Infrastructure and Productivity: A Review

Produced for West Midland Combined Authority, Productivity and Skills Commission
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Executive summary

- Research shows the long-term economic benefits of well-designed infrastructure investments, even though it has always been debatable the direction of the causality between infrastructure and growth. Good infrastructure leads to connectivity, which increases dependence and specialisation. Not only this reduces production costs and increases consumer welfare, but also creates more business opportunities, promotes market competition, and drives innovation.
- A country or a region's digital infrastructure sets constraints on what technology firms may have at their disposal, hence the quality of the digital infrastructure has a conspicuous role to play in enhancing productivity.
- The World Economic Forum ranked the UK as the 27th country for its quality of overall infrastructure in 2016 on global infrastructure, with downward trending outlook. The UK scores particularly low on the quality of roads, air transport and railroad infrastructure, and ranks among the highest in the cost of energy. In contrast, the UK scores high on technological readiness and digital infrastructure compared to other countries.

- West Midlands enjoys overall good physical and digital connectivity, but also has weaknesses in the infrastructure system, some of which are common with other regions in the countries. The key challenges include the limited air transport capacity, high energy cost and inflexible energy supply regime, less than satisfactory digital connection and an industrial structure that is prone to changes in technological advancements.
- One of the most important and yet challenging for the WMCA is to play a crucial role in leading the infrastructure development by combining and integrating transport, digital and energy infrastructure, riding on the wave of undergoing technological advancements and local institutional changes.
- To achieve this ambition, WMCA also needs urgently to enhance the knowledge stocks of the key channels through which infrastructural factors impact on firms and local economy, and assess the priorities of the developments in delivering the most benefit to the local economy.

The specific highlighted features and recommendations are the following:

Transport infrastructure

- West Midlands heavily relies on roads, which involves considerable costs and other risks. WMCA should consider taking a whole-network approach to improve the public transport networks, and join them up to improve connectivity, capacity and resilience.
- West Midlands has limited direct links to international markets, potentially weakening businesses' competitive advantages post Brexit. The government needs to assess the full impact of this limitation and prepare for proactive responses to it.

Digital infrastructure

- West Midlands needs to improve both the coverage and the reliability of broadband connection.
- Given the complex structure of the stakeholders of digital infrastructure and the sheer importance of the digital connectivity in all sectors of the economy, governments need to lead a way to understand better, build, and encourage businesses to take advantage of the technological advances in broadband connection and more broadly in digital infrastructure that facilitates the use of internet of things, big data, digital platforms and automation.
- Equally important, governments need to assist in creating an ecosystem where stakeholders of the digital infrastructure can work together towards consistent goals, and provide crucial

knowledge to encourage businesses to adopt and upgrade technology in the fast-changing market.

Energy infrastructure

- Britain faces significant challenges to maintain sustainable levels of energy supply. Businesses and consumers face high energy costs, which impairs business competitiveness and reduces consumer welfare.
- The very complicated state-driven system of the energy market has become a key barrier to resolving the issues of the UK energy infrastructure that causes high legacy costs, rigid policies and regulations, and the continued exercise of market power in the energy sector.
- WMCA needs to work with the energy market sectors to break the rigidity in the regulation and policy-making, design and provide incentives for intermittent generators to engage more with the competition, leading to a more balanced and flexible markets.
- WMCA needs to build evidence based knowledge stock to aid policy-making in several areas. In particular, research is needed to understand the relationship between the intensity and efficiency of energy usage and firm productivity, which will have significant policy implications. Locally, the authority needs to understand why the local energy consumption is largely outsourced, and assess the scope for promoting a local energy sector supply.
- WMCA needs be proactive in seeking paths to a more sustainable energy infrastructure, by promoting flexible energy supply to allow variable costs, and by encouraging the transition of the current energy sectors to alternative forms of energy supply.

1. Introduction

The purpose of this report is to review the current understanding about how infrastructure impacts on productivity and growth, in the context of the UK and the West Midlands, so as to identify the key issues in the existing infrastructure and in turn offer recommendations. Systematic economic analyses of the links between the infrastructure and firm productivity are scant, and even more so is the availability of systematic and consistent data across local regions. To aid policy making, we also highlight the important gaps in knowledge that need to be filled.

Infrastructure is hugely important to a competitive modern economy. Research has shown both conceptually and empirically the long-term economic benefits of well-designed infrastructure investments, even though the direction of the causality between infrastructure and growth has always been in debate. In contrast, ill-designed infrastructure investments lead to wasteful investment spending or reduced return to investment, misallocating scarce resources.

Although the current academic literature and available policy documentations discuss the issues of infrastructure of transport, digital communication and energy supply, mostly separately, our knowledge is not always updated about the increasingly more sophisticated and integrated infrastructure demand that have become more crucial to businesses, supply chains and the broad economy. The recent decades saw swift technological changes surrounding the digital economy we live in, to some extent in an unpredictable way. Only up-to-date knowledge and well-connected understanding about the key elements of these infrastructure developments would allow appropriate responses to fast changes.

Conceptually, the level of country's infrastructure has large implications on the economic growth and its ability to succeed in the global environment (Stewart, 2010). The development of physical, digital and alternative energy infrastructures shapes the production, consumption, and the interactions between businesses. Better quality of infrastructure leads to connectivity, which increases dependence and specialisation. Not only this reduces production costs and increases consumer welfare, but also creates more business opportunities, promotes market competition, and drives innovation. Inadequate infrastructure, apart from obstructing the realisation of these benefits, results in high maintenance costs and other negative non-pecuniary consequences that reduce welfare.

The World Economic Forum ranked the UK as the 27th country for the quality of overall infrastructure in 2016 on the global infrastructure, with downward trending outlook. This places it far behind almost all its peers, including the US which suffers notorious infrastructural problems.

According to the available international comparative statistics, the UK scores particularly low on the quality of roads, air transport and railroad infrastructure, and ranks among the highest in the cost of energy. In contrast, the UK scores high on technological readiness and digital infrastructure comparing with other countries.

While the statistical picture of the WMCA areas is incomplete due to data limitation, the report suggests that WMCA areas overall enjoy good physical and digital connectivity, but also has weaknesses in the infrastructure system. There are many challenges that it faces such as the limited air transport capacity, uneven quality of digital connectivity, high energy prices, the limited alternatives for energy generation, just to name a few. Still, exciting opportunities present themselves with undergoing technological and local institutional changes and the potential benefits to combine and integrate transport, digital and energy infrastructure developments. Clearly, policy-making processes would benefit from having the many gaps in knowledge on these issues being filled.

This brief review will focus next on each of the transport, digital and energy infrastructure types in turn, and discuss the combination and integrated issues that are relevant to more than one of these types. It is worth noting that while there are other aspects of infrastructure that are important to an economy, such as sewage, bridges and tunnels, this report focuses on transport infrastructure (airports, roads, ports and railways), digital/virtual infrastructure (communication technologies, digital platform and automation, AI) and energy-related infrastructure (electric, fuel, wind and solar plants).

2. Transport

Transport has long been recognised as fundamental to the economic development and growth, with many direct benefits onto transportation users and more widely onto the economy. Typically transport includes road, rail, aviation, and waterways. The common features of the high building costs and negative environmental externalities of transportation infrastructure determine that it is predominantly provided by public.

Physical infrastructure matters to productivity not only because it determines the accessibility of businesses to some key factors of production (labour and intermediate inputs), but also access to market (moving from production to consumption). The cost of such accessibility determines the competitiveness of a business, holding other factors constant. This

idea is most explored, conceptualised and empirically tested in the international economics and business literature, where the reduction of transport costs has positive impact on international trade. Because the friction of space – how much effort is needed to ensure the movements of goods to destination – creates trade barriers by imposing costs, the removal of the barriers occur when goods are cheaper to be transported, due to factors such as improved transport network, better quality of the transport infrastructure, or indeed more competitive transport provision.

Furthermore, although it is less argued for, an increasingly more important landscape of service trade also benefits from improved transport infrastructure. This is because, for service trade, the model of delivery is distinct compared to trade in goods as they are more sensitive to changes in technologies that enable the speedy and reliable movement of either people or information (Kneller and McGower, 2017).

Overall, given the linkages between transport infrastructure and economic growth are particularly clear, for regions like West Midlands where export and FDI contribute considerably to the economy, the transportation has important indirect effect on international business engagement.

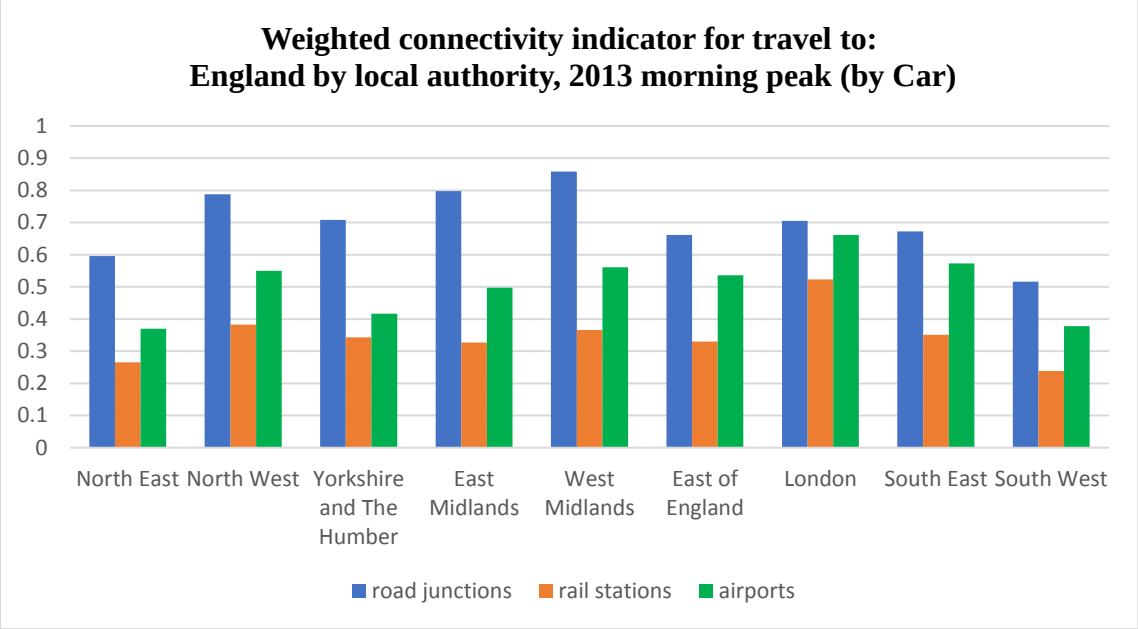
Current status of transport in the West Midlands

Overall connectivity

In terms of overall connectivity with trains stations, road junctions and airports, Figure 1 below shows that West Midlands ranks relatively well compared to other regions.[1] However, it must be noted that this ranking might not reflect the day-to-day connectivity, because investments in infrastructure play a key role in the reduction of congestions and other externalities.

Figure 1

[1] The weighted connectivity indicator is constructed using travel times to junctions or airports or rails station, weighted by size (measured by number of destinations served weekly.)

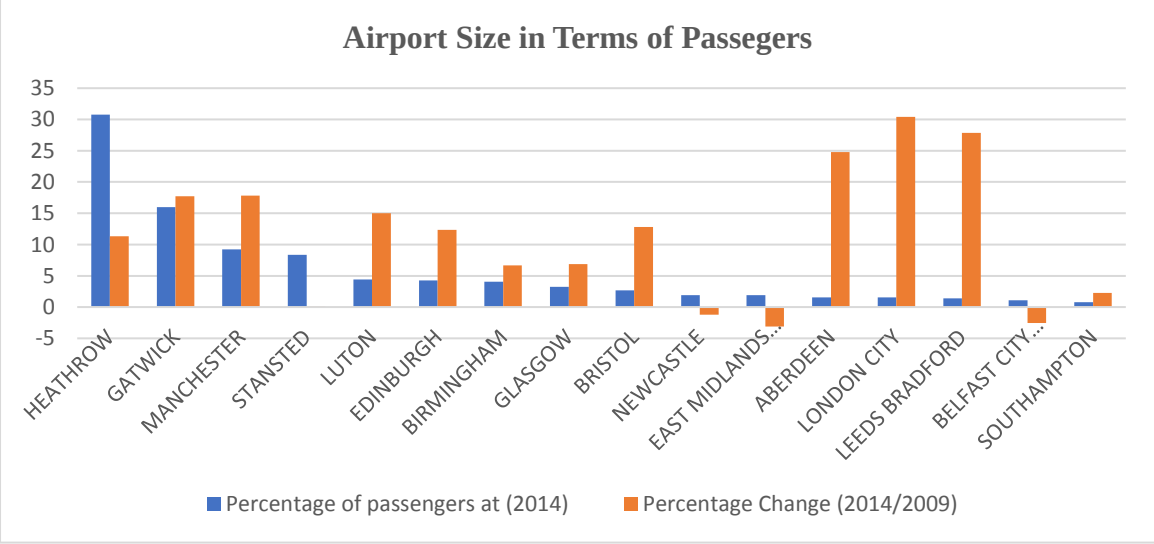


Source: Department of Transport UK.

Airport capacity

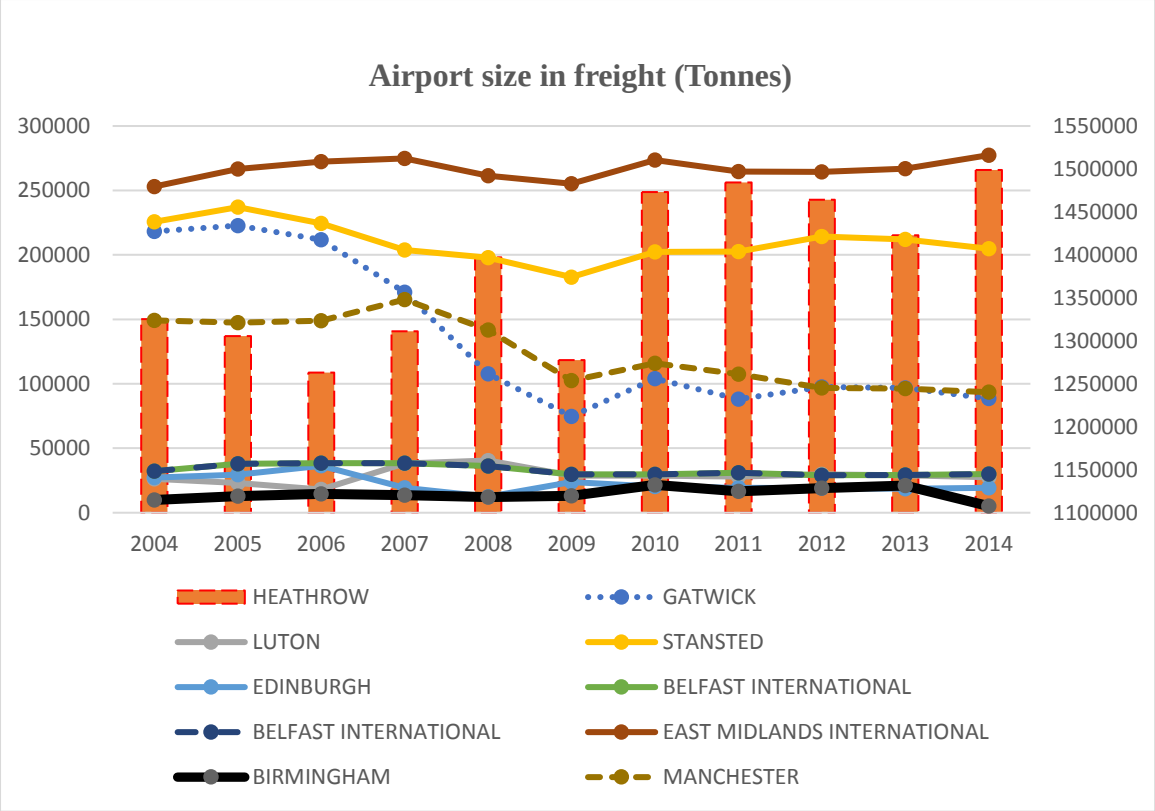
The Airport capacity matters for regional development because it has a large impact both on local and national economies. Figure 2 and 3 below shows the overall performance of the UK's biggest airports in terms of passengers and cargo in recent years. They reveal that the only airport in West Midlands, namely Birmingham airport, is far behind other leading airports.

Figure 2



Source: UK Civil Aviation Authority data.

Figure 3



Source: Authors' calculation based on UK Civil Aviation Authority data. Right axis scale is for Heathrow Airport.

Government expenditure

Figure 4 highlights the overall public spending on transportation services across the UK regions. What emerges is that London, the South East and the North West regions overall have higher investments compared to the Midlands regions. In fact, only the North East has overall lower investments in physical infrastructure. However, when we consider expenditure per capita (i.e. taking into account total population in the region) the Midlands regions are still behind many regions. In particular, the West Midlands is still below London, the North West and Yorkshire expenditure per capita.

Figure 4

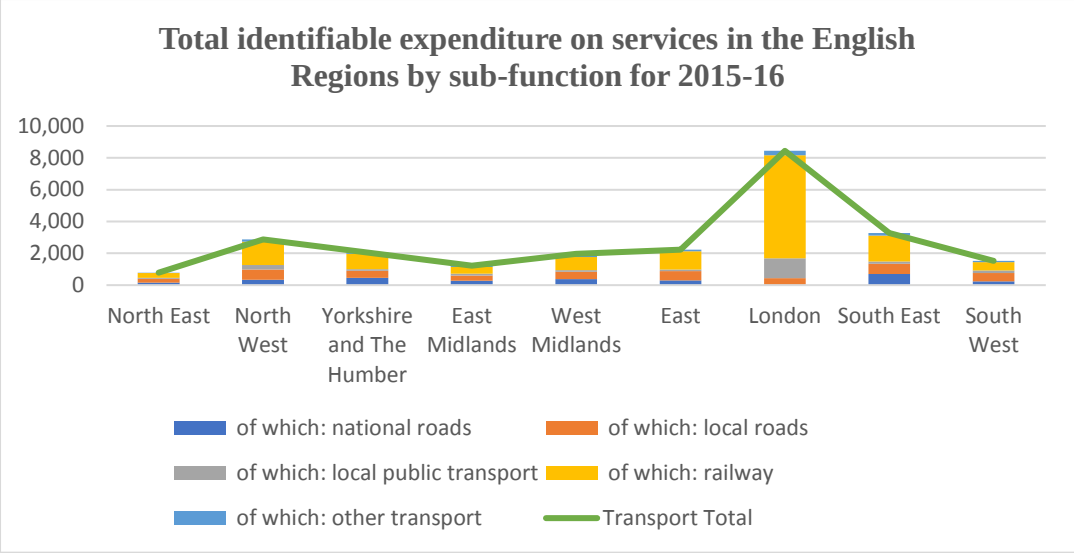
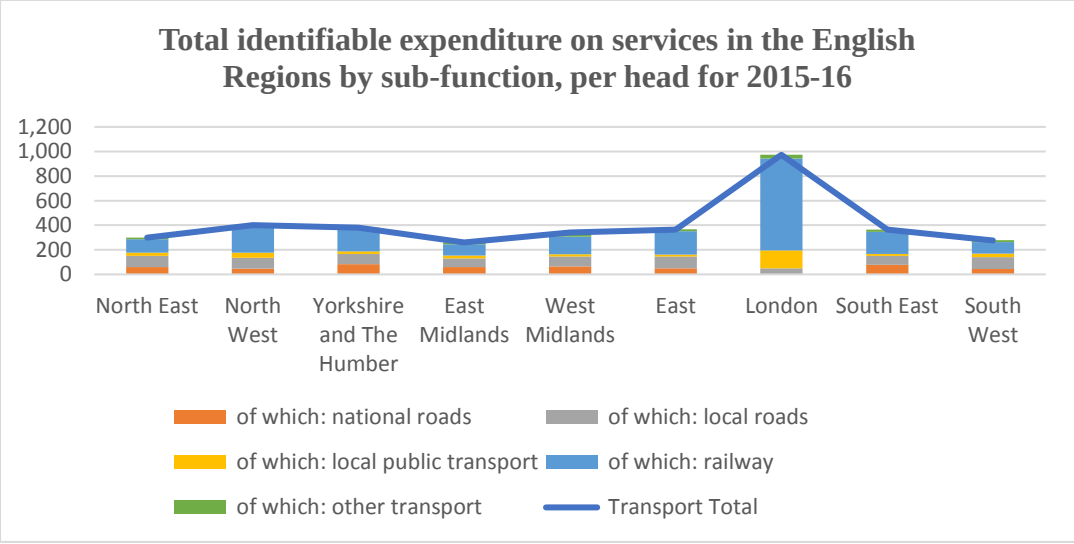


Figure 5



Source: Authors' calculation based on HM Treasury statistical data. Public Expenditure Statistical Analyses (PESA).[2]

Contribution to the economy and the investment multiplier

Investment in improvements of the transport infrastructure should lead to transport cost reduction and increased welfare. Leaving aside the reliability issues with the impact evaluation approaches, better infrastructure should generate relatively higher returns. Indeed, different types of transportation tend to have different impact on national and regional economies. In addition, the below tables show that the risk factors should also be taken into account in any relevant cost and benefit analysis. Unfortunately, only limited evidence is available at the more local level.

[2] https://www.gov.uk/government/statistics/public-expenditure-statistical-analyses-2016

Rail/Railroads

Node/what's transported: Rail yards/trains

Contribution to economy: UK	In 2014, it is estimated that railways the railways and its supply chain employ 216,000 people, generating £10.1bn of gross value added (GVA) a year.[3]
Impact/multiplier: UK	Governments received £0.7bn net from train companies.[4] The benefit–cost ratio (BCR) for the first phase of HS2 is estimated to be 1.7.[5]
Risk/cost: UK	Railway receives about £4bn in government funding to fund track renewals and improvement and deterioration of the track in recent years.
Contribution to economy: WM	According to West Midlands Rail company, which manages rail franchising for the WM, the contribution of railways to WM economy can be estimated to be about £2bn of economic benefits, which has the potential to unlock new jobs and boost economic growth.[6]
Impact/multiplier: WM	Nothing found.
Risk/cost: WM	Network Rail highlight that about £100 million spent every single week on improving the railway in Britain.[7] These costs involve improving line speeds; capacity utilisation; reliability and punctuality, access to the network.

Roadways

Node/what's transported: Trucks, buses and cars

Contribution to economy: UK	The House of Commons 2011 report contributed to the UK economy for £91.34 billion (GVA) and created 8.9 million jobs. [8]
Impact/multiplier: UK	The multiplier effect of investments in roadways/motorways is estimated to be ranging from 0.5 to 2 (Leduc and Wilson, 2012).[9]
Risk/cost: UK	According to Highways Agency Business Plan Performance Measures 2012-13, the cost per mile for maintenance of highways is £32,227.[10]
Contribution to economy: WM	Nothing found.

[3] Oxera 2015. What is the contribution of rail to the UK economy? Prepared for the Rail Delivery Group.

[4] UK rail industry financial information 2016-17. ORR

[5] It is assessed as 'medium value for money (VfM)' according to the UK Department for Transport (DfT)'s own categorisation. Source: Oxera 2012 report "Not in my kitchen: the economics of HS2".

[6] West Midlands Rail, http://www.westmidlandsrail.com/news/proposed-upgrades-to-regions-rail-network-welcomed/. West Midlands Rail is a company limited by guarantee, owned by the partner authorities, which manages rail franchising for the West Midlands.

[7] https://www.networkrailmediacentre.co.uk/news/britain-runs-on-rail-new-figures-show-the-full-extent-of-the-rail-industrys-contribution-to-the-west-midlands#.

[8] Transport and the economy. 2011 by authority of the House of Commons London: The Stationery Office Limited. p135.

[9] Highway Grants: Roads to Prosperity? by Sylvain Leduc and Daniel Wilson, 2012. Economic Letter

[10] http://assets.highways.gov.uk/about-us/corporate-documents-business-plans/Cost%20of%20maintaining.pdf

Impact/multiplier: WM	Nothing found.
Risk/cost: WM	Birmingham Post suggests that Congestion is costing the West Midlands £1 billion a year. No other sources of information is found.

Aviation/Airspace

Node/what's transported: Airports/Airplanes

Contribution to economy: UK	Aviation raised £1.9 billion in the form of Air Passenger Duty (APD), in 2009, and forecast by the Office for Budget Responsibility to grow to £3.8 billion in 2015–16. The study found that aviation represented 1.5% of the UK economy, contributing £18.4 billion towards UK GDP in 2007.[11]
Impact/multiplier: UK	Nothing found.
Risk/cost: UK	Nothing found.
Contribution to economy: WM	Birmingham Airport in 2014 total economic impact in the West Midlands was around £1.1 billion in Gross Value Added (GVA) and it also supported around 25,300 jobs as estimated by The York Aviation 2015 report[12].
Impact/multiplier: WM	The York Aviation 2015 report Birmingham Airport total impact across the UK is estimated to be around £1.7 billion in GVA and around 39,850 jobs created. [13]
Risk/cost: WM	Nothing found.

Overall, the West Midlands is known for being very reliant on roads, which causes considerable costs and other risk. CBI (2017) recommends developing a joined public transport network to improve connectivity, capacity and resilience. Along the same vein, better connections through public transport is also needed by taking a whole-network approach.

Furthermore, the transport links of the West Midlands area in the UK seem on par with other areas, but the links to international markets seem to be very limited. Post Brexit, businesses are expected to find it advantageous to directly link to international markets (CBI, 2017). Although there are figures of the economic contributions that Birmingham Airport make in the regional economy, there is little research on the negative impact of its low capacity.

[11] Transport and the economy. 2011 by authority of the House of Commons London: The Stationery Office Limited. p195.

[12] York Aviation, October 2015. The West Midlands aviation opportunity. An analysis of the economic value and potential of Birmingham Airport.

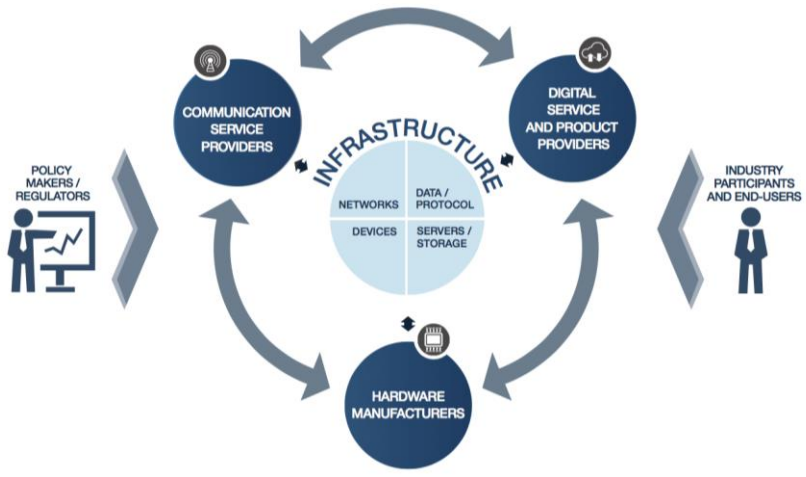
[13] York Aviation, October 2015. The West Midlands aviation opportunity. An analysis of the economic value and potential of Birmingham Airport.

3. Digital infrastructure

The digital infrastructure aims at developing, collecting and spreading information electronically. The fundamental reason why the digital infrastructure matters is due to the role of technology choice in determining productive efficiency. This is well theorised and widely supported by evidence. Put plainly, the technology at a firm's disposal influences how productive it can be. Subsequently, more productive firms are more likely to go on to do other great things – to invest, export and innovate, to name a few. Since a country or a region's digital infrastructure sets constraints on what technology firms may have at their disposal, the quality of the digital infrastructure has a conspicuous role to play in enhancing productivity.

One of the distinct features of the digital infrastructure lies in its complicated stakeholder system. Policy makers have a significant role to play in assessing the adequacy, and indeed the barriers of, technological, financial, political and social factors that maintain and develop the telecommunications network and digital ecosystem (WFE, 2017). Apart from policy-makers, regulators and the owners and dispensers of spectrum for mobile networks, there are other major players too.[14] Together, all are responsible for the fixed and mobile networks, exchange points, data centres, devices and network equipment, and platforms and protocols that make the internet work (See Figure 6).

Figure 6



Source: World Economic Forum (WEF, 2014).

[14] For example, non-governmental organizations (NGOs), industry associations, standards bodies, multistakeholder associations such as the World Wide Web Consortium (W3C), the Internet Corporation for Assigned Names and Numbers (ICANN) and the International Telecommunication Union (ITU), a UN agency (WEF, 2014).

Broadband connectivity and reliability

In terms of digital connectivity, the UK ranks well in comparison to other countries. Indeed, according to Ofcom 2017 report, more people are being connected to internet through extended coverage of fixed and mobile communications.[15]

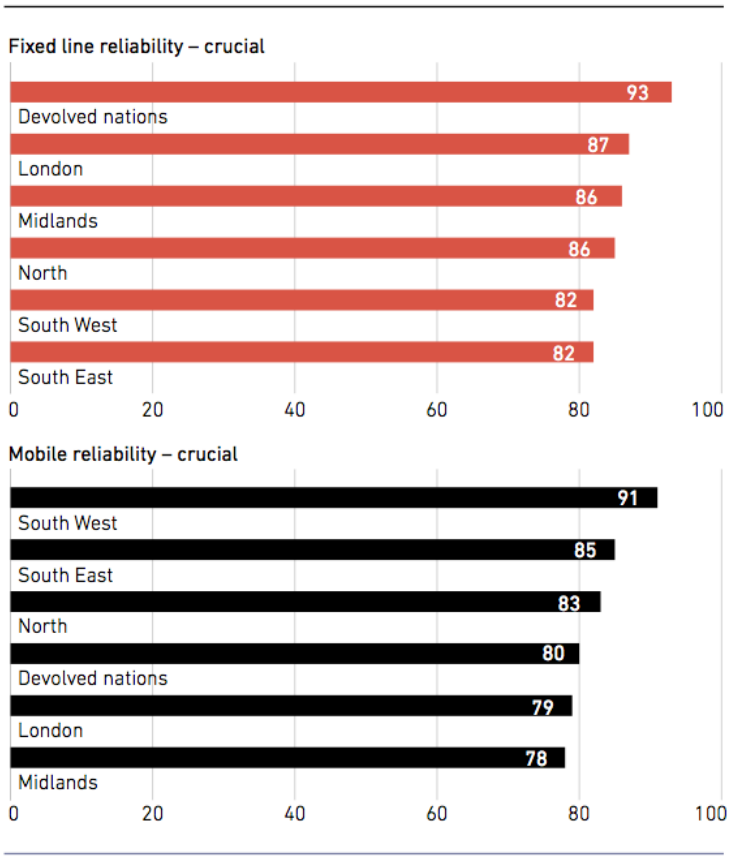
Connecting with the digital network has become crucial for businesses. WEF (2014) reports the number of broadband connections in the G-20 areas increased sixteen-fold to 2,707 million over the decade between 2005 and 2015, while the percentage of mobile connections grew from nothing to 79%.

However, the reliability and the speed of the broadband connection is still a major concern. In fact, businesses and household in many parts of the country are not satisfied with the services of the fixed and mobile coverage. In many cases, poor connectivity or coverage is the main problem. According to the Ofcom, about 1.1 million premises are unable to have adequate access to broadband (Ofcom, 2017).

The lack of fast and reliable digital connectivity is of great concern to SMEs, in particular those who are very dependent of digital connectivity. Ofcom estimates that almost 230,000 (7%) of small businesses have this problem. Urban areas in general tend to have relatively better and more reliable connectivity compared to rural areas. The recent CBI/AECOM survey finds more than four out of five businesses see the more reliable fixed and mobile connections as essential to future business operations. It also reports that 78% of SMEs and two-thirds of all firms highlight the need to maintain ambitious investment to improve the broadband speed. In the same report, a regional comparison shows that Midlands score lower than the average developed nations in terms of the appetite of investment for developing mobile broadband reliability (Figure 7).

[15] https://www.ofcom.org.uk/__data/assets/pdf_file/0024/108843/summary-report-connected-nations-2017.pdf

Table 7: Investment to improve broadband reliability



Source: CBI/AECOM (2015) report.

More specifically, the West Midlands areas do well in terms of superfast broadband coverage (see Table 1). Metropolitan areas are well connected, especially in terms of ultrafast broadband. However, when it comes to the actual users' received speed, the picture can vary across places. The best-connected users may enjoy over 10 times the speed of the worst-connected ones.

Table 1: WMCA Broadband coverage and speed

LEP	Council	Superfast (Over 30 Mbps) (% premises)	Ultrafast (Over 100 Mbps) (% premises)	Download Q4 2017 (Mbps)			Upload Q4 2017 (Mbps)		
				Bottom 20%	Mean	Top 20%	Bottom 20%	Mean	Top 20%
Black Country	Walsall	97.70%	75.10%	6.4	29.9	48.4	0.6	5	8.4
	Dudley	99.20%	91.90%	6.3	32.6	49.5	0.7	5	7.9
	Sandwell	99.20%	78.00%	7.7	35.4	54.7	0.8	5.8	8.9
	Wolverhampton	99.20%	92.50%	9	41.6	65.7	0.9	5.8	8.7
GBS LEP	Birmingham	96.60%	88.60%	6.8	37.3	56.2	0.7	6.2	8.7
	Solihull	96.60%	82.20%	7.1	33.8	53.6	0.7	5.3	8.6
	Cannock Chase	99.20%	22.10%	6.6	25.2	36.4	0.7	5.4	8.8
	Lichfield	95.20%	63.90%	7.2	29.2	46	0.6	5.4	8.9
	Redditch	99.30%	89.10%	5.6	32.1	49.1	0.8	5.6	8
	Tamworth	99.80%	86.60%	9.8	35.8	49.3	1.8	5.7	8.6
	Wyre	97.60%	6.60%	7.7	23	36.4	0.7	5	8.2
	East Staffordshire	93.70%	0.60%	4.1	21.7	36.5	0.6	5.3	8.4
	Bromsgrove	94.90%	23.60%	4.8	26.7	38.9	0.7	5.2	8.6
Coventry and Warwickshire	Coventry	95.50%	70.70%	7.1	34.3	52.6	0.7	6.1	9.1
	Warwick	95.10%	69.80%	6.3	33.5	50.7	0.7	5.9	9.7

Source: thinkbroadband.com.
Note: Superfast broadband has two definitions, the EU 30 Mbps and faster figure and the UK Westminster definition of over 24 Mbps. Ultrafast if over 100 Mbps.

Beyond broadband

It is important to note that for businesses and organisations, digital or virtual infrastructure goes beyond just broadband connection. Four broad technological areas mark the key areas of infrastructure building, AI, cybersecurity and digital platforms (for example the cloud platform). These elements of the digital infrastructure are crucial for building business models, business strategy, workforce, customer interactions, business operations. Without them, businesses are naturally constrained from being competitive against productive firms.

Internet of things (IoT)

The Internet of Things (IoT) is made up of a loose collection of disparate, purpose-built networks, all embedded with electronics, software, and sensors that enable them to exchange and analyse data. It is a robust network of networks, of transport, energy, business, education and more. The IoT has been transforming the way we live for nearly two decades, and that transformation is accelerating, paving the way for responsive solutions, innovative products, efficient manufacturing, and ultimately, amazing new ways to do business. One of

the most exciting areas that will be revolutionised by IoT is the global value chain. The connectedness and smart management using IoT will allow businesses to improve operational efficiencies less costly and seek more actively revenue opportunities with more and better data, both in terms of product and services domain and geographic domain, all of which translate into productivity gains, providing crucial competitive edge in the future markets.

Furthermore, many IoT projects promise to close the gap between poor and rich, improve distribution of the world's resources to those who need them most, and help us understand our planet, so policy-making can be more proactive and less reactive (Evans 2011).

The evolution of the IoT largely includes phases of connecting the unconnected devices and subnetworks, making smart and connected devices, and create applications that allow autonomous functioning of the networks. Each phase hinges very much on the advances of the ICT sector, which underpin data-driven innovation – for instance, the main enablers of the IoT are big data, the cloud, machine-to-machine (M2M) communication and sensors (OECD 2015c: 244), and the technology adoption of the users of the networks, businesses for example.

The ICT sector was relatively resilient to the 2007-09 global economic crisis, although has yet to retain its pre-crisis levels in some countries, and is an important venue for R&D and patenting. The UK digital sector contributed £118.4 billion to the UK economy in 2015, accounting for over 7% of UK GVA, with faster growth in contribution than average over 2010-15. It is notable that the UK digital sector enjoys trade surplus by exporting £14.5 billion worth of services to the EU in the same year, and £17.7 billion worth of services to rest of the world. For the West Midlands, only the IT, software and computer services sub-sector has created 2.08 billion GVA in 2015, 6% of the national total. While using the OECD's ICT definition, by 2016, West Midlands ICT sectors provide 95,000 jobs, 6.6% of the nation total.[16]

Big Data

Data is now the key infrastructure asset (KPMG, 2017). Across sectors there is a common need for building digital infrastructure for the purpose of collecting data, managing it and utilising it to

[16] https://www.parliament.uk/documents/commons-committees/Exiting-the-European-Union/17-19/Sectoral%20Analyses/36-Technology-ICT-Report%20FINAL.pdf.

aid the decision-making process. Governments are in the best position to understand the value of the data they own, extract information from it and utilise it to plan and manage infrastructure. Currently, this has been done in piecemeal fashion (KMPG, 2017) and hence the potential of big data is under-realised.

Smart cities

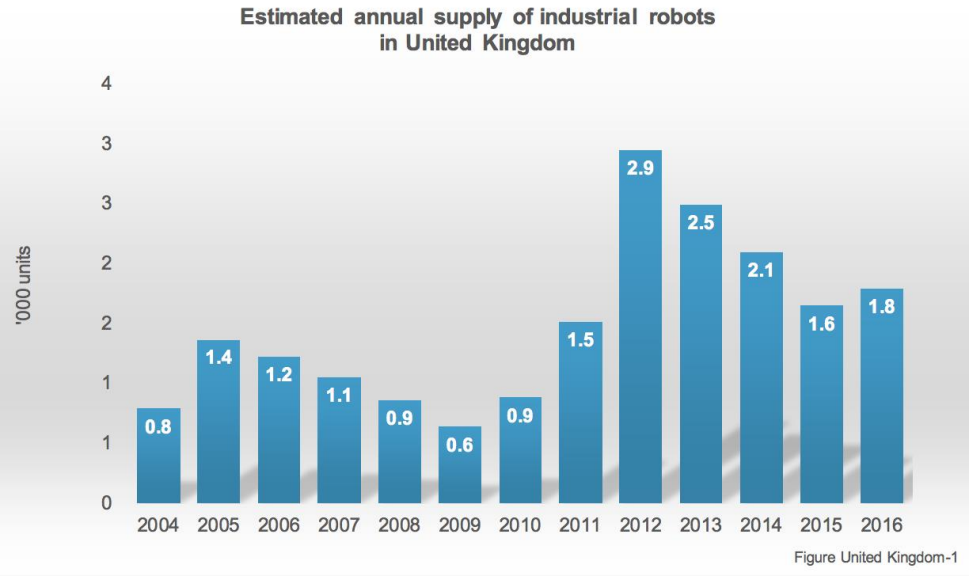
Smart city is a concept that encompasses smart solutions of transport, energy, health care, water and waste in urban living. Hence it goes well beyond the use of ICT for better resource use and less emissions. For example, it also includes a more interactive and responsive city administration, safer and secure public spaces (BIS, 2013). To be consistent with the approach of integrating and combining different types of infrastructure, smart cities provide great avenues to experiment and apply the principle in smaller scales and more supported environment, which usually makes the project more likely to succeed. The experience with smart cities will provide important lessons to all urban developments. To achieve this, governments have a fundamentally enabling role of taking a lead in removing barriers to innovation and facilitating collaboration between multiple diverse actors.

With the technological advancement, the UK has witnessed fast growth of small city markets. In the most recent Huawei's UK Smart Cities Index, Birmingham is ranked 4th of the country, for setting up a well-designed small city strategy, which benefits further from the West Midlands approach to developing digital infrastructure.

Automation

UK's robot adoption has been moderate. At the end of 2016, UK's stock of operational robots only ranked 12th in the world, with 71 robots per 10,000 employees in the manufacturing sectors, concentrating on handling operations, welding, automatic industries and plastic and chemical industries, and 39 robots per 10,000 employees in other sectors (IFR, 2017). In 2016, sales of industrial robots in the UK as a whole increased by 9% to 1,787 units (Figure 8). The IFR predicts that a moderate growth of robot installations during the period 2017 to 2020 is likely.

Figure 8



Source: IFR (2017).

It is notable that the use of robots is much more intensive in the Automotive industry, with 673 robots per 10,000 employees and rising. Figure 9 also shows that the Automotive industries lead by far the sales and stock of robots installation. Therefore, this would have bigger impact on the West Midlands regions given the weight of the Automotive sectors there. However, there is no detailed statistics of this growing phenomenon, nor a careful study to measure the potential impact on productivity and jobs, which is well warranted to bear important implications.

Figure 9

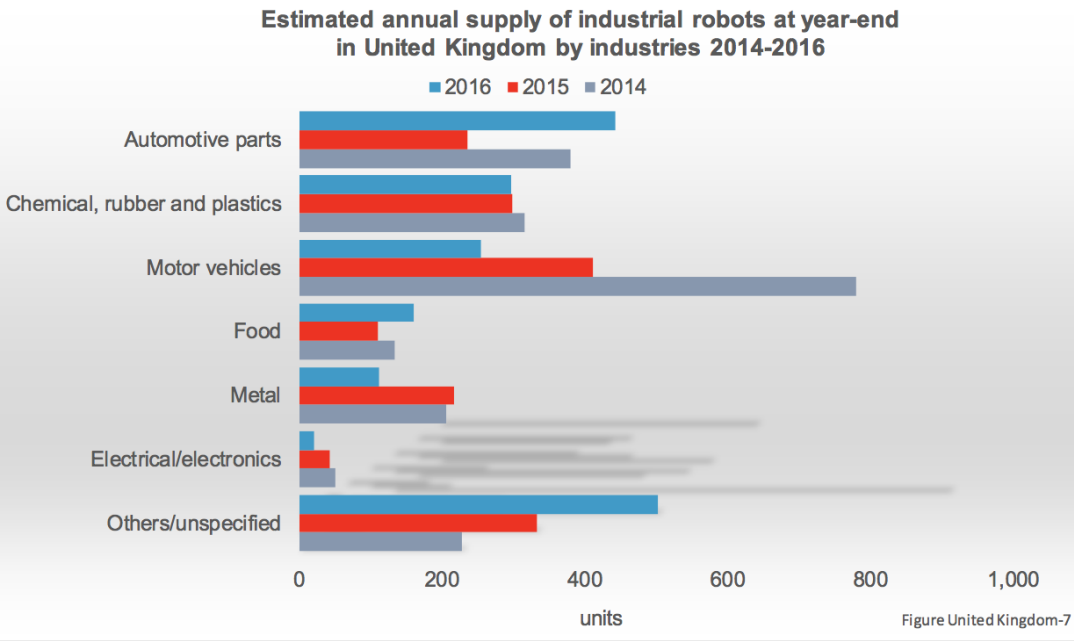


Figure United Kingdom-7

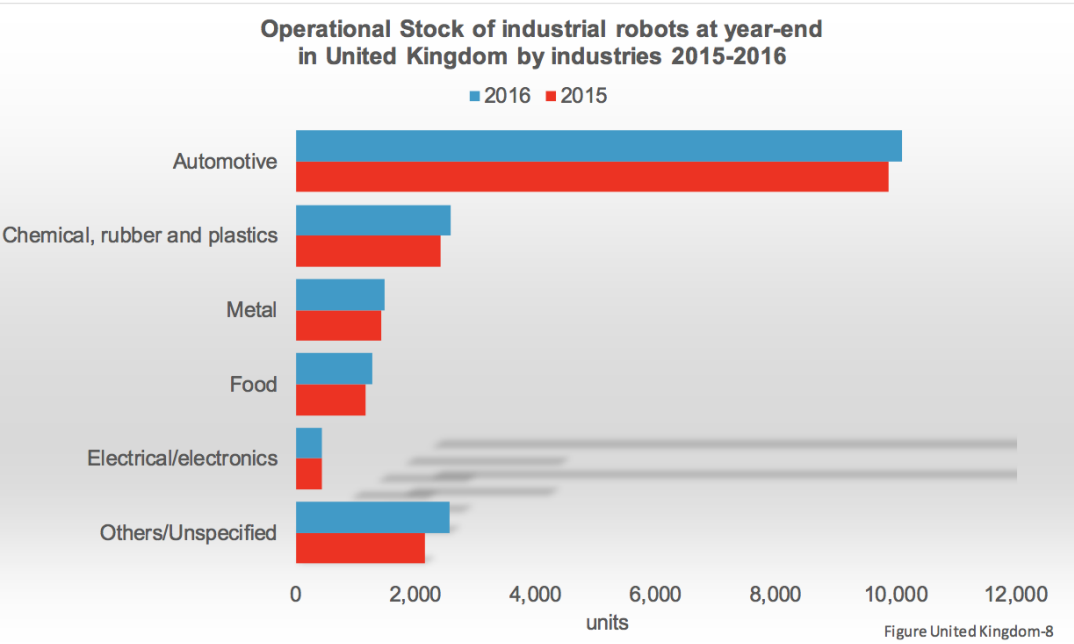


Figure United Kingdom-8

Source: IFR (2017).

Overall, both the coverage and the reliability of broadband connection in the West Midlands should be improved, consistent with the business sentiment. Given the complex structure of the stakeholders of digital infrastructure and the sheer importance in all sectors of the economy, governments need to lead a way to understand, build, and encourage businesses to take advantage of the digital infrastructure advances in broadband connection and more broadly digital connectivity that facilitates the use of internet of things, big data, digital platforms and

automation. Equally important, governments need to assist in creating an ecosystem where stakeholders of the digital infrastructure can work together towards consistent goals, and provide crucial knowledge to encourage businesses to adopt and upgrade technology in the fast-changing market.

4. Energy infrastructure

The accessibility of key energy resources in the economy - electricity, fuel (oil and gas) and water - plays a key role in economic development. Reliable and affordable energy supply allows businesses to prosper while a limited supply of these inputs constrains the overall economy.

The classic economic literature establishes that the energy infrastructure stock and investment have significant impact on the aggregate productivity (Aschauer, 1989). The recent evidence is heavily concentrated in the developing economic context, showing that an improvement in energy infrastructure enhances productivity and alters the course of the economic development in these countries.[17] At firm level, the availability and the cost of energy plays a fundamental role in producing output, as a key intermediate input of production, alongside production materials. The WEF Competitiveness Report (2013) overviews the links between electricity access, quality of electricity supply with productivity of small and medium sized firms.

Overall though, the theoretical explanations of how energy use impacts on productivity is not all clear; and the empirical evidence is limited. Theoretically, the value-added approach of total factor productivity estimation implicitly assumes that technical change only operates on capital and labour inputs, while all other inputs are used in fixed proportions. This means that the use of energy does not impact on productivity directly but indirectly through adjusting labour and capital. However, technical change is a complex process; some types of changes affect all factors of production simultaneously while others affect individual factors of production separately (Feng G, Serletis, 2008). This implies that the use of energy should affect firm's resource allocation in the production process and how effectively such allocation drives output,

[17] For example, more reliable electricity supply has large impact on firms' unit costs (Allcott et al. (2016), Grainger and Zhang (2017) for India, Fisher-Vanden et al. (2015) for China, Moya (2013) for Africa. Grainger (2017) reports that on average a 10% increase in outages leads to a 0.14 percent decrease in firm's output and 0.36 decreases in its value added in Pakistan.

hence productivity.

Based on the US industrial subsectors and firm level data, Baptist and Hepburn (2013) find a negative relationship between intermediate input intensity and TFP. The evidence suggests that intensive energy-using sectors tend to be less productive. The researchers argue that more intensive human capital accumulation in the workforce leads to positive spillovers between factors of production (Acemoglu, 1996), while well managed firms are likely to be productive while reducing their intermediate input intensity (Porter & van der Linde, 1995; Baptist and Hepburn, 2013).

Although there is no direct UK evidence, the fact that a potential reduction of energy use and material could enhance productivity has significant policy implications. This marks an area of research in which advances of knowledge would clearly benefit policy-making.

UK Aspiration: to build a competitive, flexible and secure modern energy system

While the availability and reliability of the energy supply is less problematic in the context of developed economies, the high cost of energy, especially electricity, and the environmental impact are primary concerns. Britain, as several other developed countries, faces significant challenges in maintaining sustainable levels of energy supply. Indeed, if these challenges are not adequately addressed by appropriate supply-side policies then businesses and consumers are likely to face very high costs, which may well result in detrimental effects on the competitiveness of the business sector.

High energy cost

The most thorny issue by far in the UK energy sector is that the cost of energy is too high. Helm (2017) points out that the energy cost is significantly higher than it needs to be to meet the government's objectives and, in particular, to be consistent with the Climate Change Act (CCA) and to ensure security of supply. Figure 10 shows the general trend in industrial and domestic fuel prices in the UK over the period 1994-2016. Since 2003 there has been a steady increase in the price of all energy components. In particular, heavy fuel oil and gas reached their highest price in 2012 and 2013 respectively. Since then, the price of these components has started to decline with the biggest drop in the price of Heavy fuel oil price in 2015. Figure 10 shows the

underlying trends for gas, electricity and solid fuels for domestic sectors. We observe a steady growing trend since 2010 that peaks in 2014, followed by a drop.

Figure 10

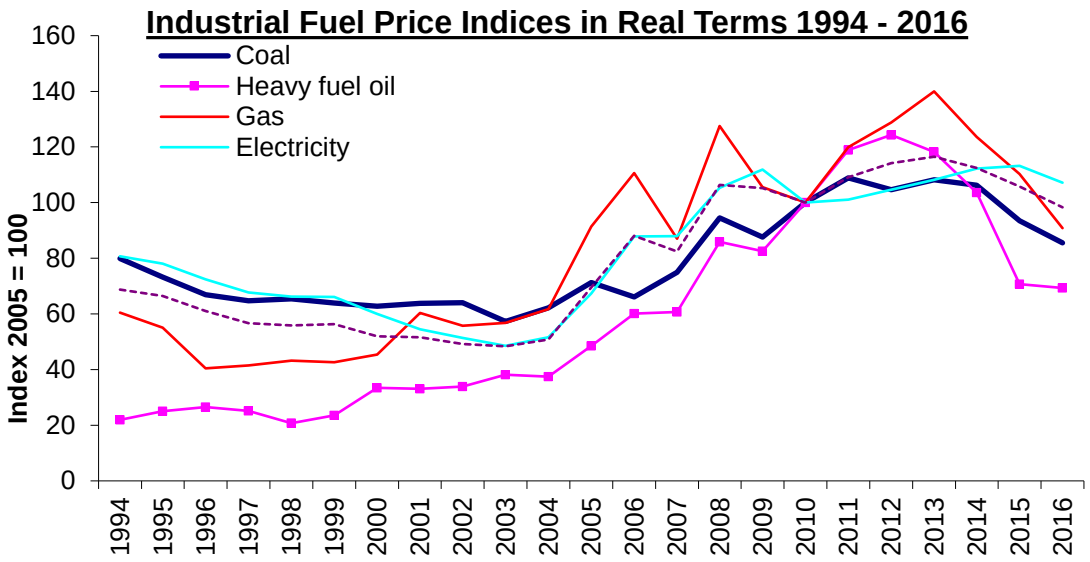
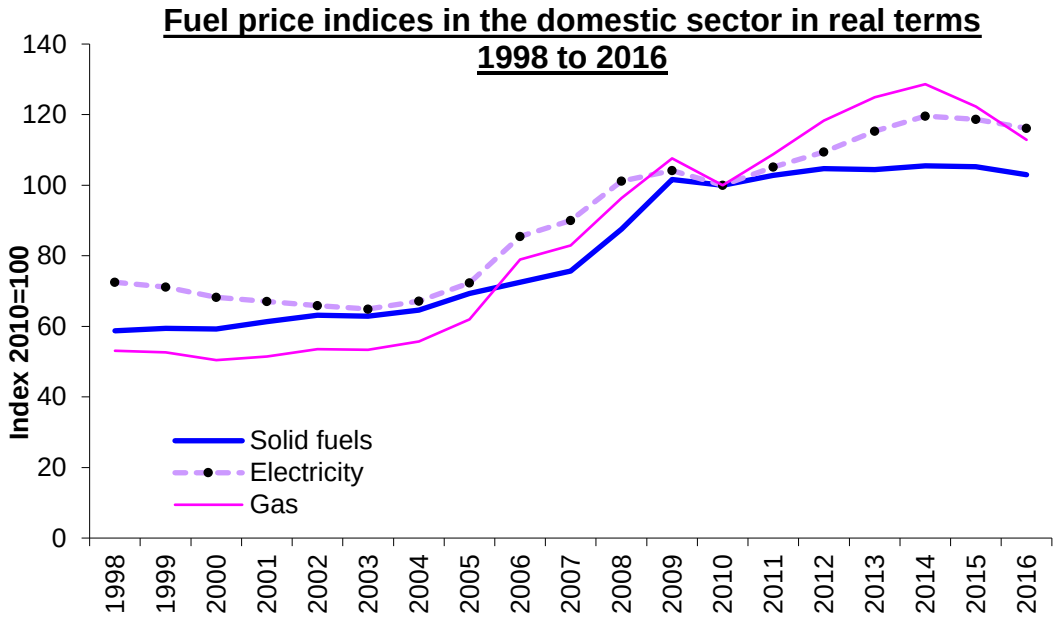


Figure 11

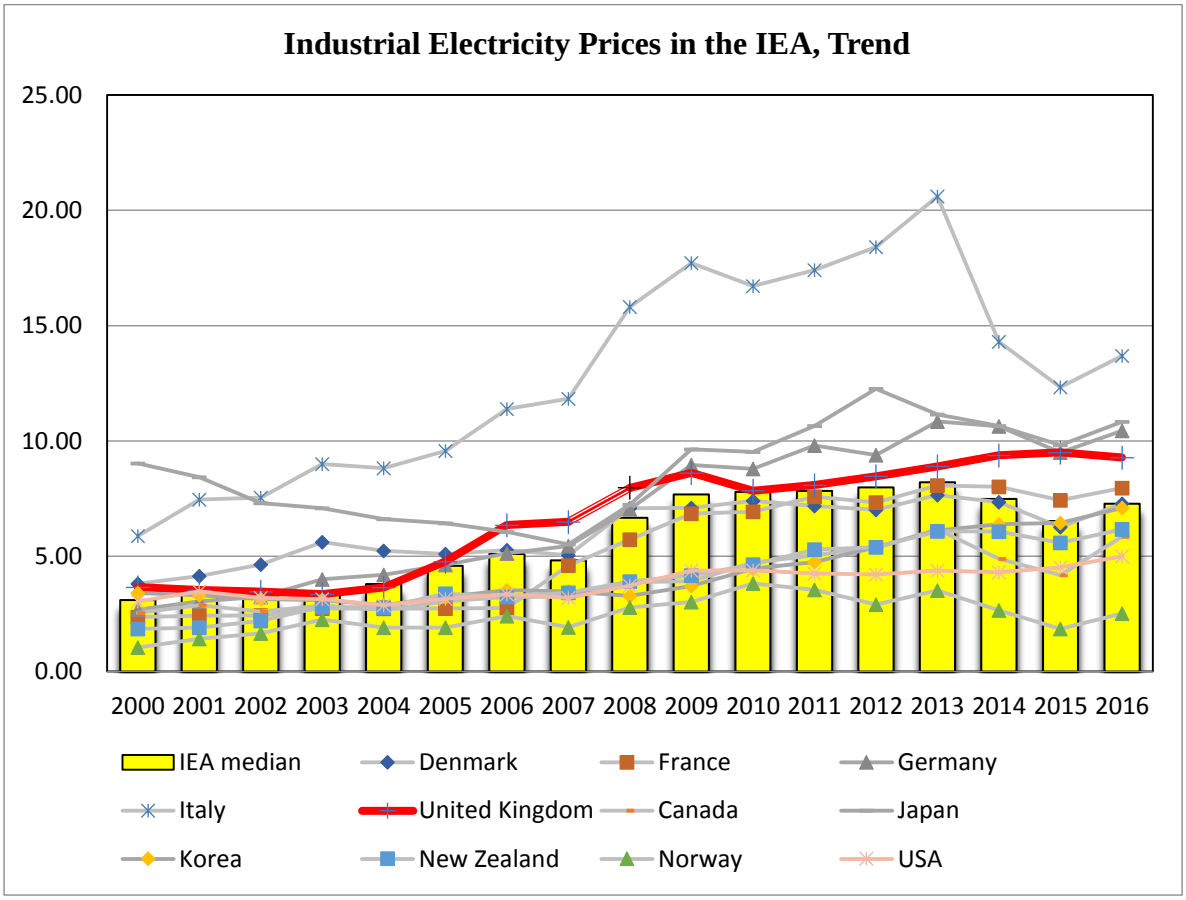


Source: Department for Business, Energy & Industrial Strategy. Industrial Fuel Price Index in Real Terms 1994-2016. 2010 price is considered as reference (100).

UK's energy price is also high when compared to its peers, which implies production cost disadvantages of British businesses particularly in the sectors that intensively use energy. Figure 12 shows that UK's electricity price level is consistently higher than the median level of the

International Energy Agency.

Figure 12



Source: Department for Business, Energy & Industrial Strategy. Industrial electricity prices in the International Energy Agency (IEA).

Furthermore, Helm (2017) explains that households and businesses have not benefited as much as they should because of legacy costs, policies and regulation, and the continued exercise of market power. UK's high energy cost, and in particular of electricity, has been driven by a set of complex factors, both economic and political. It appears to be set by major players in the concentrated market, but in fact shaped by the non-market-determined investments led by the state system. The very complex situation faced by the energy market participants prevents the price from falling as expected. There are great challenges to both reduce the price and encourage steps of decarbonisation. To promote market competition, Helm (2017) proposed a design that provides incentives for intermittent generators to engage more with the market, leading to a

more balanced and flexible markets.

Promote local energy sectors

Based on Energy Capital (Black Country LEP, 2018) estimates, the West Midlands spends on energy around £6.7 billion annually, largely supplied by non-local energy sectors, with 49% consumed by Transport sectors, and a bit less than one-third by industries, 14% of which belong to energy-intensive sectors. Locally, there are more than 10,000 companies working in the energy sector supply chain across the West Midlands, employing over 56,000 people across the Black Country, Birmingham, Solihull, Coventry and Warwickshire.[18] The region hosts some of the largest and most important energy businesses in the UK,[19] and yet, they supply only a small percentage of the total local energy consumption. Furthermore, the region could gain from exporting more energy from local businesses, and increasing the proportion of energy sourced from local businesses. It is worth noting that the latter should not be achieved for the sake of it, but through improving the competitiveness of the local energy suppliers.

Locally, every year more than £1.25 billion of capital investment is already made in energy technologies and infrastructure (excluding buildings and transport) across the West Midlands. Further investing in better energy infrastructure will reduce local energy infrastructure costs and bring wider benefits. Analysis and evaluation need to be conducted at regional level in order to quantify the local benefits of these investments, which has not been previously available because outside private wire and district heating arrangements infrastructure costs and benefits are shared nationally by the regulator (Black Country LEP, 2018).

Renewability and sustainability

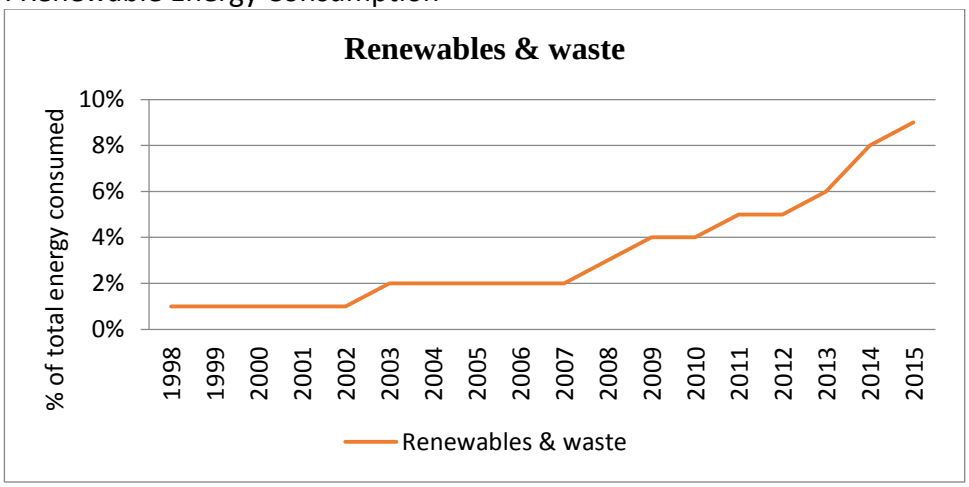
Increasingly, what is much discussed in the developed economic contexts is the renewability and sustainability of the energy infrastructure. Alternative forms of energy consumption have been developed in recent decades, i.e. wind, hydro power and biomass. Figure 4 shows the trend for the UK and highlights that the consumption has been raised from 1% in 1998 to

[18] The estimates are based on Digest of UK Energy Statistics (DUKES).

[19] For example, National Grid, E.ON UK, Worcester Bosch, and nPower, as well as some of the newest and most innovative, such as First Utility and Co-operative Energy.

about 9% in 2014. Many countries are implementing strategies of decarbonisation with the aim of reducing emissions, and there are serious reviews of energy policy underway across the world. Again, Britain's energy policy, regulation and market design are not fit for the purposes of the emerging low-carbon energy market, as it undergoes profound technical change (Helm, 2017). Looking forward, it is challenging to meet the CCA target and the carbon budget. In the UK, electricity provides around 40% of final emissions. Hence this large proportion presents both challenge and opportunity for lowering it by decarbonising the industries.

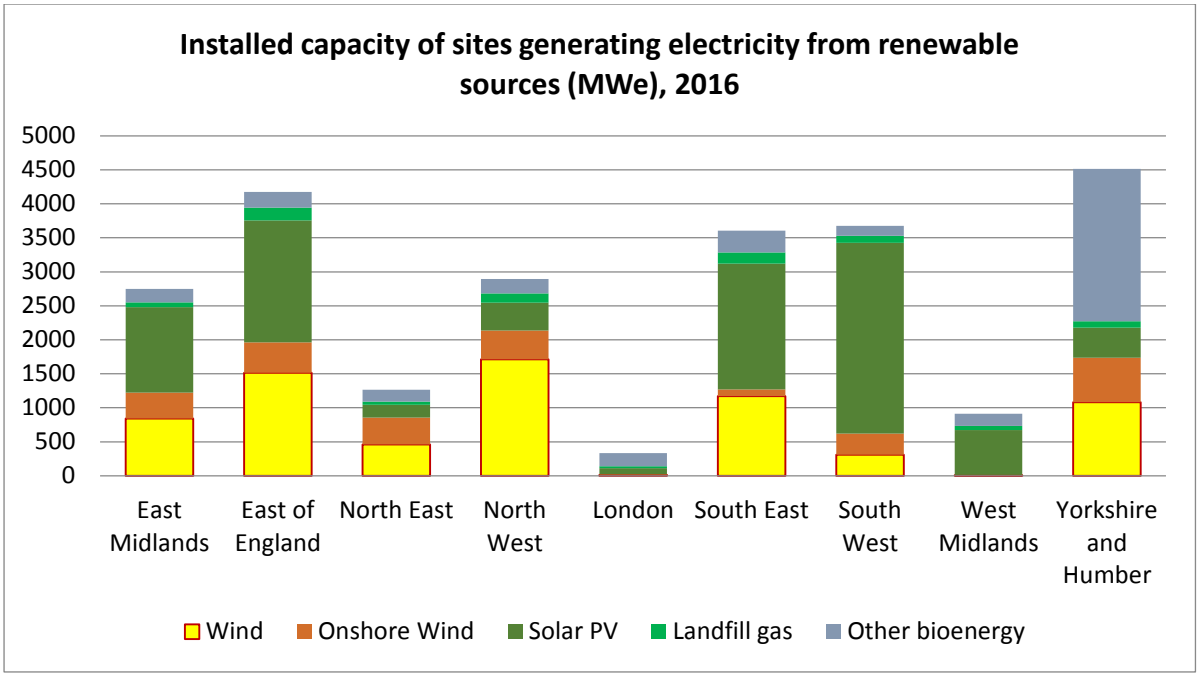
Figure 13: Renewable Energy Consumption



Source: Digest of UK Energy Statistics (DUKES) 2016, Department of Business Energy and Industrial Strategy (BEIS)

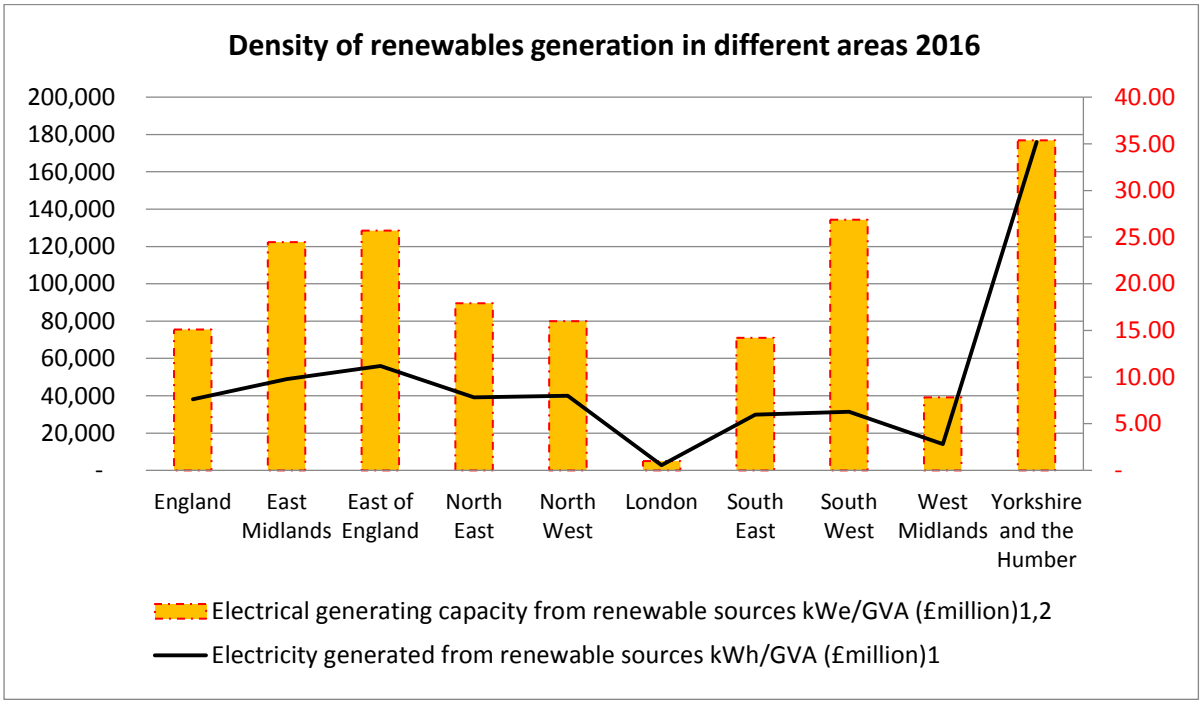
However, West Midlands areas only generate very moderate amounts of renewable energy. Figure 14 shows that both the relative capacity and density of electricity generated from renewable sources in the West Midlands are the second lowest in the country. Clearly, there is much work to be done. Black Country LEP (2018) estimates the regulated costs' considerable impact on energy costs and suggests that an energy transition over 20+ years from fossil to non-fossil fuel sources (nuclear, renewables etc) is the way forward.

Figure 14: Renewable energy generation: capacity and density



Source: Authors' calculation. Department for Business, Energy & Industrial Strategy, 2016. Density of renewable sources by regional breakdown.

Figure 15



Source: Authors' calculation. Department for Business, Energy & Industrial Strategy, 2016. Density of renewable sources by regional breakdown.

1. GVA is Gross Value Added as published as Total GVA in Regional Gross Value Added (Income Approach), December 2016 at: https://www.ons.gov.uk/economy/grossvalueaddedgva/bulletins/regionalgrossvalueaddedincomeapproach/previousReleases

2. Excludes capacity attributable to co-firing of bioenergy which has not been allocated to regions.

Depolitise the system

The state-driven system of energy market has become a key barrier to resolving the issues of the UK energy infrastructure. Helm (2017) report sets out the proposal to depolitise the process of allocating resources in energy improvement projects. This will keep ministers and non-expert officials out of the process that allocates contracts. Ministers should continue setting the policy objectives but the delivery should be managed by people who know what they are doing.

Helm (2017) also lays out the recommended governance structure. The government should establish an independent national system operator (NSO) and several regional system operators (RSOs) in the public sector, with relevant duties to supply and take on some of the obligations in the relevant licences from the regulated transmission and distribution companies. At the local level, Helm suggests to invite bids for network enhancements, generation and storage, and demand-side responses (DSR) from energy service companies. The report also suggests to separate and simplify the licenses to generate, supply and distribute energy. The currently undertaken review led by Matthew Rhodes proposes specific ways forward to reform the current energy market regulations at local economic level (Black Country LEP, 2018).

Flexible technology in improving energy infrastructure

Although there is no available existing evidence of the status WMCA is in terms of operational flexibility of energy generation, storage and supply, a flexible energy market has been recognized as the core of facilitating the cost-effective evolution to sustainable energy infrastructure. A greater availability in the variability in energy supply and variable costs associated with it would be beneficial to businesses, hence soon in demand if not already. Novel technologies need to be developed and adopted to meet this demand all while accommodating the existing infrastructure, which can be challenging (Strbac et al 2016). The examples include flexible generation, interconnection and flexible network technologies, demand side responses and energy response. Recent work estimates considerable savings in operating and investment costs from applying flexible technologies (Imperial College London and NERA, 2015).

5. Challenges and opportunities for all

With little doubt, integrating and combining different types of infrastructure development bring multiplied benefits compared with that of an individual infrastructure type. This is, above all, the most exciting avenue with numerous opportunities as well as challenges, not just in terms of technological barriers but also regulatory hurdles. There are many examples of how latest technologies influence infrastructure subsectors' design and planning to provide considerable benefits, such as design innovation, construction industry (KPMG, 2017), and transport sector development. Autonomous transport is another example that is predicted to revolutionise how people and goods move.

A key area that combines energy, digital and transport infrastructure is the electrification of transport which will provide endless scope for improving productive efficiency and welfare. Several transport modes have already been introduced to electrification, even though at different paces. Rail transport has already been widely electrified while road transport is less so. The development of electrification of transport depends upon the integration of vehicles into a reliable and affordable as well as easy-to-use infrastructure for the supply of energy. Hence, the limitations of current energy storage systems and the integration of electric vehicles into IT-based operating systems determine the usability and efficiency of the system, and thus, user acceptance. This demonstrates that the synergies between the quickly evolving systems are crucial to fulfil the potential of this technological opportunity. Moreover, these also pose the demand for a set of universal engineering skills that are independent of the transport mode to support a comprehensive and transferable development approach (European Commission, 2017).

In summary, to secure productivity gains and realise the full potential of considerable economic benefits, governments need to take the initiatives and with better modelling of potential impacts on infrastructure, invest in supporting technologies such as connected sensors, and set out clear paths in policy and regulation to incentivise the development of new and more efficient commercial models and private sector innovations (KPMG, 2017). More importantly, governments need to promote competition by removing red tapes and regulatory barriers and by encouraging innovation for new technological advancements to unlock the potential productivity gains across different infrastructural platforms.

The Midlands has seen recent developments towards that direction with the creation of the Midland Connect (MC), which was created to support the government's Midlands Engine for

Growth fullfiling the transport ambition.[20] MC is expected to play a key role in developing digital transport infrastructure through supports for autonomous vehicles, control systems and intelligent mobility.

6. Better knowledge for better policy-making

Measurement issues and reliable impact assessment methods

Perhaps there are few issues like infrastructure spending that is so unanimously agreed in principle but so hard to execute in practice. Commentators often criticise specific projects. Apart from the political factors driven by the negative externalities of building infrastructure, one of the key problems is that the evaluations of the potential impacts are inadequate or unreliable. More importantly, the productivity estimation is subject to several measurement challenges, including constructing capital stocks and counting for intangible assets. To mitigate these issues, the current research endeavour is making progress in these areas (eg. Haskel and Westlake, 2017). At the meantime, these problems point the research direction to conducting studies at disaggregated levels over a long period of time, using large samples and consistent statistical instruments to construct comparable statistics (Du and Bonner 2016).

Better measurement and more reliable evaluation methods are also key to sustainable investment. The recent report by McKinsey estimates that around the world $67 trillion will need to be spent on transport, power, water, and telecommunications infrastructure by 2030 to keep pace with the demands of growing economies. Governments struggling to finance such activities would seek private funds to close this spending gap; but the lack of reliable ways to measure performance in the delivery of infrastructure has been a barrier.

Link between infrastructure and firm productivity: how?

Surprisingly, the assumptions of the importance of physical infrastructure and its consequence in connectivity are well argued, well received, and yet still not well qualified using rigorous research. The existing studies are based primarily on aggregate data which are inherently incapable of telling us the impact of connectivity on heterogeneous groups of affected individuals and businesses. For example, how does failing to connect with other businesses set constraints on the business' supply chains and impair its competitiveness? What is the impact of connectivity in terms of the accessibility of labour and skills on start-ups and small businesses' growth

[20] https://www.midlandsconnect.uk/media/1142/mc-smart-and-digital-summary.pdf

potential? Do connectivity problems exacerbate skills problems in regions that lag behind? Moreover, the existing studies appear to assume a linear relationship between investment in infrastructure and the return on investment while in reality that relationship may take very different shapes. Is there a threshold, minimum level or an optimal level of the investment?

Which infrastructure? which connectivity?

Which infrastructure delivers the most benefit? What are the optimal combinations of different types of infrastructure development? These are particular interesting and important questions to ask when investment funds are limited and priorities are needed. Not only different infrastructural improvements have different direct impacts, but there may also be complementarities and substitutability effects between the different types of infrastructural investment. For example, transportation and technology are very interlinked. Technological advancements will enhance transport infrastructure but at the same time may substitute, to some extent, the need for physical connectivity. Unfortunately, this is an area that we know very little of, both conceptually and empirically.

Positive externalities

Private investors are happy to own infrastructure projects once they are up and running and delivering reliable yields; they are less keen on financing greenfield projects with all the risks that go with them. Often, negative externalities (from, say, pollution) of an infrastructural project is measured more carefully, while infrastructure can have positive externalities not captured by investors but which will benefit society (the building of the internet or interregional highway system, for example). Taking the full externalities into account in project evaluation hence helps incentivise private funding to work with public investment.

7. Conclusion

Infrastructure improvement is key to firm productivity and regional growth. With WMCA widening its focus on the devolution agenda and rolling out its modern industrial strategy, the stakes are high to set the priorities right in infrastructure building and improvement, one of the key pillars of the local economy. This report reviews the state of WMCA areas' infrastructure in transport, digital connectivity and energy, highlights some key issues and recommendations, and

points out some areas for further research. By understanding the current issues and encouraging all stakeholders to work together and adjust regulations, the region could improve the infrastructure locally to align with the local industrial strategy and WMCA strategic economic plan, and allocate resources where they create the greatest local growth.

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