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Broadband and Uneven Spatial Development: The Case of Cardiff City-Region

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Abstract

The internet and e-connectivity more generally are increasingly held to be an important element of business success. Evidence however suggests that the productive impacts of such technologies are contingent on factors that include firm size and sector, and human capital. It follows that if companies with these characteristics are unevenly distributed across space, the increasing importance of broadband in economic activity might impact unevenly on economic outcomes across space. We examine the Cardiff City-Region in South Wales, where the distribution of businesses and skills suggests that without policy intervention the roll out of broadband might further increase economic disparities between the relatively prosperous coastal belt and the poorer post-industrial hinterland.

Keywords

Broadband, city-regions, public policy, technology take-up and use, uneven impact

1. Introduction

Technological change is progressing at an extremely fast pace. Information technology now allows production, sale and distribution and consumption to occur in ways unthinkable only a

few decades ago (Kellerman, 2010). This fourth wave of the industrial revolution implies more fundamental changes in the way workers work and are managed, and in the scope of human work (Frey and Osborne, 2017; Goldberg and Kehoe, 2013). The first (English) industrial revolution, wherein a novel financial architecture combined with the exploitation of fossil fuels, had stark consequences for people *and* for places. The spatial distribution of people changed more quickly than any time in history (outside of wars and natural disasters), as new productive mechanisms required the clustering of workers in cities to be near factories (Floud et al., 2014). New industries and occupations were invented whilst some work became uneconomic; such urbanisation and sectoral change is a characteristic of economic development (Floud et al., 2014; Drakakis-Smith, 2012).

Current technological upheavals will have significant impacts on business location, place competitiveness and spatial development, especially as such developments enable automation and the wider application of technologies such as artificial intelligence (Brynjolfsson and McAfee, 2014). The spatial impacts of such developments, however, has been understood rather broadly, if at all (Kerry and Danson, 2016). In the UK, government policy generally downplays the importance of spatial elements in economic development and industrial and spatial planning interventions are limited (Bentley and Pugalis, 2013; Department for Business Energy & Industrial Strategy, 2017). However, if industrial (and related social) change has uneven spatial impacts, there will be differential impacts on the economic success of diverse geographical areas (Graham, 2002). For broadband particularly, whilst the narrative and associated debate is about connecting (and engaging) small and medium enterprises (SMEs), and on the urban-rural divide, evidence suggests that impacts will be much more nuanced (Mack, 2015; Mack and Grubestic, 2009; Saleminck et al., 2017; Townsend et al., 2013).

To investigate the potential for these spatially differential outcomes we examine the potential impact of high-speed broadband in the Cardiff Capital City-Region in Wales. The city-region has become an important policy agenda in Wales and the wider UK in recent years, as cities and regions have sought to access funds for social and economic development¹. Indeed following McCann (2016) the paper argues that a focus on the city-region as the unit of economic analysis and intervention will do as much to hide key developmental outcomes as reveal them. There are reasons why Wales is an illustrative case. Firstly, City-Regions and City-Deals are the primary way in which UK Government interacts with ‘economic space’; devolving relevant planning, development, transport and (sometimes) skills policies to city-region level political coalitions, along with budgets and challenging economic targets (Pike et al., 2018; HM Cabinet Office, 2016). Secondly, South Wales is an economically- and policy-interesting place. It currently has five levels of relevant governance – local authority; City-region, Welsh; UK and (historically developmentally-important) EU. It has a prosperity divergence between the coastal counties and the poorer post-industrial valleys, and a long history of policy intervention in innovation and ‘regional learning’ (Pugh, 2014; Morgan, 2016).

This paper then presents an analysis of how broadband roll-out is impacting on economic development in different parts of the city-region, introducing the first results from a novel dataset on SME digital engagement with broadband and associated technologies in the City-Region, alongside secondary data and evidence from existing studies, and asking what kinds

¹ The debate about City-Regions is UK-centric in focus, and has taken place in a context in which devolution from the national level has traditionally been limited – with the exception of the Devolved Nations (Scotland, Wales and Northern Ireland).

of businesses and sectors benefit from e-connectivity, and which places across the Cardiff City-Region might win or lose (relatively) as the productive use of high speed e-connectivity becomes an increasing factor in economic success. The following Section (Two) briefly presents the policy context for City Deals and spatial policy in Wales. Section Three summarises literature about what we know of how broadband (and ICT) contributes to productivity in businesses and hence to competitiveness. Section Four presents the research case of the Cardiff City-Region Deal, followed by the methodological approach (Section Five). Section Six presents the results and analyses business and workforce characteristics and SME use of digital technologies in the City-Region; examining how broadband roll-out might impact economic development in different parts of the City-Region. This analysis strongly suggests that if internet-enabled activity is becoming more important, the net effect is likely greater spatial economic divergence. Section Seven discusses the findings, before concluding (Section Eight).

2. City-Deals and City-Region Policy in the UK and Wales

After 2010 the UK Government made a strong statement on its approach to spatial economic policy, abolishing the nine English Regional Development Agencies in favour of smaller, business-led Local Enterprise Partnerships with a more limited remit and budgets (Bentley et al., 2010). At the same time, planning and development policy in England was re-engineered (under Austerity) to become much more local, whilst innovation policy moved to the UK level (Pike et al., 2018; Bentley and Pugalís, 2013; Hildreth and Bailey, 2013; Kerry and Danson, 2016). Meanwhile, responsibility for development policy in general shifted, with the Department of Business, Energy and Industrial Strategy (BEIS) losing policy prominence and

autonomy to the Treasury and Chancellor. This direction of travel continued under the 2015-17 Conservative Government with the Chancellor in *de facto* charge of spatial economic policy (in England). Devolution of development and related policy was subsequently led by the Treasury, via bilateral agreements between the Treasury and city-region growth coalitions (Pike et al., 2018). A number of such agreements were signed offering policy devolution and a (sometimes modest) investment pot in exchange for attainment of ‘gateway’ targets, usually based on growth in Gross Value Added (GVA) or employment, and often on the promise to directly elect a local mayor (Kennett et al., 2015). This City-Deal approach was criticised as a way to shift perceived responsibility and accountability for the impacts of UK Austerity policies from Westminster to City Hall (Kennett et al., 2015; Pike et al., 2018). Despite the existence of devolved competence in relevant areas, eight Authorities in Central Scotland signed the Glasgow City Region City-Deal, with a £1.1bn investment fund, focussed on innovation and infrastructure hoping to create 28,000 jobs².

More recently, the creation of City Deals for Swansea (UK Government and Welsh Government, 2018) and Cardiff (UK Government et al., 2016) - has formally recognised the importance of devolved regional government by including the Welsh Government as a signatory (and source of funding) in a tripartite agreement. There is little to suggest, however, that the specifics of devolution – which places planning, education, transport and economic development under the aegis of the Welsh Government greatly affected the nature of the Cardiff City-Deal³.

² <https://www.gov.uk/government/publications/city-deal-glasgow-and-clyde-valley>

³ Although the relatively new Future Generations Act, having the force of law over public policy in Wales may affect implementation; see <https://futuregenerations.wales/news/city-deal-can-be-better-deal-for-future-generations/>

3. Winners and Losers in the ICT and Broadband Revolution

The impact of information technology (ICT) on productivity has never been straightforward to conceptualise and measure, leading to Solow's famous aphorism that 'you can see the computer age everywhere except in the productivity statistics' (see Triplett, 1999: for a discussion). This is in large part because investments in ICT generate productivity increases over different (and extended) time periods, and require significant up-front investment, not just in terms of cash but also in complementary product and process innovation and in organisational restructuring (Brynjolfsson and Hitt, 2003; Pilat, 2005). ICT investment also has manifold potential impacts on firm productivity and hence competitiveness, with avenues including improved access to markets and suppliers; streamlined and lower cost management, logistical, design and other processes; and the spurring of within firm innovation (Bertschek et al., 2013; Higón, 2012). ICT also enhances the productivity of some workers whilst replacing others (Frey and Osborne, 2017; Levy and Murnane, 2005). Add to this uncertain time lags, the potential importance of unobserved variables and the relative weight of ICT impacts to other factors, and it is unsurprising that debate remains around just how (and how much) ICT affects productivity – or will in the future, as 'Industry 4.0' advances become more embedded (Hempell, 2005; Brynjolfsson and McAfee, 2014).

This uncertainty is just as prevalent when assessing the firm-level (and consequent household and place) impacts of 'broadband' adoption and use, with the question further complicated by a fast-moving technological environment. The term itself is easily understood as always-on, high-speed access to the internet, but the notion of 'high-speed' has grown over time, most

recently from 24Mbps to 30Mbps in Wales⁴. Then the question is not just whether (and how) broadband access might impact productivity, but also whether different speeds impact differentially on firms and places (Kenny and Kenny, 2011). Here, researchers have increasingly argued that there is no longer a binary distinction between access and non-access to broadband and impact, and that this is giving way to a more nuanced picture in which broadband connection and use varies across households and businesses (Grubestic and Mack, 2016; Philip and Williams, 2018; Saleminck et al., 2017), but also different types of sectors (Calvino et al., 2018). Research on SMEs shows comparatively lower use of internet enabled technologies, relative to their larger counterparts (Price et al., 2018; Thomas et al., 2015), with particular challenges identified with respect to factors such as technical expertise and digital skills (Huggins and Izushi, 2002), resources (Wolcott et al., 2008) and owner manager attitudes (Jones et al., 2012) .

Even when broadband access (or use) is treated as a binary, empirical difficulties remain, not least related to the lack of information available on how far firms have access to, and then use, broadband enabled services and then how these firms perform. Some country-level studies avoid such micro-empirical difficulties to suggest broadband roll-out spurs economic growth at national level (Roller and Waverman, 2001). Similar positive findings (again using a micro-macro approach) are reported by Koutroumpis (2009) for fifteen EU countries between 2003-2006, and Katz et al. (2010) suggest that for Germany the economic impact of broadband would total over €170bn by 2020. There is however a concern that in approaches shared by some macro-level studies (Czernich et al., 2011), instrumental variables often

⁴ <https://gov.wales/about/cabinet/cabinetstatements/2018/superfast/?lang=en>

address broadband roll-out or availability *not* actual firm take-up, let alone productive use (Holt and Jamison, 2009; Forman et al., 2003).

Several studies have undertaken extensive survey work to fill the theoretical gaps. Grimes et al. (2012) combined a compulsory survey of over 6,000 New Zealand businesses with a longitudinal business database to estimate a 7-10% productivity improvement consequent on broadband adoption. Such time- and firm-extensive data are the exception however. For example, while Bertschek et al. (2013) surveyed 4,400 German businesses, their findings – that broadband positively impacted on innovation but not labour productivity – may have been affected by their two-year survey timeframe (2001-2003); perhaps too short to allow any innovative actions to play out. In Italy meanwhile, Colombo et al. (2013) report on the (discoverable but very contingent) productivity impacts on Italian small and medium businesses, whilst Haller and Lyons (2015) find no impact at all for Irish manufacturers. These firm level studies (and see Díaz-Chao et al., 2015; Hall et al., 2013) for work on ICT more generally) are complemented by a suite of ‘meso-level’ investigations that seek to examine the performance (or location) of firms in small areas (US Counties for example) that are differentiated by broadband provision or adoption (Mack, 2014; Whitacre et al., 2014; McCoy et al.; Mack and Rey, 2014). These investigations, mostly using US data, reveal some interesting facts about the relative economic performance of places that benefit from broadband provision, and by implication the firms that are based there. This work is important in seeking to link broadband impacts with the local economic context (Kolko, 2012; Mack and Faggian, 2013; Mack and Rey, 2014). In each of these studies broadband is found to have economic and productive impacts (although not, perhaps for households), but only in partnership with other necessary within-firm, and perhaps place-related competencies and factors.

Drawing from this range of studies enables a picture of what types of firms, workers and places might benefit *relatively more* from broadband provision and/or take-up. Table 1 summarises these stylised facts, accepting the evidence is far from definitive. There are several factors that emerge with perhaps the clearest finding that for broadband to have positive economic impacts a high level of ‘complementary’ human capital is required – in terms of occupations and/or qualifications (Mack and Faggian, 2013; McCoy et al.; Arvanitis and Loukis, 2009). Another repeated finding is that ‘knowledge intense’ firms and specific industries – professional and business services, telecoms, utilities, finance and insurance – benefit more than manufacturing and retail operations (Kolko, 2012; Johnston et al., 2007); Mack (2015). The work of Elizabeth Mack and colleagues is especially interesting in a spatial context, suggesting that not only the economic structure of a place matters, but also its relationship to other places – be this the relevant urban/metro core or dominant knowledge hub – as does economic history (Mack and Rey, 2014; Mack, 2015).

Whilst some of these insights may directly apply only to the US context, the possibility that there is a nuanced relationship between broadband, business productivity and economic and geographic space is important when reflecting on a currently rather crude spatial context to broadband policy in the UK. The literature reviewed above, while focusing on the broadband-related growth potential, suggests more consideration might be given to the potential for broadband deployment (and related policies) to maintain and prevent further decline of economic activity in challenged places. In this respect, the introduction of new technologies can be seen as part of path development strategies in which policies seek to upgrade the technology available to businesses in an area, and limiting the potential for path dependency

and lock-in (Martin and Sunley, 2006; Martin, 2010). While the outcome from such processes are difficult to detect in practice, the path development literature implies that broadband and related technologies have a range of spatial development possibilities in less developed regions, ranging from economic growth, economic decline and upgrade of existing paths (Coenen et al., 2015).

Table 1 - The economic impacts of broadband and internet access

Impact Domain	Findings	Studies
Firms	Requires firms with higher levels of internal human capital/highly qualified workers/occupations	Mack and Faggian (2013) Arvanitis and Loukis (2009)
	Requires wider organisational response and restructuring, favouring the 'fleet of foot'	Arvanitis and Loukis (2009) Colombo et al (2013)
	Greater cost savings and impacts and swifter adoption in medium and large firms	Fornefeld <i>et al</i> (2008) Johnston <i>et al</i> (2007)
	Requires use of advanced, rather than basic, enabled software/services	Colombo <i>et al</i> (2013)
Industry	More beneficial to services than manufacturing and retail	Johnston <i>et al</i> (2007); Haller and Lyons (2015)
	Largest effects in 'modern' (business/professional/management/technical) services; utilities; communications; finance and insurance; science	Kolko (2012)
Workers	ICT Complementary to highly skilled and qualified workers;	Frey and Osborne (2017) Mack and Faggian (2013) Levy and Murnane (2005)
	ICT substitute for 'routine' jobs and workers	Frey and Osborne (2017)
	Automation impacts low skill workers relatively more	Arntz et al (2016)
Places	Positive impact on location of knowledge intensive firms	Mack and Rey (2014)
	More modest locational impact in places with 'industrial legacy' and in US rust belt	Mack and Rey (2014)
	Encouraging of new firm start-ups and positive impacts on local economic growth - but only where local human capital is high	McCoy et al. (2016)
	Impacts diminished by near location to already tech-dominant metro area	Mack and Rey (2014)
	More beneficial to rural areas and agricultural firms, and to intermediate urban locations	Mack and Grubestic (2016) Mack (2014)

		Mack (2015)
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4. The Research Case – the Cardiff City-Region

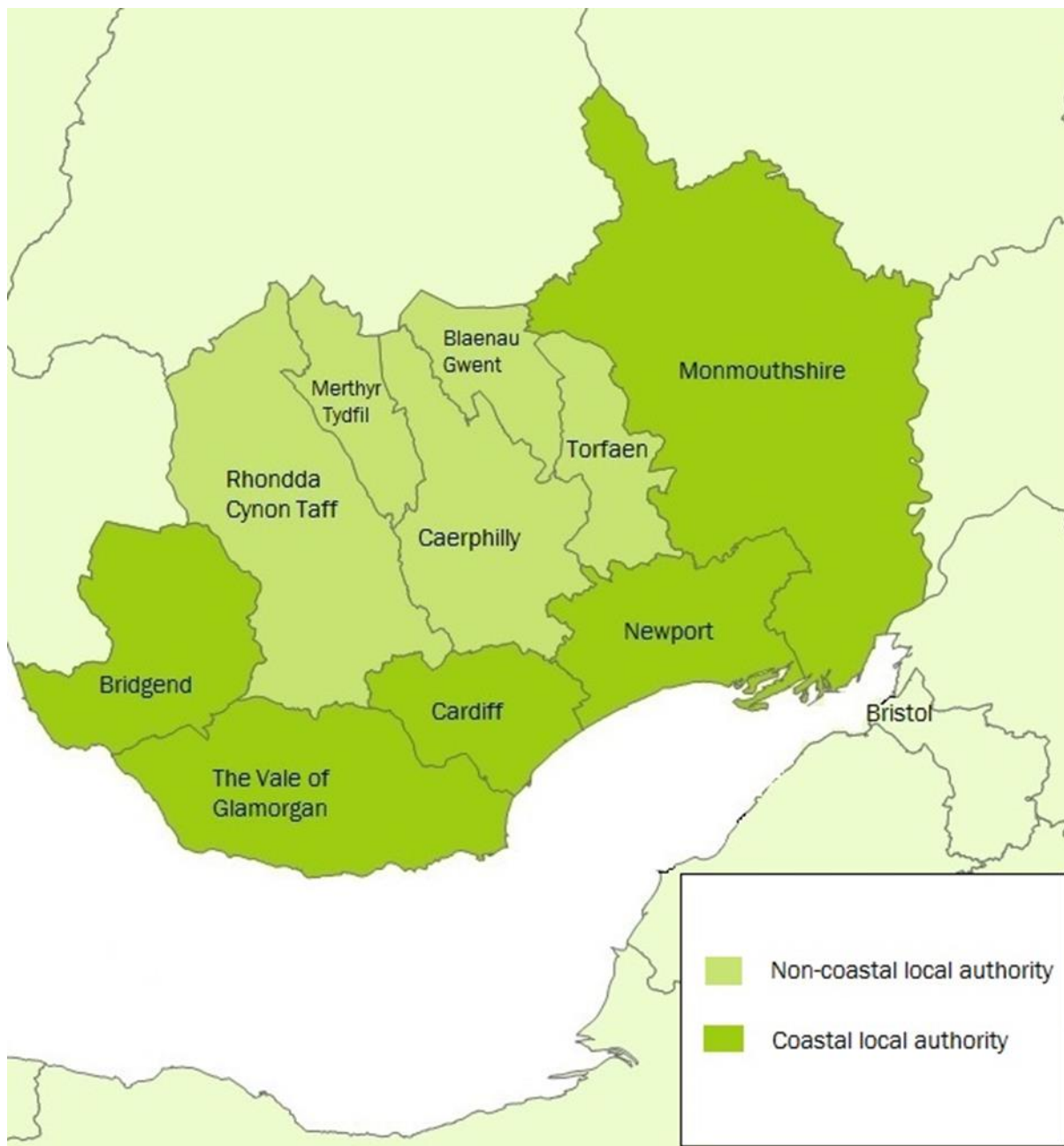
The literature suggests that the productivity and growth impacts of broadband will be mediated by firms' sector, orientation and size, and especially by the existence of complementary human capital. These factors are uneven over space enabling analysis of how an economy which increasingly values the outputs of broadband-enabled activities, services and products will affect economic development over space. This is potentially applicable (and policy relevant) in a place such as the Cardiff City-Region, with significant differences in economic conditions, firm populations and skills and qualifications within a single functional economic area (Jones et al., 2015).

The area in South East Wales covered by the Deal is in desperate need of regeneration. Whilst the five authorities that cover the coastal belt (two cities and two largely rural Counties, plus Bridgend) are relatively prosperous, the Valleys hinterland – home to around 1m people – suffers from long established economic and dysfunction related to the decline of coal mining and manufacturing (Dicks, 2013). Employment rates and economic inactivity in all Valleys authorities are worse than the UK (Jones et al., 2015). Whilst South East Wales overall has a GVA per head in 2014 at around 73% of the UK average, this ranges from around 90% of the UK in the NUTS3 area of Cardiff and the Vale of Glamorgan, down to only 65% of the UK in the Valleys (Office for National Statistics, 2017).

Cardiff has performed better economically than the rest of Wales, helped by employment growth over the longer term in (principally) retail and hospitality and the public sector. Of a total workforce in 2015 of 214,000, around 83,000 in-commute, 63,000 of these from Valleys authority of Rhondda-Cynon-Taff alone (Welsh Government, 2016a). The long term shift of employment opportunities (along with population and infrastructure) from the Valleys to the coast, forms a backdrop for city-regional policymaking, collaboration and debate. ‘Saving’ the Valleys has been a perennial theme, and with ameliorative policies over recent decades (whether enacted by UK government or Welsh Government) following the UK-standard approach developed in the 1980s. Inward investment, skills (and entrepreneurship) development, enterprise zones and new connectivity infrastructure are consistent themes (Dicks, 2013; Stroud et al., 2015). These interventions have failed to improve the position of the Valleys relative to the UK, for complex and poorly understood reasons, stemming from the ongoing legacy of the decline of the coal industry, and reflected in statistics on jobs, unemployment, benefits and health (Foden et al., 2014).

The coastal County of Bridgend lies somewhere in between in terms of economic conditions and industrial history (see Figure 1).

Figure 1 – The Cardiff Capital City Region



The Cardiff City-Region, and Wales more generally, is now at the forefront of Superfast (24Mbps+) broadband availability across most of its geography, largely due to a publicly funded roll-out of fibre (Ofcom, 2015). It has also secured funding for additional high speed fixed and mobile broadband infrastructure roll-out through the Department for Culture, Media and Sport (DCMS) Local Full Fibre Network fund (UK Government, 2018). Yet, as the literature makes clear the penetration or provision of broadband does not guarantee business take up, let alone productive use (Whitacre et al., 2014): this is by no means then

wholly, or even largely, a ‘supply side’ problem (especially in Wales). If then, we assume that engaged businesses who require broadband can access reliable and speedy services on site (or move premises), the question arises as to whether different parts of the City-Region might, via their firms, workers and other economic characteristics, make ‘better’ use of this technology than others, with implications for within-region uneven spatial development (Boschma et al., 2013).

5. Methodology

The paper adopts a case-study methodology (Yin, 1994; Feagin et al., 1991) making use of three main data sources: evidence from a survey of SMEs in the Cardiff City-Region, secondary analysis of policy documents, and published ONS (Office of National Statistics) datasets. These sources enable us to capture both the context for broadband adoption and the consequent use by SMEs in the City-Region. The survey data forms part of a longitudinal study of SMEs in Wales, undertaken by the authors⁵. The survey is being disseminated to SMEs in all sectors of the Welsh economy between 2016 and 2020. The data reported in this paper relates to the most recent dissemination – 2018, where some 190 responses were received from the City-Region. This data is post coded, allowing analysis of SME use of broadband to be assessed in different parts of the City-Region. The analysis presents the results in the form of an index, consisting of a scale of 40 items, coded from survey

⁵ The survey forms part of the Superfast Broadband Business Exploitation Project, part-funded by the European Regional Development Fund (ERDF), through Welsh Government.

questions, with a maximum score of 100⁶. The index captures five dimensions of digital engagement (See Table 2).

Table 2 - Five dimensions of digital engagement

Category	Measure
ICT infrastructure <i>Focusing on adoption of broadband</i>	Broadband adoption and speed of connection
ICT Investment <i>ICT-related resources of the SME</i>	Business budget for ICT-related expenditure Spending on hardware, software, network, broadband subscription and ICT-related staff training
ICT capabilities <i>SMEs' access to human ICT-related resources</i>	ICT human skills, internal and external to the business Proportion of staff with intermediate or above ICT skills Employment of ICT specialists and/or use of external ICT support
Digital applications <i>SMEs' use of cloud packages for a variety of business functions</i>	Use of cloud computing packages for a variety of business functions, website and its functionality Social media and other broadband-enabled applications
E-commerce <i>SMEs' engagement in online transactions with customers and suppliers</i>	Proportion of total sales serviced online Proportion of purchases transacted online, and the breadth of online channels for making e-sales and e-purchases.

The digital engagement index scores of individual SMEs in the sample were visually examined to identify any trends in the data and group businesses into the categories noted above. Based on these insights, four clusters of firms in terms of digital engagement characteristics were identified.

⁶ All binary items were coded as 0/1, while items that refer to ranges were coded from 1 upwards in ascending order. The scores are unweighted, but binary items were multiplied by a constant of 2 to calibrate the scale to a maximum of 100.

Table 3 - Main characteristics of the digital engagement index groups

Digital Maturity Group	Main Characteristics
Digitally Embedded	Such businesses are adopters of superfast broadband with a very high proportion of employees with above average ICT skills. They use a high number of digital applications and secure the majority of their sales from online transactions.
Active Exploiters	Such businesses are likely to have adopted superfast broadband, have a high proportion of staff with above average ICT skills, and use a wider range of digital platforms and technologies. Nearly half of businesses in this cluster report online channel as the main source of sales.
Passive Exploiters	Such businesses tend to have adopted standard broadband and are likely to have staff with above average ICT skills. They make use of basic cloud-based applications, but the use of online platforms to generate e-sales is low.
Digitally Disengaged	Such businesses tend to have adopted standard broadband, and have a high proportion of employees with below average ICT skills. The majority do not use digital technologies and report no sales from online transactions.

Policy documentation was sourced from a literature review of websites, and from UK and Welsh Government, including policy statements on the City Regional and City Deals in Wales. Secondary datasets were also identified from previous research, to support the primary data, and provide context for the spatial impacts. In most cases, relevant, up to date and reasonably robust economic data are available for the ten local authorities that comprise the Cardiff Capital City-Region⁷. These comprise the coastal cities of Cardiff and Newport, and largely rural coastal Counties of Monmouth and Vale of Glamorgan; plus five urban, post-industrial inland counties suffering severe economic and social deprivation (Rhondda-Cynon-Taff; Bleanau Gwent; Caerphilly; Merthyr Tydfil and Torfaen).

⁷ Some relevant data (or example on population skills and occupations) are available for 2011 from the UK Census at very local area and are the subject of a paper in development; see <http://www.neighbourhood.statistics.gov.uk/dissemination/LeadHome.do> .

The greatest lacuna relates to unobservable firm characteristics – including the composition of workforce, organisational approach and capability, and here access to (and take up of) broadband. There is also potential concern with our analysis: that of conflating issues relevant to the resident population of an area with those affecting local firms. In reality, many residents work in different counties, with Cardiff being by far the greatest attractor of labour; for Caerphilly and Vale of Glamorgan outflows of commuters are larger than the number of residents working domestically (Welsh Government, 2016b). Here then we must be aware that there will be a complex relationship between broadband; firm productivity and success; local (within county) economic activity; and the welfare of the resident population. It may be that (some) residents of a County are able to commute easily to work in innovative and productive broadband-enabled firms in more successful parts of the City-Region. We should not then conflate local economic activity with local welfare outcomes (see Section 6).

Our research questions for this paper can therefore be summarised as follows: How might broadband roll-out of high speed broadband impact economic development in different parts of a region? and What kind of businesses and sectors might benefit from greater e-connectivity?

6. Data Presentation and Analysis

In this section, we draw from our dataset on SME digital engagement in the City region, as well as secondary data on how well-placed firms and workers in the ten different counties that comprise the Cardiff City-Region may be to take productive advantage of broadband.

6.1 Secondary data

Table 2 presents some key summary data related to human capital across the City-Region, aggregated to Counties, using job-related training, qualifications and wages as proxies. It is notable that overall the poorer Valleys area performs worse than the Coast in terms of resident human capital. The starkest difference is in the level of qualified population, where the five worst Counties are those in the Valleys (around 28% having a degree or equivalent), and where there is an over 11 percentage-point advantage for the Coast area (almost 40%). This difference is driven in part by the three higher educational establishments located (in whole or part) in Cardiff, but the two rural Coast counties have similarly high levels of qualified labour. Note we use the NVQ4+ level of qualifications here to address Mack and Faggian's (2013) finding that it is this level of qualification that matters most for broadband impact, but Valleys authorities perform worse than the Coast at every level of qualifications attainment, albeit to a lesser extent (Office for National Statistics, 2016a). The position is somewhat better for the Valleys in terms of workers receiving job-related training in the prior 3 months, with two Valleys authorities in the 'top five' for training, although overall the level of job related training is lower in the Valleys.

It is worth noting that pay is much lower in the Valleys than on the Coast, suggesting lower levels of labour productivity and human capital embedded in Valleys workers and firms.

Wages on the Coast are almost 8% higher⁸. Here there is some heterogeneity between

⁸ Here we have used estimates of the resident workforce from the Annual Population Survey (Office for National Statistics, 2106b) in conjunction with the Annual Survey of Earnings and Hours to estimate average gross wages for the Valleys and coast: there may then be some small error in our presented estimates for these aggregate areas due to differing survey methodologies.

Counties. Cardiff and Bridgend present the highest level of wages by far, related to in the first case, employment in high value services and in the (relatively well paid) public sector, and in the latter case many high-paying manufacturing jobs, including some large multinational firms – although in Bridgend’s case, the susceptibility of well-paid but routine manufacturing tasks to automation should be a concern (Frey and Osborne, 2017). Notably, the two Coast authorities that are in the lower half of the wage distribution are the rural areas of the Vale and Monmouth, although sample sizes restrict our ability to judge whether their rurality and consequent agricultural and related employment are the cause. It is perhaps interesting that there is some evidence that rural firms and areas benefit more from broadband than others, but the notion of rurality and distance employed in the relevant US studies is very different to that in the UK (Mack and Grubestic, 2009).

Table 4 – Broadband-Relevant Labour Market Characteristics: Cardiff Capital City-Region

Job related training 2015 (% 16-64yrs last 13 weeks)		Qualified Population 2015 (% pop. NVQ4+/Bachelor degree)		Gross weekly wages 2014 (£) (all employees)	
Merthyr Tydfil	14.2	Blaenau Gwent	19.0	Merthyr Tydfil	404.70
Caerphilly	15.3	Merthyr Tydfil	25.4	Blaenau Gwent	431.20
Blaenau Gwent	16.7	Torfaen	27.4	Torfaen	451.00
The Vale of Glamorgan	19.9	Caerphilly	28.0	The Vale of Glamorgan	456.00
Bridgend	20.0	Rhondda, Cynon, Taff	29.6	Monmouthshire	463.90
Cardiff	20.2	Bridgend	31.0	Caerphilly	466.50
Rhondda, Cynon, Taff	20.3	Newport	34.0	Newport	471.50
Torfaen	23.9	The Vale of Glamorgan	40.7	Rhondda, Cynon, Taff	477.90
Monmouthshire	24.1	Monmouthshire	41.7	Cardiff	504.40
Newport	24.7	Cardiff	43.5	Bridgend	509.50
<i>Valleys</i>	<i>18.5</i>	<i>Valleys</i>	<i>27.9</i>	<i>Valleys</i>	<i>446.26</i>
<i>Coast</i>	<i>21.3</i>	<i>Coast</i>	<i>39.4</i>	<i>Coast</i>	<i>481.06</i>

Source: Office for National Statistics (2017); Office for National Statistics (2016a)

Note: Valleys areas are shaded in this table

As far as the data allow us to judge then, the Valleys labour force would seem to be in a poorer position than that of the Coast to take productive advantage of broadband roll-out. There is a caveat here however: *so far*, manual work that is harder to routinize and requires contextual awareness, such as driving, care work and food serving have resisted computerisation (as have high-end professional occupations), leading Goos and Manning (2007) to talk about the divergence of the economy into ‘lovely and lousy jobs’. The extent to which this remains true (witness for example very rapid recent strides in vehicle automation and the prevalence of order-via-screen in McDonald’s) will have important implications for areas that specialise in supplying labour for such dextrous occupations (Autor, 2015).

The results from prior studies also suggest that *firms* within the Valleys part of the region might be less advantaged than those on the Coast by any increase in the economic importance in broadband-enabled activities (Table 3), although here data are more restricted and the findings from prior studies less definitive. In the first part of the Table, we follow Kolko (2012) and present information on the industries that appear to benefit most from broadband provision, amended from the US NAICS to UK-relevant SIC2007 categories⁹. The work of other studies such as (Calvino et al., 2018; Gandhi et al., 2016) generally supports the finding that broadband and ICT has most impact in these industries.

Here, again the data are clear. The first part Table 5 presents the percentage of firms located in each County and across our two sub-regions that are in Kolko's top 'broadband benefitting' industries (industries that experience a 12%+ increase in employment following broadband penetration). The two Coast cities, and the two rural Coast counties have (proportionally) significantly more of such firms. The bottom five counties in this regard are our five Valleys authorities (Bridgend is closer to the Valleys than its Coastal compatriots, but still marginally better; the dataset here, the UK Business Counts, is notionally at least a Census so sampling considerations do not apply). Overall the Valleys has 15% of its businesses in the most broadband-benefitting industries, the Coast 22.4%. The best authority in this regard, Cardiff, at 25.5% has almost 2.5 times (proportionately) more businesses than the worst (Blaenau Gwent at 10.5%). The Table also provides information on the size of businesses in different counties, particularly in the medium-large size bands that studies such as (Fornfeld et al., 2008) suggest might benefit more from broadband. Here we present the

⁹ 2-Digit SICs 36, 61, 62, 63, 64, 65, 66, 69, 70, 71, 72, 73, 74; covering utilities, telecoms, computing, financial services, professional and business services and technical and scientific activities

number of firms of such size in proportion to the resident population, as the overall number of firms (and hence local employment opportunity) varies across the region. We can see there is again a differential in favour of the Coast, with around 25% more such firms per head of population than the Valleys. Here, though, the rural Coast authorities perform quite poorly, with a relatively small ‘Mittelstand’ of mid-sized firms. Care needs to be taken here however with business size and broadband exploitation interacting in ways not fully understood (Johnston et al., 2007), but the overall import of Table 3 is clear, reinforcing the earlier labour market analysis.

Table 5 - Broadband Relevant Firm Characteristics: Cardiff Capital City-Region

Percent of private firms in top broadband-benefitting industries 2015		Medium/Large firms (50-250emp) per 10,000 Population 2015	
Blaenau Gwent	10.5	The Vale of Glamorgan	5.1
Merthyr Tydfil	12.3	Blaenau Gwent	5.7
Rhondda, Cynon, Taff	15.5	Monmouthshire	6.0
Caerphilly	16.0	Merthyr Tydfil	6.8
Torfaen	16.2	Caerphilly	6.9
Bridgend	16.7	Rhondda, Cynon, Taff	7.2
Newport	20.6	Bridgend	7.4
The Vale of Glamorgan	21.3	Torfaen	8.7
Monmouthshire	21.7	Newport	11.2
Cardiff	25.5	Cardiff	13.5
Valleys	15.0	Valleys	8.1
Coast	22.4	Coast	10.1

Source: (Office for National Statistics, 2016b)

Note: Valleys areas are shaded in this table

The analysis of US local areas and broadband productivity by Mack and Rey (2014), whilst only one study and in a very different national context, offers further concern. That paper

suggests that the nature and hierarchy of metropolitan areas might affect how far broadband attracts ‘knowledge intense’ firms. Some findings may have limited application to the UK – for example that broadband may offset transaction costs in sprawling urban areas such as Las Vegas. However, the finding that broadband has less of an ‘attractive’ effect for metropolitan areas with an industrial past, and, a separate finding, for those in the rust belt states, may be important. Mack and Rey (2014) also suggest that new broadband provision in areas near already established technology or knowledge hubs has no economic impact. Our five Valleys authorities all have an industrial legacy, and are all in the geographic shadow of Cardiff as the existing hub for knowledge intense firms. If broadband exploitation does rely in part upon the attraction of high value firms, the relative attractiveness of the Valleys and Coast should be considered relevant, especially given McCoy et al. (2016)’s finding that in Ireland, broadband must be combined with high levels of local human capital to stimulate business re-location (as well as start-up).

In summary then, the secondary evidence suggests that the prospect of broadband roll-out narrowing intra-regional economic disparities in South Wales is remote, at least in the absence of ameliorative policy. The opposite is more likely, and indeed, the relative widening of intra-Wales economic disparities in the last decade may be in part related to telecommunications investments already enacted. If future competitiveness and productivity in ‘Industry 4.0’ relies increasingly upon leveraging cloud and internet infrastructures and services, and if ICT relatively enhances the productivity of the highest-qualified in the workforce who are concentrated on the Coast (and especially in the cities), then the ‘policy off’ prospect is for more uneven economic development within this (and perhaps other similar) regions (Graham, 2002; Akerman et al., 2015; Boschma et al., 2013).

6.2. Findings from the digital engagement index

Table 6 presents data on SMEs in the City-Region according to their digital engagement. This draws from our 2018 dataset of SMEs in the City-Region, and comprises part of our ongoing research¹⁰. The index presents coastal and non-coastal SMEs in four digital engagement groups and shows a greater proportion of coastal SMEs in the Active Exploiter and Digitally embedded groups, with SMEs located in non-coastal areas accounting for the majority of Passive Exploiters and Digitally Disengaged.

Table 6 - Businesses in coastal and non-coastal local authorities of the Cardiff City Region by Digital engagement group (number and %)

Digital maturity group	Non-coastal LAs	Coastal LAs	Total
Digitally Embedded	8 14.55%	33 24.44%	41 21.58%
Active Exploiters	22 40%	55 40.74%	77 40.53%
Passive Exploiters	19 34.55%	40 29.63%	59 31.05%
Digitally Disengaged	6 10.91%	7 5.19%	13 6.84%
Total	55 100%	135 100%	190 100%

Source: (WERU, 2018)

¹⁰ Further details of this research can be found at <https://blogs.cardiff.ac.uk/business-school/2019/02/14/wales-in-the-digital-economy-emerging-evidence-on-the-importance-of-place/>

These findings indicate that the mean index score was 49.2 for coastal SMEs, against 46.5 in non-coastal areas. T-test analysis, however, suggests the mean of digital maturity engagement index between Non-coastal and Coastal groups in Cardiff region are not significantly different. Our ongoing survey research will seek to improve the survey response and reliability of this data, allowing for further analysis of digital engagement and its antecedents with the dataset covering a wide range of broadband and technology related behaviours, as well as including multiple firm characteristics and thus allowing for a number of analytical approaches.

7. Discussion

Much of the above analysis may come as no surprise to the authors of Cardiff's original City-Region strategy (Welsh Government, 2012). This was predicated on leveraging city-region development using Cardiff as the internationally recognised 'brand', and the key employment generator. Forecasts suggesting the population is to grow faster than any other UK city in the period to 2040 have reinforced this narrative (Welsh Government, 2013). This conceptual approach – effectively a Perrouxian growth pole paradigm emphasising agglomeration economies – is also inherent in the various city deals signed by the (former) UK Chancellor. Although the relevant deals are often light on detail the sense in reading the agreements is that cities, and their research and education establishments, hubs and brands, are the motive development force, and that the attraction of (inward) investment is the primary development mechanism. Under this reading of the economic landscape, cities will do their job of attracting investment and growing the employment base, providing economic opportunity for

those living within the functional economic area. One can argue that the identification of the intra-region South Wales Metro transport network as the key project for the Cardiff City-Deal responds to the vision of Cardiff as offering increasing opportunity to better-connected Valleys residents.

However, as the literature shows, the ability of firms and places to benefit from broadband depends in large part on their available human capital (and the way it is organised). The penetration of ICT, the internet and cloud into businesses' production functions will result in the increased value of some workers and occupations, and a fall in the productivity and usefulness of others. Individuals who live in poor places are more likely to be in the second category than those living in already prosperous, core locations, and we know the lower skilled and qualified tend to search for employment more locally, and that spatial and social network factors matter in employment success (Cingano and Rosolia, 2012; Huber and Nowotny, 2013).

The data reported raises concerns about the prospect of Coastal-located broadband and cloud exploiting firms lifting all South Wales boats are questionable, with ONS data showing that firms in the Valleys as a whole are smaller than those on the coast, are less likely to be in industries thought to benefit most from technology (professional services, finance and utilities for example), and face a local workforce with lower levels of training and far lower levels of university qualifications. While the survey evidence does not point to statistically significant differences in digital engagement between coastal and Valleys SMEs, improved response rates in ongoing surveys may help to show the different positions of firms in the Valleys and Coast more clearly.

There are some signs that the Welsh Government realises this danger; there has been a long debate about the structure and function of the South Wales Metro; the idea that it should enable polycentric development via the connecting of complementary regional ‘mini growth poles’ has come to the fore (Barry, 2016) and, the Welsh Government and the EU have sponsored a programme of business support to ensure SMEs in Wales are placed to take advantage of the benefits of Superfast Broadband. How far such regional policy actions can ameliorate pervasive economic disadvantages through broadband deployment and other policy initiatives is of course an open question (McQuaid, 2002; Becker et al., 2010).

8. Conclusions

There are ongoing and robust debates about the impact of technology on the demand for labour (Arntz et al., 2016). Here, though we are less concerned with whether ICT and automation reduces demand for labour in aggregate, and more with whether it adds to or mitigates already-evident core periphery economic trends; this paper builds on earlier analysis of the spatial implications of broadband (Leamer and Storper, 2001) by seeking to place the emergence of broadband-enabled firm activities and resultant economic development more firmly within a spatial context. Using the example of the Cardiff Capital City-Region in South Wales, our case suggests that the increasing economic importance of e-connectivity would suggest (*ceteris paribus*) an increased level of economic disparity across space. This increased disparity would be driven by the very different levels of relevant human capital, and the very different industrial structures in the post-industrial Valleys and the more prosperous coastal cities and rural counties. Moreover, there is some suggestion in the

literature that post-industrial areas, those near already established tech-heavy centres, will be less successful in attracting knowledge intensive firms (Mack and Rey, 2014)

This is not a happy analysis for those seeking more ‘even’ economic development.

Technology-driven economic change may increase the unevenness of outcomes and – especially in large conurbations like the Valleys – creating geographically concentrated communities of lower skilled and poorly people for whom finding employment is increasingly difficult. The varied implications of these trends are important and worrying. Indeed, the increased importance of e-connectivity may already have contributed to the increased spatial economic divergence we have seen in the UK – North-South, intra-regional and intra-urban (Martin and Sunley, 2015; Jones et al., 2015).

The current devolution of power to more local areas as part of the last and current UK Chancellors’ City-deal approach to economic development creates both threats and opportunities. The threat is in the implied and sometimes explicit orientation of the City-deals on global competitiveness, connectivity and the identification of key city-regional industries and competencies as the path to economic success. This approach may prejudice the success of poorer places and people compared to the already relatively rich. The opportunity however relates to the devolution of power to the lower spatial scale, where there may be a more nuanced approach to economic development and a deeper understanding of the challenges faced by both specific parts of society and locales. Here, a more interventionist and ‘careful’ set of economic policies might emerge which seek to harness the power of e-connectivity to build the capacities of those currently economically left behind, and to spur a real ‘march of the makers’ by renewing and re-equipping re-shored manufacturing to succeed in the future

economy (Bailey and De Propris, 2014). Such policies could seek to marry together supply side support for infrastructure, with demand-side measures that seek to encourage business use and exploitation (OECD, 2008; Price et al., 2018; Henderson, 2017). This may help to prevent further decline of local areas, and provide infrastructure and support that can help businesses to modernise their processes, become more efficient and compete more effectively. Finally, the ways in which these tensions and policy responses play out in city-regions, as their economies increasingly automate, virtualise and head to the Cloud will be extremely interesting and should be placed high on future research agendas.

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References

- Akerman A, Gaarder I and Mogstad M. (2015) The Skill Complementarity of Broadband Internet. *The Quarterly Journal of Economics* 130: 1781-1824, DOI: 10.1093/qje/qjv028.
- Arntz M, Gregory T and Zierahn U. (2016) *The Risk of Automation for Jobs in OECD Countries*, Paris: OECD Publishing.
- Arvanitis S and Loukis EN. (2009) Information and communication technologies, human capital, workplace organization and labour productivity: A comparative study based on firm-level data for Greece and Switzerland. *Information Economics and Policy* 21: 43-61.
- Autor DH. (2015) Why Are There Still So Many Jobs? The History and Future of Workplace Automation. *Journal of Economic Perspectives* 29: 3-30, DOI: 10.1257/jep.29.3.3.
- Bailey D and De Propris L. (2014) Manufacturing reshoring and its limits: the UK automotive case. *Cambridge Journal of Regions, Economy and Society* 7: 379-395, DOI: 10.1093/cjres/rsu019.
- Barry M. (2016) *The next steps for the South Wales Metro Wales*
[^http://www.walesonline.co.uk/business/business-news/next-steps-south-wales-metro-11313133](http://www.walesonline.co.uk/business/business-news/next-steps-south-wales-metro-11313133).
- Becker S, Egger P and von Ehrlich M. (2010) Going NUTS: The effect of EU Structural Funds on regional performance. *Journal of Public Economics* 94: 578-590.
- Bentley G, Bailey D and Shutt J. (2010) From RDAs to LEPs: A New Localism? Case Examples of West Midlands and Yorkshire. *Local Economy* 25: 535-557, DOI: 10.1080/02690942.2010.532356.
- Bentley G and Pugalis L. (2013) New directions in economic development: Localist policy discourses and the Localism Act. *Local Economy* 28: 257-274, DOI: 10.1177/0269094212473940.

- Bertschek I, Cerquera D and Klein GJ. (2013) More bits – more bucks? Measuring the impact of broadband internet on firm performance. *Information Economics and Policy* 25: 190-203, DOI: 10.1016/j.infoecopol.2012.11.002.
- Boschma R, Iammarino S and Steinmueller E. (2013) Editorial: Geography, Skills and Technological Change. *Regional Studies* 47: 1615-1617, DOI: 10.1080/00343404.2013.823306.
- Brynjolfsson E and Hitt L. (2003) Computing Productivity: Firm-Level Evidence. *The Review of Economics and Statistics* 85: 793-808.
- Brynjolfsson E and McAfee A. (2014) *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*: WW Norton & Company.
- Calvino F, Criscuolo C, Marcolin L, et al. (2018) A taxonomy of digital intensive sectors. science, Technology and Industry Working Papers, No. 2018/14, <https://www.oecd-ilibrary.org/content/paper/f404736a-en>.
- Cingano F and Rosolia A. (2012) People I Know: Job Search and Social Networks. *Journal of Labor Economics* 30: 291-332, DOI: 10.1086/663357.
- Coenen L, Moodysson J and Martin H. (2015) Path Renewal in Old Industrial Regions: Possibilities and Limitations for Regional Innovation Policy. *Regional Studies* 49: 850-865, DOI: 10.1080/00343404.2014.979321.
- Colombo MG, Croce A and Grilli L. (2013) ICT services and small businesses' productivity gains: An analysis of the adoption of broadband Internet technology. *Information Economics and Policy* 25: 171-189, DOI: 10.1016/j.infoecopol.2012.11.001.
- Czernich N, Falck O, Kretschmer T, et al. (2011) Broadband Infrastructure and Economic Growth. *The Economic Journal* 121: 505-532, DOI: 10.1111/j.1468-0297.2011.02420.x.
- Department for Business Energy & Industrial Strategy. (2017) The UK's Industrial Strategy. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf.

- Díaz-Chao Á, Sainz-González J and Torrent-Sellens J. (2015) ICT, innovation, and firm productivity: New evidence from small local firms. *Journal of Business Research* 68: 1439-1444, DOI: 10.1016/j.jbusres.2015.01.030.
- Dicks B. (2013) Participatory Community Regeneration: A Discussion of Risks, Accountability and Crisis in Devolved Wales. *Urban Studies* 51: 959-977, DOI: 10.1177/0042098013493023.
- Drakakis-Smith D. (2012) *Urbanisation, housing and the development process*: Routledge.
- Feagin JR, Orum AM and Sjoberg G. (1991) *A case for the case study*: UNC Press Books.
- Floud R, Humphries J and Johnson P. (2014) *The Cambridge Economic History of Modern Britain: Volume 1, Industrialisation, 1700–1870*: Cambridge University Press.
- Foden M, Fothergill S and Gore T. (2014) The state of the coalfields: Economic and social conditions in the former mining communities of England, Scotland and Wales. *Centre for Regional Economic and Social Research, Sheffield Hallam University*.
- Forman C, Goldfarb A and Greenstein S. (2003) Which industries use the Internet? *Organizing the New Industrial Economy*. Emerald Group Publishing Limited, 47-72.
- Fornefeld M, Delaunay G and Elixmann D. (2008) The impact of broadband on growth and productivity. *Comisión Europea (DG Information Society and Media), MICUS*.
- Frey CB and Osborne MA. (2017) The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting and Social Change* 114: 254-280, DOI: 10.1016/j.techfore.2016.08.019.
- Gandhi P, Khanna S and Ramaswamy S. (2016) Which industries are the most digital (and why)? *Harvard Business Review*. <https://hbr.org/2016/04/a-chart-that-shows-which-industries-are-the-most-digital-and-why>.

- Goldberg K and Kehoe B. (2013) Cloud robotics and automation: A survey of related work. *EECS Department, University of California, Berkeley, Tech. Rep. UCB EECS-2013-5*.
- Goos M and Manning A. (2007) Lousy and lovely jobs: The rising polarization of work in Britain. *The Review of Economics and Statistics* 89: 118-133.
- Graham S. (2002) Bridging Urban Digital Divides? Urban Polarisation and Information and Communications Technologies (ICTs). *Urban Studies* 39: 33-56, DOI: 10.1080/00420980220099050.
- Grimes A, Ren C and Stevens P. (2012) The need for speed: impacts of internet connectivity on firm productivity. *Journal of Productivity Analysis* 37: 187-201.
- Grubestic TH and Mack EA. (2016) *Broadband Telecommunications and Regional Development*, Abingdon (Oxon): Routledge.
- Hall BH, Lotti F and Mairesse J. (2013) Evidence on the impact of R&D and ICT investments on innovation and productivity in Italian firms. *Economics of Innovation and New Technology* 22: 300-328, DOI: 10.1080/10438599.2012.708134.
- Haller SA and Lyons S. (2015) Broadband adoption and firm productivity: Evidence from Irish manufacturing firms. *Telecommunications Policy* 39: 1-13, DOI: 10.1016/j.telpol.2014.10.003.
- Hempell T. (2005) What's spurious, what's real? Measuring the productivity impacts of ICT at the firm-level. *Empirical Economics* 30: 427-464, DOI: 10.1007/s00181-005-0248-6.
- Henderson D. (2017) Assessing the impact of business broadband use on the Welsh economy. *Welsh Economic Review* 25: 28-36, DOI: 10.18573/j.2017.10196.
- Higón DA. (2012) The impact of ICT on innovation activities: Evidence for UK SMEs. *International Small Business Journal* 30: 684-699, DOI: 10.1177/0266242610374484.

- Hildreth P and Bailey D. (2013) The economics behind the move to ‘localism’ in England. *Cambridge Journal of Regions, Economy and Society* 6: 233-249, DOI: 10.1093/cjres/rst004.
- HM Cabinet Office. (2016) City-Deals and Growth Deals. <https://www.gov.uk/government/policies/city-deals-and-growth-deals>.
- Holt L and Jamison M. (2009) Broadband and contributions to economic growth: Lessons from the US experience. *Telecommunications Policy* 33: 575-581.
- Huber P and Nowotny K. (2013) Moving across Borders: Who is Willing to Migrate or to Commute? *Regional Studies* 47: 1462-1481, DOI: 10.1080/00343404.2011.624509.
- Huggins R and Izushi H. (2002) The Digital Divide and ICT Learning in Rural Communities: Examples of Good Practice Service Delivery. *Local Economy* 17: 111-122, DOI: 10.1080/02690940210129870.
- Johnston DA, Wade M and McClean R. (2007) Does e-Business Matter to SMEs? A Comparison of the Financial Impacts of Internet Business Solutions on European and North American SMEs. *Journal of Small Business Management* 45: 354-361, DOI: 10.1111/j.1540-627X.2007.00217.x.
- Jones M, Orford S and Macfarlane V. (2015) *People, places and policy: Knowing contemporary Wales through new localities*: Routledge.
- Jones P, Simmons G, Packham G, et al. (2012) An exploration of the attitudes and strategic responses of sole-proprietor micro-enterprises in adopting information and communication technology. *International Small Business Journal* 32: 285-306, DOI: 10.1177/0266242612461802.
- Katz RL, Vaterlaus S, Zenhäusern P, et al. (2010) The impact of broadband on jobs and the German economy. *Intereconomics* 45: 26-34, DOI: 10.1007/s10272-010-0322-y.
- Kellerman A. (2010) Mobile Broadband Services and the Availability of Instant Access to Cyberspace. *Environment and Planning A: Economy and Space* 42: 2990-3005, DOI: 10.1068/a43283.

- Kennett P, Jones G, Meegan R, et al. (2015) Recession, Austerity and the 'Great Risk Shift': Local Government and Household Impacts and Responses in Bristol and Liverpool. *Local Government Studies* 41: 622-644, DOI: 10.1080/03003930.2015.1036986.
- Kenny R and Kenny C. (2011) Superfast broadband: is it really worth a subsidy? *Info* 13: 3-29, DOI: 10.1108/14636691111146127.
- Kerry C and Danson M. (2016) Open Innovation, Triple Helix and Regional Innovation Systems: Exploring CATAPULT Centres in the UK. *Industry and Higher Education* 30: 67-78, DOI: 10.5367/ihe.2016.0292.
- Kolko J. (2012) Broadband and local growth. *Journal of Urban Economics* 71: 100-113, DOI: 10.1016/j.jue.2011.07.004.
- Koutroumpis P. (2009) The economic impact of broadband on growth: A simultaneous approach. *Telecommunications Policy* 33: 471-485, DOI: 10.1016/j.telpol.2009.07.004.
- Leamer EE and Storper M. (2001) *The Economic Geography of the Internet Age*. Cambridge, MA: National Bureau of Economic Research, http://dx.doi.org/10.1057/9781137472311_4.
- Levy F and Murnane RJ. (2005) *The new division of labor: How computers are creating the next job market*. Princeton University Press.
- Mack E and Faggian A. (2013) Productivity and Broadband: The Human Factor. *International Regional Science Review* 36: 392-423, DOI: 10.1177/0160017612471191.
- Mack E and Grubestic T. (2009) Broadband provision and firm location in Ohio: An exploratory spatial analysis. *Tijdschrift voor economische en sociale geografie* 100: 298-315, DOI: 10.1111/j.1467-9663.2008.00487.x.
- Mack EA. (2014) Broadband and Knowledge Intensive Firm Clusters: Essential Link or Auxiliary Connection? *Papers in Regional Science* 93: 3-29, DOI: <http://onlinelibrary.wiley.com/journal/10.1111/%28ISSN%291435-5957/issues>.

- Mack EA. (2015) Variations in the Broadband-Business Connection across the Urban Hierarchy. *Growth and Change* 46: 400-423, DOI: 10.1111/grow.12095.
- Mack EA and Rey SJ. (2014) An econometric approach for evaluating the linkages between broadband and knowledge intensive firms. *Telecommunications Policy* 38: 105-118, DOI: 10.1016/j.telpol.2013.06.003.
- Martin R. (2010) Roepke Lecture in Economic Geography; Rethinking Regional Path Dependence: Beyond Lock-in to Evolution. *Economic Geography* 86: 1-28.
- Martin R and Sunley P. (2006) Path dependence and regional economic evolution. *Journal of Economic Geography* 6: 395-437, DOI: 10.1093/jeg/lbl012.
- Martin R and Sunley P. (2015) On the notion of regional economic resilience: conceptualization and explanation. *Journal of Economic Geography* 15: 1-42, DOI: 10.1093/jeg/lbu015.
- McCann P. (2016) *The UK regional–national economic problem: Geography, globalisation and governance*: Routledge.
- McCoy D, Lyons S, Morgenroth E, et al. (2016) The impact of broadband and other infrastructure on the location of new business establishments. *Journal of Regional Science*: n/a-n/a, DOI: 10.1111/jors.12376.
- McQuaid RW. (2002) Entrepreneurship and ICT Industries: Support from Regional and Local Policies. *Regional Studies* 36: 909-919, DOI: 10.1080/0034340022000012333.
- Morgan K. (2016) Nurturing novelty: Regional innovation policy in the age of smart specialisation. *Environment and Planning C: Politics and Space* 35: 569-583, DOI: 10.1177/0263774X16645106.
- OECD. (2008) *Broadband Growth and Policies in OECD Countries*: Organisation for Economic Co-operation and Development.
- Ofcom. (2015) Communications Market Report: Wales.
http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr15/2015_CMW_Wales.pdf.

- Office for National Statistics. (2016a) *Annual Population Survey*. ^
<https://www.nomisweb.co.uk/articles/948.aspx>.
- Office for National Statistics. (2016b) *UK Business Counts – Enterprises*. ^
<https://www.nomisweb.co.uk/query/construct/summary.asp?menuopt=200andsubcomp>.
- Office for National Statistics. (2017) *Gross Value Added*. ^
<https://www.ons.gov.uk/economy/grossvalueaddedgva>
- Philip L and Williams F. (2018) Remote rural home based businesses and digital inequalities: Understanding needs and expectations in a digitally underserved community. *Journal of Rural Studies*, DOI: 10.1016/j.jrurstud.2018.09.011.
- Pike A, Coombes M, O’Brien P, et al. (2018) Austerity states, institutional dismantling and the governance of sub-national economic development: the demise of the regional development agencies in England. *Territory, Politics, Governance* 6: 118-144, DOI: 10.1080/21622671.2016.1228475.
- Pilat D. (2005) The ICT productivity paradox. *OECD economic studies* 2004: 37-65.
- Price L, Shutt J and Sellick J. (2018) Supporting rural Small and Medium-sized Enterprises to take up broadband-enabled technology: What works? *Local Economy* 33: 515-536, DOI: 10.1177/0269094218791508.
- Pugh R. (2014) ‘Old wine in new bottles’? Smart Specialisation in Wales. *Regional Studies, Regional Science* 1: 152-157, DOI: 10.1080/21681376.2014.944209.
- Roller L-H and Waverman L. (2001) Telecommunications Infrastructure and Economic Development: A Simultaneous Approach. *American Economic Review* 91: 909-923, DOI: 10.1257/aer.91.4.909.
- Salemink K, Strijker D and Bosworth G. (2017) Rural development in the digital age: A systematic literature review on unequal ICT availability, adoption, and use in rural areas. *Journal of Rural Studies* 54: 360-371, DOI: 10.1016/j.jrurstud.2015.09.001.

Stroud D, Fairbrother P, Evans C, et al. (2015) Governments matter for capitalist economies: Regeneration and transition to green and decent jobs. *Economic and Industrial Democracy* 39: 87-108, DOI: 10.1177/0143831X15601731.

Thomas B, Miller C and Simmons G. (2015) An Examination of Regional Policy Implications Pertaining to SME E-Business Adoption in South-East Wales. *Strategic Change* 24: 429-446, DOI: 10.1002/jsc.2020.

Townsend L, Sathiaselalan A, Fairhurst G, et al. (2013) Enhanced broadband access as a solution to the social and economic problems of the rural digital divide. *Local Economy* 28: 580-595, DOI: 10.1177/0269094213496974.

Triplett JE. (1999) The Solow productivity paradox: what do computers do to productivity? *The Canadian Journal of Economics/Revue canadienne d'Economique* 32: 309-334.

UK Government. (2018) £95 million for local full-fibre broadband projects.
<https://www.gov.uk/government/news/95-million-for-local-full-fibre-broadband-projects>.

UK Government, Welsh Government, Blaenau Gwent County Borough Council, et al. (2016) Cardiff Capital Region City Deal.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/508268/Cardiff_Capital_Region_City_Deal.pdf.

UK Government and Welsh Government. (2018) Swansea Bay City Region Deal.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/611685/Swansea_City_Deal_-_English.pdf.

Welsh Government. (2012) Science for Wales: A strategic agenda for science and innovation. Cardiff: WG, <http://gov.wales/docs/det/publications/120306scienceen.pdf>.

Welsh Government. (2013) Local Authority Population Projections.

<http://gov.wales/statistics-and-research/local-authority-population-projections/?lang=en>.

Welsh Government. (2016a) Commuting.

<https://stats.wales.gov.uk/Catalogue/Business-Economy-and-Labour-Market/People-and-Work/Employment/Commutin>.

Welsh Government. (2016b) *Innovation Advisory Council for Wales*. ^

<http://gov.wales/topics/science-and-technology/innovation/iacw/?lang=en>.

WERU. (2018) The Digital Maturity Survey for Wales 2017. Cardiff University,

https://www.cardiff.ac.uk/_data/assets/pdf_file/0009/1175517/Cardiff-Business-School-Digital-Maturity-Survey-2017-ENGLISH-F.pdf.

Whitacre B, Gallardo R and Strover S. (2014) Does rural broadband impact jobs and income?

Evidence from spatial and first-differenced regressions. *The Annals of Regional Science* 53: 649-670, DOI: 10.1007/s00168-014-0637-x.

Wolcott P, Kamal M and Qureshi S. (2008) Meeting the challenges of ICT adoption by

micro-enterprises. *Journal of Enterprise Information Management* 21: 616-632, DOI: 10.1108/17410390810911212.

Yin R. (1994) Case study research: Design and methods. California: Sage Publishing,