research would be to undertake case studies to enrich quantitative results and derive more specific policy lessons and recommendations.

13 References

Acemoglu, D., Johnson, S., and Robinson, J. A. (2005). Institutions as a Fundamental Cause of Long-run Growth. Handbook of Economic Growth, 1, 385-472.

Acemoglu, D. and Restrepo, P. (2018). Artificial Intelligence, Automation and Work. NBER Working Paper No. 24196.

Aghion, P., Howitt, P., Howitt, P. W., Brant-Collett, M., and García-Peñalosa, C. (1998). *Endogenous growth theory*. MIT press.

Aitken, A., Boshoff, J., Nguyen, D., Rincon-Aznar, A., and Stochino, A. (2019). Places and Spaces: Mapping Britain's Regional Divides. General Election Briefing. NIESR and Nuffield Foundation.

Andrews, D. Criscuolo, C. and Gal, P.N. (2019). The Best versus the Rest: Divergence across Firms During the Global Productivity Slowdown. CEP Discussion Papers dp1645, Centre for Economic Performance, LSE.

Bloom, N., and Van Reenen, J. (2007). Measuring and Explaining Management Practices across Firms and Countries. The Quarterly Journal of Economics, 122(4), 1351-1408.

Bloom, N., and Van Reenen, J. (2010). Why do management practices differ across firms and countries?. *Journal of Economic Perspectives*, 24(1), 203-24.

Bloom, N., Lemos, R., Sadun, R., Scur, D., and Van Reenen, J. (2014). JEEA-FBBVA Lecture 2013: The new empirical economics of management. Journal of the European Economic Association, 12(4), 835-876.

Bournakis, I., Papanastassiou, M. and Pitelis, C. (2019) The impact of multinational and domestic enterprises on regional productivity: evidence from the UK', Regional Studies, 53(2), 159-170.

Bryson, A. and Forth, J. (2015), The UK's Productivity Puzzle. IZA Discussion Paper No. 9097.

Cohen, W. M., and Levinthal, D. A. (1989). Innovation and Learning: The Two Faces of R&D. The Economic Journal, 99(397), 569-596.

Derbyshire, J., Gardiner, B., and Waights, S. (2013). Estimating the Capital Stock for the NUTS2 regions of the EU27. Applied Economics, 45(9), 1133-1149.

Driffield, N. and Love, J.H., (2005). Who Gains from Whom? Spillovers, Competition and Technology Sourcing in the Foreign-owned Sector of UK manufacturing. Scottish Journal of Political Economy, 52(5), pp.663-686.

Driffield, N., J. Du, M. Hart, J. Love, and Tapinos, E. (2010). A Comparative Evaluation of the Impact of UK Trade & Investment's R&D Programme and other UKTI Support that Impacts R&D. Aston University: UKTI Research Report.

Dunning, J.H. (1988) The Eclectic Paradigm of International Production. A restatement and Some Possible Extensions. Journal of International Business Studies, (Spring):1-31

Enterprise and Skills Board (2018) Enterprise and Skills Board Strategic Plan, available at: https://www.gov.scot/publications/working-collaboratively-better-scotland/ . Accessed on 18/02/2021.

Eurofound and International Labour Organization (2019). *Working conditions in a global perspective*, Publications Office of the European Union, Luxembourg, and International Labour Organization, Geneva.

FDI Intelligence. (2020). fDi European Cities and Regions of the Future 2020/21. The Best and Brightest among Europe's Investment Destinations, Financial Times, London.

Foad, H., (2012). FDI and Immigration: A Regional Analysis. The Annals of Regional Science, 49(1), pp. 237-259.

Forth, J and McNabb, R. (2008), Workplace Performance: A Comparison of subjective and Objective Measures in the 2004 Workplace Employment Relations Survey. *Industrial Relations Journal*, 39: 104-123.

Jorgenson, D. W., Kuroda, M., and Nishimizu, M. (1987). Japan-US industry-level productivity comparisons, 1960–1979. *Journal of the Japanese and International Economies*, 1(1), 1-30.

Jorgenson, D. W., Mun S. Ho, and. Stiroh, K.J. (2005). *Information Technology and the American Growth Resurgence*. Cambridge, MA: The MIT Press.

Griffith, R., S. Redding and J. Van Reenen (2004). Mapping the Two Faces of R&D: Productivity Growth in a panel of OECD industries. Review of Economics and Statistics, 86(4), 883-895.

Griffith, R., Huergo, E., Mairesse, J., and Peters, B. (2006). Innovation and Productivity across four European countries. Oxford Review of Economic Policy, 22(4), 483-498.

Godley A. C., (1999). Pioneering Foreign Direct Investment in British Manufacturing. Business History Review, 73(3), pp.394-429.

Gorg, H. and Greenaway, D. (2004) Much ado about nothing? Do domestic firms really benefit from foreign direct investment? World Bank Research Observer 19(2), 171-197.

Greenwood, J. and Jovanovic, B. (2001) Accounting for Growth. In: Hulten, C.R., Dean, E.R, and M.J. Harper (eds), *New Developments in Productivity Analysis*, p.p. 179-224.

Harris, R., and Moffat, J. (2017). The Sources of the Scotland–Rest of the UK productivity Gap: Implications for policy. Regional Studies, 51(9), 1297-1311.

Kelly, J-F., Mitchell, M., and Zymek, R. (2018) Wealth of the Nation. David Hume Institute.

Jäger, K. (2018). EU KLEMS Growth and Productivity Accounts 2017 release - Description of Methodology and General Notes, September 2017, Revised July 2018.

Lucas, R E. (1990). Why Doesn't Capital Flow from Rich to Poor Countries. American Economic Review 80(2), 92–96.

McGowan, A. and Andrews, D. (2015) Labour Market Mismatch and Labour Productivity Evidence from PIAAC Data. OECD Economics Department Working Paper No. 1209. Paris: OECD Publishing.

McLaren, J. (2018). Scotland's Economic Growth and Productivity Slowdown - Explanations, Implications and Potential Solutions. Scottish Trends Analysis Paper.

O'Mahony, M., and Timmer, M. P. (2009). Output, Input and Productivity Measures at the Industry level: the EU KLEMS database. The Economic Journal, 119(538), F374-F403.

O'Mahony, M., and Vecchi, M. (2009). R&D, knowledge spillovers and company productivity performance. *Research Policy*, 38(1), 35-44.

Organisation for Economic Co-operation and Development (OECD). (2003). The Sources of Economic Growth in OECD Countries.

Organisation for Economic Co-operation and Development (OECD). (2018), The Elusive Quest for Regional Convergence?. In Productivity and Jobs in a Globalised World: (How) Can All Regions Benefit?, OECD Publishing, Paris, https://doi.org/10.1787/9789264293137-4-en.

Rincon-Aznar, A., Forth, J., Mason, G., O'Mahony, M. and Bernini, M. (2015). UK Skills and Productivity in an International Context, BIS Research Paper No. 262.

Scottish Government. (2016). Labour Productivity 1998-2014. Available at: https://www2.gov.scot/Topics/Statistics/Browse/Economy/PROD2014. Accessed on: 30/01/2020.

Scottish Government (2018a). National Performance Framework, Measuring Progress, National Indicator Performance. Available at: https://nationalperformance.gov.scot/measuring-progress/national-indicator-performance. Accessed on: 28/01/2020.

Scottish Government. (2018b). Labour Productivity 2018 Quarter 2. Available at: https://www2.gov.scot/Topics/Statistics/Browse/Economy/PROD18Q2. Accessed on: 28/01/2020.

Temple, J., (1999). The New Growth Evidence. Journal of Economic Literature (1), 112- 156.

Ugur, M., Trushin, E., Solomon, E., and Guidi, F. (2016). R&D and productivity in OECD firms and industries: A hierarchical meta-regression analysis. *Research Policy*, 45(10), 2069-2086.

Van Ark, B. and Jäger, K. (2017), Recent Trends in Europe's Output and Productivity Growth Performance at the Sector Level, 2002-2015, International Productivity Monitor, Number 33, Fall 2017.

Van Ark, B., O'Mahoney, M., and Timmer, M. P. (2008). The productivity gap between Europe and the United States: trends and causes. *Journal of Economic Perspectives*, 22(1), 25-44.

Vandenbussche, J., Aghion, P., and Meghir, C., (2006). Growth, Distance to Frontier and Composition of Human Capital. Journal of Economic Growth, 11(2), 97-127.

14 Appendix

14.1 Appendix tables and pictures

Table A1: Regions in the top quartile of the GDP per capita distribution

NUTS1	Region	GDP p.c. 2009	NUTS1	Region	GDP p.c. 2017
LU0	LUXEMBOURG	62500	LU0	LUXEMBOURG	78500
BE1	RÉGION DE BRUXELLES-CAPITALE/BRUSSEL	53400	BE1	RÉGION DE BRUXELLES-CAPITALE/BRUSSELS*	61700
DE6	HAMBURG	50400	DE6	HAMBURG	59700
UKI	LONDON	45300	UKI	LONDON	56500
FR1	ILE-DE-FRANCE	43000	IE0	IRELAND	54500
NL3	WEST-NEDERLAND	38500	FR1	ILE-DE-FRANCE	52900
SE1	ÖSTRA SVERIGE	36300	DE5	BREMEN	45000
DE5	BREMEN	35900	NL3	WEST-NEDERLAND	43500
FI2	ÅLAND	35500	DE2	BAYERN	43400
DE7	HESSEN	34400	SE1	ÖSTRA SVERIGE	42300
ES3	COMUNIDAD MADRID	33000	DE7	HESSEN	42100
AT1	OSTÖSTERREICH	32300	DE1	BADEN-WÜRTTEMBERG	41900
DE2	BAYERN	32200	AT3	WESTÖSTERREICH	40900
AT3	WESTÖSTERREICH	32100	FI2	ÅLAND	38200
DE1	BADEN-WÜRTTEMBERG	31600	DK0	DANMARK	37900
IE0	IRELAND	31600	AT1	OSTÖSTERREICH	37700
ITC	NORD-OVEST	31500	ES3	COMUNIDAD MADRID	37600
EL3	ATTIKH	31300	NL4	ZUID-NEDERLAND	37600
NL4	ZUID-NEDERLAND	31000	DE3	BERLIN	36300
ITH	NORD-EST	30100	ITC	NORD-OVEST	36000
DK0	DANMARK	29800	BE2	VLAAMS GEWEST	36000
ITI	CENTRO (IT)	29600	DEA	NORDRHEIN-WESTFALEN	35700
ES2	NORESTE	29200	ITH	NORD-EST	34800
DEA	NORDRHEIN-WESTFALEN	29100	UKJ	SOUTH EAST (ENGLAND)	34200
UKJ	SOUTH EAST (ENGLAND)	28900	AT2	SÜDÖSTERREICH	33900
NL1	NOORD-NEDERLAND	28900	DE9	NIEDERSACHSEN	33700

Source: Eurostat, own calculations.
Notes: RÉGION DE BRUXELLES-CAPITALE/BRUSSELS HOOFDSTEDELIJK GEWEST is the full official name.

Table A2: Regions in the second highest quartile of the GDP per capita distribution

NUTS1	Region	GDP p.c. 2009	NUTS1	Region	GDP p.c. 2017
FI1	MANNER-SUOMI	28800	SE2	SÖDRA SVERIGE	33600
BE2	VLAAMS GEWEST	28700	ES2	NORESTE	33200
DE3	BERLIN	28300	DEC	SAARLAND	33200
NL2	OOST-NEDERLAND	28100	FI1	MANNER-SUOMI	33000
SE2	SÖDRA SVERIGE	27400	DEB	RHEINLAND-PFALZ	32800
AT2	SÜDÖSTERREICH	27000	NL2	OOST-NEDERLAND	31900
HU1	KÖZÉP-MAGYARORSZÁG	26400	ITI	CENTRO (IT)	31500
DEC	SAARLAND	26400	SE3	NORRA SVERIGE	31400
SE3	NORRA SVERIGE	25900	HU1	KÖZÉP-MAGYARORSZÁG	31100
CY0	ΚΥΠΡΟΣ	25800	DEF	SCHLESWIG-HOLSTEIN	30200
ES5	ESTE	25700	NL1	NOORD-NEDERLAND	29900
FRK	AUVERGNE-RHÔNE-ALPES	25600	FRK	AUVERGNE-RHÔNE-ALPES	29900
DEB	RHEINLAND-PFALZ	25200	UKH	EAST OF ENGLAND	29500
UKM	**SCOTLAND**	**25200**	ES5	ESTE	29400
DE9	NIEDERSACHSEN	25100	**UKM**	**SCOTLAND**	**29200**
FRL	PROVENCE-ALPES-CÔTE D’AZUR	24700	MT0	MALTA	29100
UKH	EAST OF ENGLAND	24300	FRL	PROVENCE-ALPES-CÔTE D’AZUR	28500
DEF	SCHLESWIG-HOLSTEIN	24000	FRG	PAYS DE LA LOIRE	28000
UKK	SOUTH WEST (ENGLAND)	23700	UKD	NORTH WEST (ENGLAND)	28000
FRG	PAYS DE LA LOIRE	23600	UKK	SOUTH WEST (ENGLAND)	28000
UKD	NORTH WEST (ENGLAND)	23200	DED	SACHSEN	27900
FRF	ALSACE-CHAMPAGNE-ARDENNE-LORRAINE	22789.19	EL3	ATTIKH	27500
FRB	CENTRE — VAL DE LOIRE	22400	RO3	MACROREGIUNEA TREI	27500
FRI	AQUITAINE-LIMOUSIN-POITOU-CHARENTES	22344.65	CZ0	ČESKÁ REPUBLIKA	26800
FRJ	LANGUEDOC-ROUSSILLON-MIDI-PYRÉNÉES	22316.71	DEG	THÜRINGEN	26800

Source: Eurostat, own calculations.

Table A3: Regions in the third highest quartile of the GDP per capita distribution

NUTS1	Region	GDP p.c. 2009	NUTS1	Region	GDP p.c. 2017
FRH	BRETAGNE	22200	UKG	WEST MIDLANDS (UK)	26600
FRM	CORSE	22000	DE4	BRANDENBURG	26500
ES1	NOROESTE (ES)	21900	FRH	BRETAGNE	26400
UKE	YORKSHIRE AND THE HUMBER	21900	CY0	KYPROS	26400
UKF	EAST MIDLANDS (UK)	21400	FRI	AQUITAINE - LIMOUSIN - POITOU-CHARENTES	26100
EL4	NISIA AIGAIOU, KRITI	21100	UKN	NORTHERN IRELAND (UK)	25800
BE3	RÉGION WALLONNE	21000	DEE	SACHSEN-ANHALT	25700
ES7	CANARIAS (ES)	21000	FRJ	LANGUEDOC-ROUSSILLON - MIDI-PYRÉNÉES	25700
UKG	WEST MIDLANDS (UK)	21000	SI0	SLOVENIJA	25500
CZ0	CESKO	20900	BE3	RÉGION WALLONNE	25500
SI0	SLOVENIJA	20900	FRD	NORMANDIE	25500
UKN	NORTHERN IRELAND (UK)	20900	UKF	EAST MIDLANDS (UK)	25400
DED	SACHSEN	20700	FRF	ALSACE - CHAMPAGNE-ARDENNE - LORRAINE	25300
ES4	CENTRO (ES)	20600	DE8	MECKLENBURG-VORPOMMERN	25300
UKC	NORTH EAST (UK)	20400	UKE	YORKSHIRE AND THE HUMBER	25200
DE4	BRANDENBURG	20200	FRB	CENTRE - VAL DE LOIRE	25200
PT1	CONTINENTE	20200	FRM	CORSE	25000
MT0	MALTA	19800	ES1	NOROESTE (ES)	24700
PT3	REGIÃO AUTÓNOMA DA MADEIRA (PT)	19800	FRC	BOURGOGNE - FRANCHE-COMTÉ	24200
DE8	MECKLENBURG-VORPOMMERN	19500	FRE	NORD-PAS-DE-CALAIS - PICARDIE	24100
DEE	SACHSEN-ANHALT	19400	EE0	EESTI	23600
DEG	THÜRINGEN	19100	LT0	LIETUVA	23600
			ES4	CENTRO (ES)	23100
			UKL	WALES	23100
			PT1	CONTINENTE	23100
			UKC	NORTH EAST (UK)	23000

Source: Eurostat, own calculations.

Table A4: Regions in the bottom quartile of the GDP per capita distribution

Nuts1	**Region**	**GDP p.c. 2009**	**Nuts1**	**Region**	**GDP p.c. 2017**
ES6	SUR (ES)	18900	PT3	REGIÃO AUTÓNOMA DA MADEIRA (PT)	22800
UKL	WALES	18800	ES7	CANARIAS (ES)	22600
EL6	KENTRIKI ELLADA	18300	SK0	SLOVENSKO	21500
PT2	REGIÃO AUTÓNOMA DOS AÇORES (PT)	18300	PL5	MAKROREGION POLUDNIOWO-ZACHODNI	21300
ITG	ISOLE	18000	ES6	SUR (ES)	20800
ITF	SUD	17700	PL2	MAKROREGION POLUDNIOWY	20400
EL5	VOREIA ELLADA	17700	PT2	REGIÃO AUTÓNOMA DOS AÇORES (PT)	20400
RO3	MACROREGIUNEA TREI	17600	PL4	MAKROREGION PÓLNOCNO-ZACHODNI	20300
SK0	SLOVENSKO	17500	LV0	LATVIJA	19800
FRY	RUP FR - RÉGIONS ULTRAPÉRIPHÉRIQUES FRANÇAISES	15900	ITF	SUD	19300
EE0	EESTI	15700	FRY	RUP FR - RÉGIONS ULTRAPÉRIPHÉRIQUES FRANÇAISES	19300
HR0	HRVATSKA	15200	BG4	YUGOZAPADNA I YUZHNA TSENTRALNA BULGARIA	18600
PL5	MAKROREGION POLUDNIOWO-ZACHODNI	15000	HR0	HRVATSKA	18600
PL2	MAKROREGION POLUDNIOWY	14600	ITG	ISOLE	18600
PL4	MAKROREGION PÓLNOCNO-ZACHODNI	14400	HU2	DUNÁNTÚL	18400
LT0	LIETUVA	13800	EL4	NISIA AIGAIOU, KRITI	18200
BG4	YUGOZAPADNA I YUZHNA TSENTRALNA BULGARIA	13500	RO1	MACROREGIUNEA UNU	17900
HU2	DUNÁNTÚL	13100	PL7	MAKROREGION CENTRALNY	17800
LV0	LATVIJA	12800	PL6	MAKROREGION PÓLNOCNY	17500
PL6	MAKROREGION PÓLNOCNY	12600	RO4	MACROREGIUNEA PATRU	16800
RO1	MACROREGIUNEA UNU	11200	EL6	KENTRIKI ELLADA	16500
RO4	MACROREGIUNEA PATRU	11000	EL5	VOREIA ELLADA	15500
HU3	ALFÖLD ÉS ÉSZAK	10000	PL8	MAKROREGION WSCHODNI	14500
RO2	MACROREGIUNEA DOI	8400	HU3	ALFÖLD ÉS ÉSZAK	14000
BG3	SEVERNA I YUGOIZTOCHNA BULGARIA	7900	RO2	MACROREGIUNEA DOI	13500
			BG3	SEVERNA I YUGOIZTOCHNA BULGARIA	11300

Source: Eurostat, own calculations.

Table A.5: GDP per capita PPS (Euro) – Alternative benchmark EU regions

NUTS1	**Region**	**2017 GDP per capita PPS (Euro)**	**Average GDP growth 2009-2017**
IE0	Éire/Ireland	54500	6.07
FR1	Île de France	52900	1.94
DE2	Bayern	43400	2.19
DE1	Baden-Württemberg	41900	1.98
DK0	Danmark	37900	1.54
ES3	Comunidad de Madrid	37600	1.65
NL4	Zuid-Nederland	37600	1.72
DE9	**Niedersachsen**	**33700**	**2.14**
ES2	Noreste (ES)	33200	1.62
DEB	**Rheinland-Pfalz**	**32800**	**1.75**
ES5	Este (ES)	29400	1.70
UKM	**Scotland**	**29200**	**0.49**

Source: Eurostat, own calculations.

Table A.6 Labour productivity growth and drivers, 2009–2016 – Alternative benchmark EU regions

NUTS1	**Region**	**Growth in LP (%)**	**Contribution from (pp)**		
			Capital	**Labour quality**	**TFP**
IE0	Éire/Ireland	6.22	1.59	0.24	4.38
DK0	Danmark	1.72	0.60	0.27	0.84
DE2	Bayern	1.62	0.47	0.15	1.01
DEB	Rheinland-Pfalz	1.54	0.59	0.17	0.78
DE1	Baden-Württemberg	1.48	0.39	0.11	0.97
DE9	Niedersachsen	1.46	0.36	0.09	1.01
ES5	Este (ES)	1.33	0.86	0.41	0.06
NL4	Zuid-Nederland	1.23	0.46	0.10	0.67
ES3	Comunidad de Madrid	1.13	0.68	0.07	0.38
ES2	Noreste (ES)	1.10	0.65	0.08	0.37
UKM	**Scotland**	**1.04**	**0.62**	**-0.05**	**0.47**
FR1	Île de France	0.37	0.57	-0.08	-0.13

Table A7: Share of managers who participated in job related training or education (last 13 weeks).

UK Region	**2013**	**2014**	**2015**	**2016**	**2017**
North East	25.55	30.69	24.97	20.75	20.06
North West (inc Merseyside)	20.14	23.37	23.36	20.08	22.33
Yorkshire and Humberside	20.91	24.93	22.30	24.96	23.94
East Midlands	25.67	26.28	26.78	19.86	23.51
West Midlands	24.36	24.20	24.56	19.74	22.78
Eastern	23.59	20.52	25.63	23.70	22.53
London	26.62	24.22	25.74	27.66	24.40
South East	24.94	24.68	24.33	21.82	23.16
South West	23.95	25.69	24.30	28.54	22.32
Wales	29.50	26.97	27.33	29.48	23.81
Scotland	**25.52**	**27.15**	**26.63**	**21.55**	**20.09**
Northern Ireland	18.36	28.11	20.26	19.61	21.95
UK	24.33	24.73	24.82	23.49	22.85

Source: LFS. Note: managers are defined according to the SOC10 classification.

Table A.8. Share of managers who hold a graduate qualification.

UK Region	**2013**	**2014**	**2015**	**2016**	**2017**
North East	34.8	35.2	36.86	39.5	37.78
North West (inc Merseyside)	31.98	33.34	36.16	37.86	36.61
Yorkshire and Humberside	33.19	33.47	31.33	38.48	39.48
East Midlands	34.25	34.8	33.33	32.8	33.44
West Midlands	35.3	32.79	34.07	32.28	33.84
Eastern	29.94	33.94	29.57	36.83	35.81
London	56.52	57.65	58.08	59.85	64.01
South East	37.78	38.9	37.02	40.84	40.63
South West	33.34	35.2	30.37	38.06	40.38
Wales	29.33	32.4	37.92	37.92	43.28
Scotland	**37.69**	**39.7**	**39.7**	**40.59**	**37.74**
Northern Ireland	34.87	30.87	39.16	42.66	45.23
UK	37.46	38.81	38.15	41.18	41.97

Source: LFS. Note: qualification groups are defined based on the highest qualification that individuals completed.

14.2 Data construction

Output and labour input data

To compute GDP per capita across NUTS1 regions we use Eurostat data (PPS) which are available on an annual basis. Labour productivity is defined as real gross value added (GVA) per hour worked in constant (2010) Euro prices. These data also come from the Eurostat economic accounts converted to constant prices using national GVA deflators (extracted from an additional source, EU KLEMS). We apply deflators at the national level, which implies the same deflator for all NUTS1 regions within a country.

Labour productivity is the amount of output produced per unit of labour input. Empirically it is defined in a number of ways, for instance using gross output or value added to measure production, and the number of people employed (or full-time equivalent) and/or total number of hours worked. This is not a trivial distinction as differences in measurement can explain observed differences in labour productivity when countries and regions are compared.

We measure labour input as total hours worked which is also available from Eurostat. We thus follow guidelines from the SNA2008. Hours works are the preferred aggregate measure of labour input for productivity analysis, as it reflects the volume of work engaged per year in self-employment and employee jobs for the production of goods and services by resident units of production. Total hours of work are usually derived by combining available estimates of annual hours actually worked per person in employment with average employment levels. Measurement issues that affect estimates of hours worked can be particularly acute but considerable efforts are devoted to harmonising the measurement of actual hours worked in EU countries.

Labour quality data

Within a modern growth accounting framework (see Jorgenson et al. 1987; Jorgenson et al, 2005; O'Mahony and Timmer, 2009), we can identify the contribution of labour quality to labour productivity performance. For this analysis, we base our measure of labour quality only on 'certified skills'

For the computation of labour quality measure, we use data on the proportion of the workforce at different levels of education (e.g. high, medium, low) from the European Labour Force Survey (available from Eurostat). Information on these shares were then combined with tabulations of wage rates for equivalent education categories from the EU KLEMS database. This is necessary to account for the relative marginal productivities of different types of workers. An increase in the 'labour quality term' would indicate a shift in education towards a more highly educated workforce (which are on average paid higher wages than those at lower levels of education).

We use share of employment by educational attainment to measures changes in labour quality. These data are also from Eurostat, which reports three educational categories (classified as high, level and medium, following the International Standard Classification (ISCED11): less than primary, primary and lower secondary education (levels 0-2), upper secondary and post-secondary non-tertiary education (levels 3 and 4) and tertiary education (levels 5-8)).

We use wages as a proxy for productivity, when computing the contribution of labour inputs to labour productivity (within the growth accounting framework). Wages by educational level are available from EU KLEMS (only available at the national level) which is a limitation. This assumes that all regions within a country have the same wage bill share by education group.[25] We have tested this assumption using UKLFS data for Scotland and find a very high correlation (over 0.9) between wages shares computed using national and regional data.

Capital stocks data

Data on regional capital stocks have been provided by Ben Gardiner and colleagues at Cambridge Econometrics. This is an updated database from a work earlier conducted for the European Commission (Derbyshire, Gardiner and Waights, 2013). The authors produced capital stock estimates for NUTS1 and NUTS2 regions for the EU27 using the Perpetual Inventory Method (PIM) approach. Note that the latest data are available until 2016, so any analyses using capital stocks are limited to 2016. Section 12.3 in the Appendix below contains further details on the full methodology followed to arrive at measures of regional capital stocks that are consistent with National Accounts Gross Fixed Capital Formation figures.

Total factor productivity

To derive TFP we compute factor (capital and labour) shares at a regional level, from Eurostat sources. The labour share is computed as the compensation to labour divided by the GVA, and capital share is obtained residually as 1 minus the labour share.

Innovation data

Patent data consist of applications to the European Patent Office (EPO) from the OECD EPO Regpat database (January 2020 release) on which an intensive text mining procedure of name disambiguation has been performed. This was necessary to distinguish the applications by individual inventors' patents from those by the business sector or public research institutions. The latter applicants have been identified with an automatic search procedure using a large set of keywords, expressed in all European languages (for instance, Center, Department, etc.)

R&D expenditure are taken from Eurostat Science and Technology dataset. These data are comprised of R&D expenditure by instititutional sector (government sector, business sector,

[25] We have computed labour quality contribution for Scotland using wages from the UKLFS. Results do not change quantitatively.

higher education sector, etc.) as a share of regional GDP, or expressed in levels in real EU Purchasing Power Standards (PPS).

Managerial practices and on-the job training data

The UK LFS is a survey aim to provide information on the UK labour market. It is conducted quarterly, and the sample covers around 40,000 UK households. Proxies for the quality of managerial practices and on-the-job training across UK regions are constructed from the micro data underlying the UK Labour Force Survey[26]. We extract data from the individual-level files. From these data we extract information on the proportion of managers engaging in job-related training and the percentage of managers who hold a graduate degree in the region. We look at the trends during the period 2013 to 2017.

Foreign Direct Investment

Traditional sources of FDI data come from UNCTAD for national level data or from microdata that are aggregated to chosen levels of geography. The latter, while useful and possible for the UK are made more complicated across nations as conditions of access hinder analysis and differences in survey design and data gathered are challenging to take into account. For this reason, we utilise data that are available via the FDI Markets database which collates information on FDI projects. That is, announcements of new investments by foreign firms collected by the Financial Times, gathered monthly.

FDI Markets is part of a suite of Insights offered by the Financial Times. FDI Markets is a comprehensive record of FDI transactions globally. It includes information on host and destination countries, areas and cities, it also collects details on the firm investing, which sector they belong to, the number of jobs created and the capital investment amount. Some of these quantities are estimates based on other details known about the transaction. It remains the most comparable international source of sub national data on FDI flows. Note that data on stocks of FDI are not collected at sub-national levels.

Data have been extracted for the period 2003 (the first year for which data are available) to 2017. Data are available by 'investment project', which contains information on the investing firm, national source, estimates for capital investment and jobs, as well as whether the investment is new, an expansion or co-location. Data have been aggregated by year to the industry (6 sector – consistent with the capital stock data), regional level (NUTS1) although data at the city level is available. Data have been extracted for the UK at the NUTS 1 level and for the selected benchmark group. Scottish data is available at NUTS2 level and discussed in more detail at regional distribution of FDI at the Scottish level on Section 5.3.

[26] Which are accessed through the UK Data Archive.

14.3 Growth accounting methodology

Growth accounting remains is a widely used empirical tool to map the sources of growth across geographical and industrial units, despite new growth theorists questioning the restrictiveness of some of the assumptions, which we describe below. Another usual criticism is also that that estimates of TFP growth are frequently considered rather a measure of our ignorance. Temple (1999) offers a thorough review of the usefulness of growth accounting methodology and other cross-country empirical approaches.

Formally we begin from the following Cobb-Douglas production function:

$$Y = AL^{\propto}K^{\beta} \quad \text{(A.1)}$$

where Y is total output, L is the labour input, K is the capital input and A is the total factor productivity. The parameters $\propto$ and β denote the labour and capital shares in production.

Equation (A.2) decomposes the growth rate of total output into changes in 'observable' factors, that is, capital and labour inputs, plus the change in 'unobservable' factors. The latter term is known as total factor productivity (TFP), which is broadly interpreted as technological progress. Taking logarithms of the variables and first differences from a standard representation of a production function we arrive at the following expression:

$$\Delta y_{rt} = \overline{w}_{L,r}\Delta l_{rt} + \overline{w}_{K,r}\Delta k_{rt} + \Delta TFP_{rt} \quad \text{(A.2)}$$

where ΔY_{rt} is the growth rate of GVA between years *t* and *t*-1 in a given region *r*; ΔL_{rt} is the growth rate in labour input; ΔK_{rt} is the growth rate in capital input; ΔTFP_{rt} is the growth rate in TFP over two consecutive periods; $w_{L,rt}$ represents the share of labour compensation and $w_{K,rt}$ denotes the share of capital compensation (these shares measured as the average of the two consecutive periods such that $\overline{w}_{L,r} = \frac{(w_{rt}^{L} + wr_{t-1}^{L})}{2}$; $\overline{w}_{K,r} = \frac{(w_{rt}^{K} + wr_{t-1}^{K})}{2}$).

This representation shows that contribution that capital and labour make to output growth is given by 'the growth in each factor of production' weighted by 'the regional GDP share attributed to each factor'. The factor shares are costs shares, implied by the classical assumptions of constant returns to scale and competitive factor markets, and absence of externalities (Hulten et al 2001). Thus, the elasticities of output to inputs are imposed in this framework. Given the condition that $\propto + \beta = 1$, practically the contribution of TFP is computed as a residual by subtracting the cost-weighted growth in inputs from the growth in output.

Following later methodological advances from the original growth accounting formulation (see Jorgenson et al, 2005), the labour input in equation (2) can be split into two distinct components: changes in total hours worked (ΔH_{rt}) and changes in labour quality ($\Delta Qual_{rt}$):

$$\Delta l_{rt} = \Delta h_{rt} + \Delta Qual_{rt} \qquad \text{(A.3)}$$

In our empirical exercise, we use capital stocks as measured of *K*. A more refined measure of capital use is that of capital services, which weights capital stocks by their user costs (OECD Measuring Capital, 2009)[27]. Note that equation (4) can also be represented in terms of labour productivity (measured as output per hour worked):

$$\Delta \left(\frac{Y}{H}\right)_{rt} = w_{L,rt}\Delta LQual_{rt} + w_{K,rt}\Delta\left(\frac{K}{H}\right)_{rt} + \Delta TFP_{rt} \qquad \text{(A.4)}$$

Equation (5) allows one to directly quantify the impact of a) capital deepening or intensity, that is, the amount of capital available per hour worked, b) labour quality (mainly though changes in skill composition of the workforce), and c) growth in total factor productivity.

14.4 Level accounting

The *levels accounting* approach now decomposes the differences in levels of labour productivity (measured as GVA per hour worked) into differences in capital intensity, in labour quality and TFP. This is computed relative to a benchmark unit (The BE2 region of Vlaams Gewest), at a given point in time, in our case the average 2009-2006 in our case.

$$\ln\frac{GVA_r/H_r}{GVA_{BE2}/H_{BE2}} = \widehat{w}_L \ln\frac{Q_r^L/H_r}{Q_{BE2}^L/H_{BE2}} + \widehat{w}_K \ln\frac{Q_r^K/H_r}{Q_{BE2}^K/H_{BE2}} + \ln\frac{TFP_r}{TFP_{BE2}} \qquad \text{(A.5)}$$

where Q^L is the quantity index of labour, Q^K is the quantity index of capital, H is hours worked, $\widehat{w}_L$ is the share of labour in value added averaged over the two regions (the base region and the one of interest) such that $\widehat{w}_L = \frac{(w_r^L + w_{BE2}^L)}{2}$; similarly for capital we define $\widehat{w}_K$ as the share of capital input in value added averaged over the two regions $\widehat{w}_K = \frac{(w_r^K + w_{BE2}^K)}{2}$ The following condition holds $\widehat{w}_L + \widehat{w}_K = 1$.

[27] http://www.oecd.org/sdd/productivity-stats/43734711.pdf

14.5 Note on the construction of capital stocks

14.5.1 Overview and data

Capital stock estimates at the NUTS2 level were computed using the Perpetual Inventory Method (PIM), based on the following equation:

$$K_t = (1-\delta)K_{t-1} + GFCF_t \qquad \text{(A.6)}$$

where K is the real net capital stock, d is the depreciation rate, and GFCF is real Gross Fixed Capital Formation. The subscript t denotes the time period. The following sources were used to obtain the data necessary to use the method:

- historical data from the European Commission's AMECO[28] database to obtain a value for the initial capital stock at the national level;
- GFCF series previously produced by Cambridge Econometrics for 6 sectors at the NUTS 2 level;
- depreciation rates from the EU-KLEMS database.[29]

14.5.2 Initial capital stock

The first step entails computing a starting value for the regional capital stock at the NUTS2 level. National capital stock from AMECO is disaggregated by sector based on GFCF shares in the starting year:

$$K_{Nj,0} = \frac{GFCF_{j,0}}{GFCF_{N,0}} K_{N,0} \qquad \text{(A.7)}$$

with subscript j being the sector, N the national total and 0 denoting the initial period. Sectoral capital stock at the national level is then disaggregated by region:

$$K_{ij,0} = \frac{\sum_t GFCF_{ij,t}}{\sum_t GFCF_{Nj,t}} K_{Nj,0} \qquad \text{(A.8)}$$

with subscript i being the region, j the sector, and N the total by country.

[28] https://ec.europa.eu/economy_finance/ameco/user/serie/SelectSerie.cfm.
[29] http://www.euklems.net/.

14.5.3 Depreciation rates

The EU-KLEMS datasets contains depreciation rates and capital stock figures by 34 sectors and 10 assets. An aggregation procedure was applied in order to get depreciation rates for the six sectors breakdown of the GFCF figures. First, a weighted average of depreciation rates by assets within each of the 34 EU-KLEMS sectors is computed:

$$\delta_j = \sum_A \delta_{a,j} \bar{s}_{a,j} \tag{A.9}$$

with j being the EU-KLEMS sector, a the asset, A the set of assets, δ the deprecation rate and $\bar{s}$ the time average share of capital stock by asset in each sector. These depreciation rates are then aggregated at the level of the six sectors:

$$\delta_{CE} = \sum_J \delta_j \bar{s}_j \tag{A.10}$$

with J denoting the set of EU-KLEMS sectors within each of the 6 sectors and $\bar{s}_j$ being the time average share of capital stock of the EU-KLEMS sectors within each of the 6 sectors.

14.5.4 Producing the regional capital stock

Equipped with the initial regional capital stock by sector computed in equation (A.7), the regional GFCF by sector, and with the depreciation rates by sector computed in equation (A.9), it was possible to run equation (A.6) forward for each period to obtain regional capital stock series by sector.

14.5.5 NUTS 2016 consistency

The regional capital stocks were estimated using the 2013 NUTS classification. To be compatible with other data for Scotland, and to generally be as up-to-date as possible with definitions, it was necessary to convert them to the 2016 classification.