frontier economics

SUPPORTING 5G INVESTMENT IN THE UK MOBILE MARKET

A report prepared for Vodafone

October 2021

Non-confidential version

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EXECUTIVE SUMMARY

5G is expected to bring significant social and economic benefits to the UK. 5G has the potential to unlock new, advanced use cases across industries throughout the UK, but a step change is needed in the latency, capacity and speed of existing mobile networks. These opportunities can be seized if mobile network operators (MNOs) are encouraged to shift their roll-out plans and carry out fast, nationwide 5G upgrades to all aspects of their networks – the so-called **Full 5G scenario**.

The Government has set ambitious targets to ensure that the UK profits from this technological evolution. It wants the UK to be a world leader in 5G. That makes implementing Full 5G of central importance. A Full 5G network will have advanced features – such as network slicing, where the public network is virtually segmented – which can be used to meet consumers' and businesses' needs without having to invest in duplicate infrastructure, providing optimal economies of scale. A public network with Full 5G capabilities is also likely to be the best way of providing comprehensive access to high-quality services across the UK, rather than limiting it to urban and industrial 'islands' where demand is highest (see Section 2 for more detail). 5G has the potential to help narrow the rural/urban digital divide, bolstering growth in all parts of the UK.

As such, a Full 5G roll-out will maximise the benefits of the new technology throughout the UK. A number of studies have attempted to quantify these gains, with some suggesting that Full 5G could generate £158bn of additional output over the next 10 years.[1] Importantly, Full 5G will also avoid creating another digital divide.

However, rapid deployment of Full 5G is not the only strategy available to MNOs. The alternative is to keep making incremental investments, by for instance focusing 5G upgrades on the radio access network in urban areas. But such an approach would fail to tap the full economic potential of 5G. This risk of sub-optimal outcomes for the UK that fall short of the Government's policy objectives stems in part from **the challenges of Full 5G deployment** discussed below (see Section 3).

1. Costs of Full 5G are substantial

First, the costs of Full 5G are significant. A rapid roll-out would result in material increases in MNOs' annual network spending. Full 5G would require expensive and complex upgrades to an MNO's radio access network, backhaul and core. ✂

Revenues from existing use cases and customers do not depend on Full 5G

Second, Full 5G is not necessary to maintain revenues from existing use cases (e.g. mobile broadband services). MNOs can meet continued growth in demand for mobile broadband by upgrading their networks; they can manage without Full 5G. Therefore, unlike with 4G, an MNO's existing user base is not directly at risk if it chooses not to invest in rapid deployment of Full 5G.

In addition, mobile broadband is likely to remain a relatively commoditised offering. That means any improvements in quality of service brought about by new

[1] WPI Economics, 'Levelling up: How 5G Can Boost Productivity across the UK'

technology will continue to be competed away, rather than leading to increased revenues from a 5G 'premium'.

2. MNOs' ability to generate returns from new 5G use cases is highly uncertain

Finally, MNOs face a high level of uncertainty on the returns from new 5G use cases, such as B2B services reliant on low latency, as most are still nascent.

Costly upfront R&D will be required to realise many of these use cases – with no guarantee that there will be significant demand for them. Even where a new use case is successful, MNOs cannot be sure of being able to capture enough of the value that is created to secure a return on their investments. This is because 5G is likely to be only one input into the delivery of these use cases, which will also require an ecosystem of hardware, software and other digital services. As a result, the overall profit pool from new applications is likely to be split among a range of providers, some of which may have a strong market position as a 'gatekeeper' for these new use cases. In addition, current net neutrality rules limit MNOs' bargaining power and their ability to capture a fair share of profits from new use cases if and when they are taken up.

These factors drive a risk of a market failure

These obstacles in the way of Full 5G deployment create an **investment hold-up problem** (see Section 4). The MNOs need to invest first, before the full ecosystem mentioned above has been developed. But they are also aware that they may not earn enough from the new 5G services to cover the heavy initial investment costs.

There is therefore a **material risk** that, under the status quo, **rapid Full 5G deployment by multiple competing MNOs may not happen** in the UK. Instead, because of the investment hold-up problem, the result might be one of the following sub-optimal market outcomes:

- MNOs follow a wait-and-see strategy (similar to the roll-out of 3G), invest only incrementally and deploy Full 5G networks **slowly, waiting for evidence from other markets on the returns on new use cases and thereby delaying the benefits** to UK industry and the wider economy; or
- A single MNO escapes competition to become a **dominant provider of Full 5G**, profiting from a position as a gatekeeper to capture sufficient returns but depriving the UK market of the benefits of network competition. This ultimately leads to lower investment and worse outcomes.

Neither of these scenarios would maximise value for the UK economy in the longer term. There is thus a **need for policy intervention** to mitigate this risk and create the incentives to ensure that MNOs invest in Full 5G and that healthy network competition is maintained for 5G (and subsequent technologies). To this end, investors need to have confidence that the long-term regulatory environment will be conducive to a profitable business case for investment in competing Full 5G networks.

Ofcom and policy-makers can mitigate this risk

There is a **natural role for Ofcom and Government to make regulatory and policy changes that facilitate competitive 5G investment**. In the future, when considering policy interventions in the mobile industry, Ofcom/Government should rebalance their policy objectives to put more weight on dynamic investment incentives. Doing so will align the incentives of the MNOs to invest in Full 5G with the Government's ambitions. To be effective, such an overarching policy change should be reflected consistently across individual regulations (see Section 5). The Figure below summarises key policy recommendations. They can broadly be viewed as either:

- Increasing certainty of returns so that MNOs' perceived downside risk of limited returns post-investment is lowered;
- Managing the costs of Full 5G investment to increase the expected returns from Full 5G investment; and
- Ensuring market structures in the mobile (and fixed) industry are conducive to the competitive deployment of Full 5G.

Figure 1 Overview of policy recommendations

Issue		Policy recommendation
	Addressing net neutrality	▪ Reassess whether net neutrality laws are fit for purpose for service-driven mobile networks. ▪ Provide more clarity on the services that are classified as 'specialised services' under the net neutrality laws.
	Level playing field compared to MPNs	▪ Ensure that the development of the new MPN players does not endanger the public deployment of Full 5G networks.
	Annual licence fees	▪ Ofcom should revisit its framework for setting ALFs to ensure that they are not excessive and do not deter investment.
	Approach to consolidation	▪ Pragmatic assessment of consolidation, recognising the importance of efficiencies and the impact on investment incentives.
	Consumer protection	▪ E.g. Ofcom should support 2G/3G switch-off in a coordinating role with minimal intervention.
	Support for rural rollout	▪ Open to innovative network sharing agreements, as rural and urban needs may differ. ▪ Direct support e.g. through subsidies should be provided where commercial roll-out is not viable.
	Backhaul pricing	▪ Ofcom should ensure competitive and fair backhaul access and pricing.

Source: Frontier Economics.

1 INTRODUCTION

The Government's aim is for the UK to be a world leader in 5G and has set ambitious targets for rolling out the new technology. [2] The Government is of the view that 5G could bring a step change in industrial productivity and economic activity, generating significant positive externalities which would benefit all parts of the country. In its *Future Telecoms Infrastructure review*, the Government set out that:

> *"5G has the potential to transform communications. It could impact almost all areas of life, from health and social care, to transport and agriculture, through to the provision of ultrafast wireless broadband connections. 5G also offers* ***huge*** *potential economic benefits. A recent EU study estimated that in 2025 benefits from the introduction of 5G capabilities could reach* ***€113.1 billion per year*** *across the region."*[3]

5G will mark a break from previous rounds of mobile technology. Full deployment requires complex and expensive upgrades to multiple elements of the network, with limited assurances about the profitability of the new use cases the network will be able to support. As such, there are fundamental uncertainties in the business case for 5G investment. This creates the risk that, unlike with 4G, operators will not roll out competing 5G networks at pace, thereby thwarting both the ambitions of the UK Government to lead the way in 5G and Ofcom's ambition to support investment in strong, secure mobile networks.[4]

Regulatory interventions can play an important role in influencing market outcomes, by facilitating or inadvertently deterring investment. Ofcom should take this into account when considering how best to avoid the risk of a sub-optimal outcome in 5G. Policy priorities in mobile markets should be recalibrated to ensure that networks are deployed to achieve the maximum long-term benefit for the wider UK economy and society.

This report, commissioned by Vodafone in the context of Ofcom's review of its Mobile Strategy, aims to explore these ideas in more detail. It is structured as follows:

- Section 2 discusses the nature of 5G and the potential benefits it could bring to the UK economy;
- Section 3 sets out the characteristics of MNOs' Full 5G investment decision;
- Section 4 sets out the market failure that could result from the characteristics of the 5G investment decision, creating a need for policy intervention; and
- Section 5 sets out the regulatory and policy levers that can be used to incentivise socially optimal 5G roll-out.

[2] DCMS, *Future telecoms infrastructure review,* 2018.

[3] DCMS, *Future telecoms infrastructure review,* 2018, page 17.

[4] Ofcom, Mobile Strategy – Terms of reference, May 2021

2 FULL 5G COULD BRING SIGNIFICANT BENEFITS TO THE UK ECONOMY

5G presents the UK with an opportunity to deliver revolutionary applications using mobile networks. The full suite of 5G capabilities which will include, in some cases, ultra-low latency of less than 1 millisecond and download speeds of up to 10 Gbps, will enable a range of new use cases. These are expected to be increasingly B2B-focused, yielding substantial benefits to businesses and the UK economy as a whole, as well as transforming the services available to consumers.

This section sets out in more detail:

- What 5G can offer in terms of services and use cases;
- How 5G differs from previous technologies;
- The benefits 5G could bring to the UK economy; and
- How this ties in with Government targets on the expected roll-out of 5G.

2.1 5G has the potential to revolutionise mobile service offerings

Mobile technologies are developed in 'generations' to ensure common standards both within and across countries. This allows users to have confidence that they can access mobile services across a wide geography and lets operators benefit from economies of scale. Each new generation has improved network functionality, increasing the number of uses for consumers and businesses.

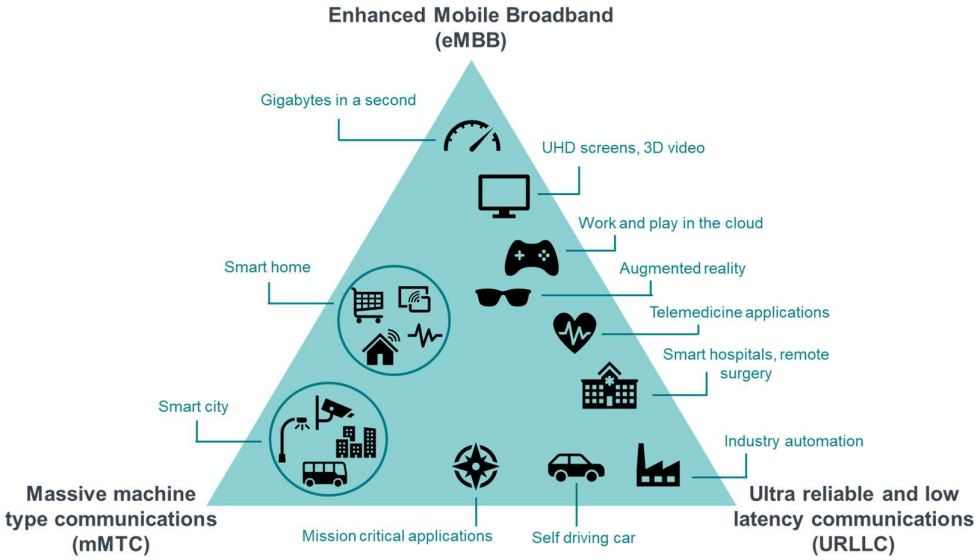
5G is the next, fifth, generation in mobile technology. In 2015, the International Telecommunication Union (ITU)[5] set a series of ambitious objectives for 5G that were intended to revolutionise the mobile industry. They included step changes in all metrics of network performance, including latencies of less than 1 millisecond and bandwidth of over 10 Gbps. The ITU defined three categories of 5G use cases that this technological leap forward will support.

These are:

- **Enhanced mobile broadband** ('eMBB') **–** Enhanced indoor and outdoor broadband could increase mobile download speeds for consumers, make Ultra HD streaming possible and allow regular use of augmented and virtual reality.
- **Massive machine type communications** ('mMTC') **–** 5G will enable faster and more reliable communication for the Internet of Things ('IoT') devices, paving the way for smart agriculture, smart cities, energy network monitoring and remote healthcare (remote patient monitoring, remote medical proctoring).
- **Ultra-reliable and low latency communications** ('URLLC') – 5G will permit faster and larger data transfers, enabling autonomous vehicles, smart energy grids, industrial automation and more remote medical procedures (e.g. remote surgery).

[5] The International Telecommunication Union ('**ITU**') is the independent body that sets the technology standard. ITU, *Setting the Scene for 5G: Opportunities and Challenges*, 2018

Figure 2 5G use case scenarios



Source: Frontier Economics adapted from ITU.

The true revolutionary potential of 5G is to be found in mMTC and URLLC applications. eMBB will incrementally improve existing use cases, such as streaming on smart mobile devices, which include, for the most part, smartphones and smart tablets. But mMTC and URLLC could unlock completely new applications of mobile technology across industries, leading to the development of a more advanced digital economy supporting smart cities and the IoT. A selection of these possible use cases is set out in the Figure below.

Figure 3 Examples of potentially revolutionary new use cases

Sector	Possible use cases	Example
 Manufacturing	▪ Better real-time management of data. ▪ Remote maintenance of machines. ▪ Machine-to-machine communication, speeding up production processes.	▪ Vodafone has partnered with Ford to implement 5G connectivity in Ford's new manufacturing facility in Essex. The connectivity enables Ford to capture a continuous flow of data from installed sensors. It also allows analysis and remote control of new laser welding machines.
 Healthcare	▪ Improved patient monitoring with IoT. ▪ Remote surgical operations. ▪ Assisting medical scans in rural areas by centralising experienced professionals.	▪ The Cardiff and Vale University Health Board is trialling the use of Proximie, a global technology platform that allows clinicians and surgeons to virtually 'scrub in' to any operating room in the world, for remote assisted support, guidance and training. The technology allows more patients to be seen in a shorter time and connects experts from further afield to support patient care.
 Education	▪ 3D video cameras, 4K videos and holograms. ▪ Virtual classrooms that enhance learning.	▪ Coventry University with Vodafone created a 5G network that allows interactive remote learning. The ultra-low latency of 5G allowed healthcare students to take immersive, real-time augmented and virtual reality tours of the human body, improving their learning experience.
 Rural areas	▪ Remote education, working and healthcare to be more reliable, closing the digital gap between rural and urban communities.	▪ As part of the 5G Rural Dorset trial, Vodafone UK will be working to bring 5G mobile coverage to the rural and coastal communities near Lulworth Cove. Vodafone's 5G signal will aide tourists and the businesses that serve them, but also locals in their everyday lives.

Source: Vodafone and Ford 5G trial - GSMA, Ford and Vodafone Harness Private 5G Networks to Continually Optimise Vehicle Manufacturing, May 2021. Cardiff and Vale Health Board 5G trial - Vodafone UK News Centre, Proximie and Vodafone in successful 5G remotely assisted surgery trials, May 2021. Vodafone and Coventry University 5G trial - Vodafone 5G Customer Stories, Vodafone launches UK's first commercial standalone 5G network with Coventry University. 5G Rural Dorset, Vodafone UK News Centre, Creating a 5G-powered future for rural Dorset, September 2020.

2.2 5G differs materially from previous technologies

2.2.1 New use cases require end-to-end network upgrades

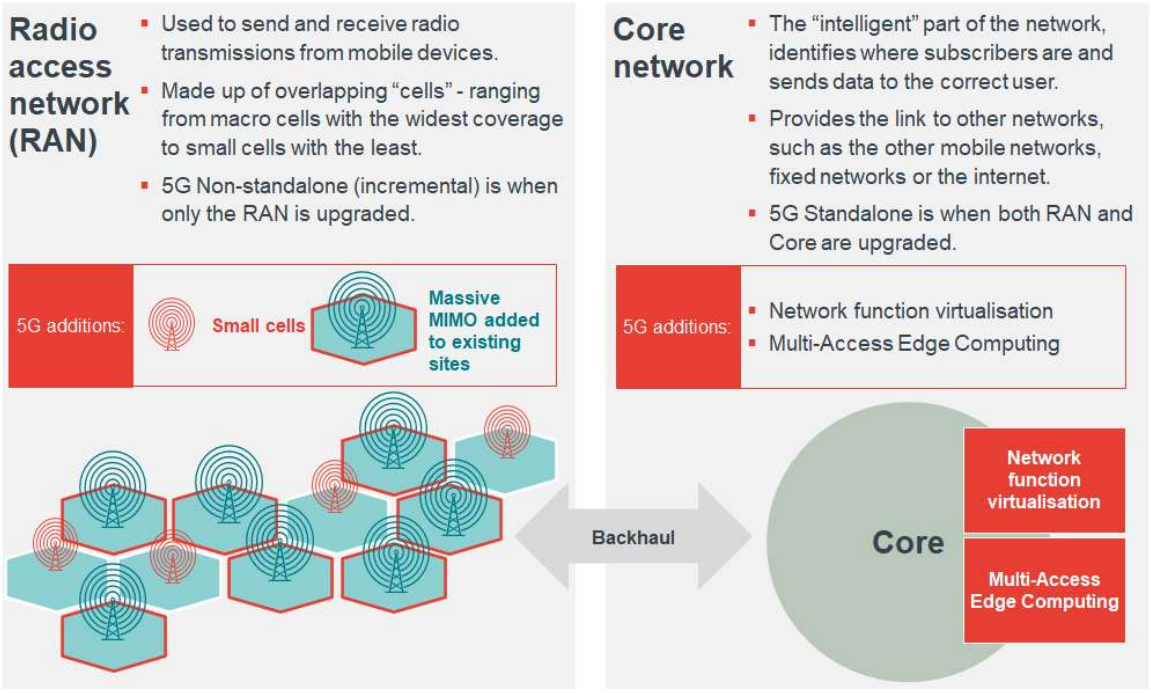
Mobile networks to date have supported two main sets of use case:

- Mobile voice calls (since first generation networks); and
- 'Best effort' Internet access (since GPRS, also known as 2.5G technology).

As new technologies came on stream, they were deployed incrementally in both the radio and core networks in the knowledge that the two main use cases could be supported, albeit with a lower quality of service, by the legacy core and radio networks. This provided seamless coverage while new technologies were introduced.

However, for 5G to enable URLLC and mMTC (which support the most productive new use cases), extensive changes are needed across the *entire* mobile network. This will mean not just upgrades to the radio network but also additional investments in the core network (e.g. network virtualisation, as legacy networks will not support these use cases).

Figure 4 5G additions to mobile network architecture



Source: Frontier Economics.

In particular, the following changes will be required:

- **Upgrades to the radio access network** (RAN) – To support continued growth in traffic and demand for ever higher speeds, macro cells in the RAN will use new massive MIMO[6] (mMIMO) antennas to re-use spectrum to send and receive multiple signals simultaneously, improving the spectral efficiency. A limited number of small cells may also be required to support the higher capacity needed for 5G technologies in particular locations.
- **Redesign of the core network** – The core network will also require significant upgrades and additions, as it must cater for higher traffic and support a range of different use cases, some of which will call for lower latency and greater reliability. This is achieved through a number of features, including:

[6] Multiple input, multiple output.

  - Network Function Virtualisation – This "virtualises" the network by decoupling software from hardware and makes greater use of cloud computing. This should allow easier upgrades and increase the flexibility of the network, enabling it to respond to new demands.
  - Multi-Access Edge Computing – This is an evolution in cloud computing that brings the "intelligence" of the core to the "network edge", i.e. closer to end users. Since information travels shorter distances, lower latency and higher reliability can be assured.
- **Upgrade to the backhaul network** – Backhaul connects the RAN to the core network. The requirements of 5G for high capacity, fast speed and low latency call for a high-performance backhaul network. Accordingly, an increasing proportion of radio sites will need to be connected to fibre networks to provide the necessary bandwidth, latency and resilience.

2.2.2 The nature of the network upgrades allows for a continuum of roll-out scenarios

As part of their 5G deployment strategy, MNOs can choose:

- The 'breadth' of their 5G network, i.e. the extent of the radio network's population and geographic coverage; and
- The 'depth' of their migration towards 5G, i.e. whether new technologies are introduced incrementally as an overlay to existing networks or the full network 'stack' is refreshed.

For example, there will be industrial use cases which can be met by standalone mobile private networks (MPNs) with 5G capabilities. This gives network operators a choice of investment approach where there is relatively certain demand from a single industrial user in a given area:

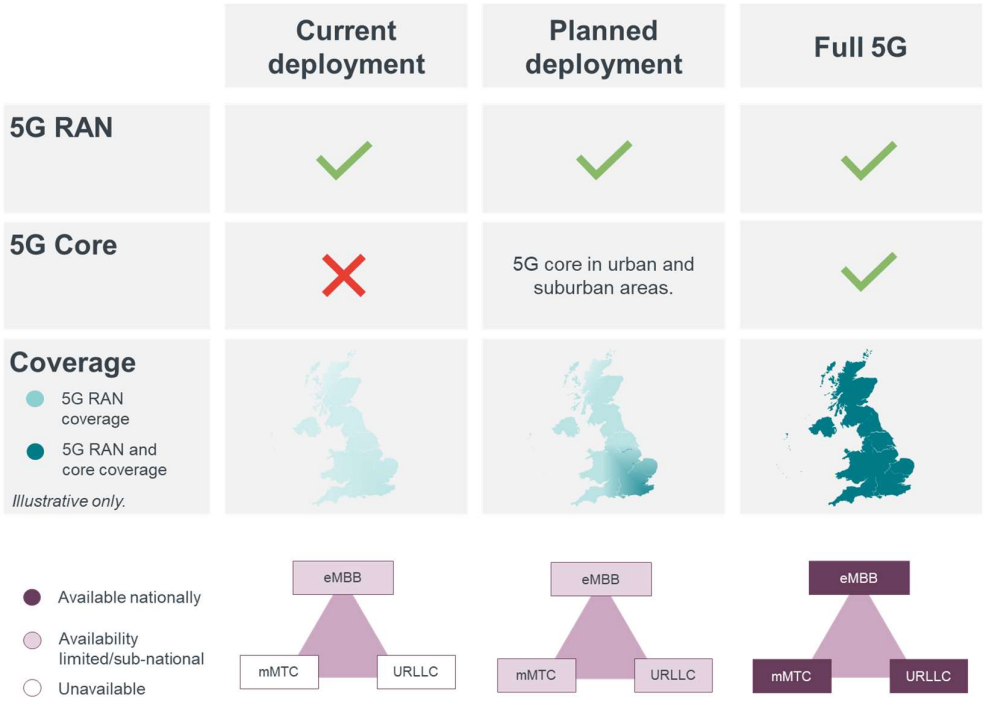
- **Dedicated MPNs** – Standalone private 5G networks could be set up using dedicated infrastructure confined to a specific area.
- **Virtual MPNs** – Alternatively, similar capabilities could be delivered using network slicing capabilities, whereby the nationwide public Full 5G network is virtually 'segmented' or 'sliced' to provide equivalent capability.

The use of network slicing will deliver important **economies of scope** as a single, Full 5G network would be able to serve all potential use cases. The long run incremental cost of service with such deployment will likely be lower than a deployment model that uses a combination a public 5G network with sub-national coverage and islands of dedicated MPNs..

An MNO's 5G network can therefore vary in the breadth and depth of its capabilities, depending on the extent to which the MNO decides to invest in the network elements described in Section 2.2.1. This will in turn affect the geographic availability of the 5G use cases outlined in Section 2.1 across the UK.

Figure 5 sets out the variation that could be observed. These range from networks with limited 5G deployment (i.e. the current set-up) to a Full 5G network that has a 5G RAN and 5G core providing nationwide coverage.

Figure 5 Continuum of 5G roll-out and implications for use cases



Source: Frontier Economics.

Current deployment

To date MNOs have deployed 5G networks with a 5G RAN in urban areas. Due to 5G standards being incomplete the deployment has been on the 4G core i.e. Non-standalone (NSA) deployment.

This supports improvements in capacity and speed for existing use cases (e.g. eMBB) but will not significantly enhance other aspects of service quality for businesses or consumers.

Some dedicated MPNs are also being deployed on a small scale installed to cater to particular industrial needs. These MPNs ensure higher-quality service in pockets of the UK where there is a private business need, but they will not lead to wider productivity gains and externalities to the whole of the country.

Planned deployment

MNOs are planning to expand on their current deployment to include a 5G core in urban and suburban areas, in addition to the 5G RAN to deliver services on a standalone (SA) basis. The remainder of the MNOs' networks will still rely on a 4G core and a mix of 4G and 5G RAN.

This would result in improvements in mobile broadband because more of the population will be covered by 5G RAN bringing increases in capacity and bandwidth. But mMTC and URLLC use cases would still be limited to urban and suburban pockets – or to areas with an MPN.

Dedicated MPNs and virtual MPNs may be available, but the latter would only be in areas where the public 5G network is upgraded with a 5G RAN and a 5G core.

Full 5G

In this scenario, MNOs would roll out a nationwide public Full 5G network. It would have an upgraded 5G RAN and 5G core with national coverage, enabling high speeds and low latencies.

With Full 5G, the entire suite of 5G use cases (e.g. eMBB, URLLC and mMTC) would be opened up to all urban, suburban and rural communities. Dedicated MPNs and virtual MPNs would be available, too. Given economies of scope, most industrial needs would likely be addressed using virtual MPNs.

Incremental scenarios

Between the currently planned deployment and Full 5G there is a continuum of possible 5G networks, giving MNOs optionality at every stage of the roll-out process. They can choose to move along the continuum at a forecast pace, or defer or accelerate at any stage, depending on their incentives and the strength of the business case. This contrasts with the experience with 4G, where there was a clear business case for competitive roll-out across most of the UK as fast as possible, subject to practical constraints. This is discussed further in Section 3.

2.3 The Government expects significant benefits to the UK from Full 5G

From the range of options described above, rapid Full 5G deployment is likely to produce the **most efficient and socially optimal outcome**. The Full 5G public network leads to economies of scale and scope, thereby reducing costs. The savings can be passed on to customers in the form of lower prices.

As discussed in the previous section, an important driver of the **economies of scope** is that a single network technology serves all potential use cases. In addition, Full 5G will bring the most benefits to the UK, as it will unlock the full range of new commercial use cases. The nationwide availability of these applications will generate positive externalities that will profit the entire UK economy.

More detail of these benefits is provided in the following sub-sections.

2.3.1 Nationwide availability of new, commercial use cases

As set out above, the main potential of 5G lies in mMTC and URLLC use cases. These will unlock new, advanced use cases across a wide range of industries. Examples of these benefits are set out in the Figure below, which also shows various estimates of their value. These include gains of £2.6bn for the UK economy from improved productivity.

Figure 6 Illustrative examples of the benefits of new advanced 5G use cases



5G factory trials	5G farming	5G health and social care
In Worcester, a 5G trial in a factory found that a 2% efficiency gain could result from using 5G connectivity for: ▪ condition monitoring; ▪ visual monitoring; and ▪ augmented reality manufacturing processes as part of Industry 4.0. If extrapolated nationwide, the productivity gains from making use of Full 5G in factories would add £2.6bn to the UK economy	5G Rural Dorset (with support from DCMS and a consortium of partners including Vodafone) is trailing 5G use cases as part of its *Future of Food* project. These use cases tackle poor connectivity in rural areas – which is a key obstacle to take-up of new technologies. The 5G use cases include: ▪ agri-tech; ▪ 5G robotics; and ▪ data precision and accuracy. These use cases will make real-time applications possible, improving farmers' response times.	The Liverpool 5G health and social care testbed has shown that the cumulative implementation of the use cases considered could save c.£250k per 100 users per year (after use case service costs). These use cases include: ▪ remote monitoring of medication administration; ▪ social gaming apps; and ▪ sensors monitoring conditions and environments that may adversely affect health.

Source: *Worcestershire 5G Testbed and Trials, Final Report, November 2020 - https://www.wlep.co.uk/wp-content/uploads/W5G-Final-Report-Public-Release-1.pdf; 5G RuralDorset,* 5G RuralDorset project to deliver first 5G-ready agri-robot, *February 2021 - https://5gruraldorset.org/2021/02/12/5g-ruraldorset-project-to-deliver-first-5g-ready-agri-robot/; Liverpool 5G Health and Social Care Testbed, Benefits, Outcomes and Impact, November 2019 - https://liverpool5g.org.uk/wp-content/uploads/2020/05/Liverpool-5G-Heath-and-Social-Care-Testbed-Benefits-Outcomes-Impact.pdf*

2.3.2 Positive externalities that will benefit the UK as a whole

The use cases set out in this section and many others are likely to boost productivity across the UK, bolstering economic growth. This will create positive externalities which will only be accrued once Full 5G is available.

5G applications will enable **productivity increases** across industries because of the efficiencies that Full 5G makes possible. The boost to productivity will counter-act the low growth in output per worker that the UK has experienced since the financial crisis, particularly in manufacturing.[7]

These productivity boosts will also spill over into **wide-ranging benefits for the UK economy as a whole**. This is because higher levels of output per worker will have a multiplier effect, as the benefits of new 5G use cases ripple through the economy. Several studies have attempted to quantify the potential magnitude of these gains. One of them finds that Full 5G could generate £158bn of additional

[7] LSE Business Review, *If the UK is high tech, why is productivity growth slow? Economists weigh in*, March 2020.

economic output in the UK over the next 10 years due to productivity improvements.[8]

The development of 5G applications and the widespread reach of Full 5G could help address the **urban/rural digital divide**, by giving people in rural areas faster internet connections.[9] The proportion of homes without internet access fell from 11% in March 2020 to 6% in March 2021, but narrowing the digital divide remains a key policy objective. The Government has recognised the need to improve productivity in rural economies through better digital connectivity, and has warned that the lack of appropriate services can constrain the ambition, performance and growth of rural businesses.[10] The Government has provided significant support for higher speed fixed broadband roll-outs to more remote areas. But 5G can meet rural connectivity needs more widely than fixed broadband, helping close the digital divide and bringing new services to the rural UK.

As mentioned in Section 2.1, there will be benefits for existing users of mobile networks, but these will be less revolutionary for consumers than for industry. eMBB will offer better quality than current 4G services. Users will find that downloads are faster, streaming is smoother and online gaming, to take one example, is increasingly seamless. There could also be transformational B2C applications, such as virtual reality and holographic online streaming, which, to the degree they require mobility, could be dependent on Full 5G deployment.

2.4 Full 5G is consistent with Government targets, but the UK risks lagging behind

The roll-out by MNOs of Full 5G networks holds the key to the Government achieving its aim of making the UK a "*world leader in 5G*".[11] The *Future Telecommunications Infrastructure Review*[12] said a full fibre and 5G service on a wide scale would ultimately be required to give consumers and businesses the speed, resilience and reliability they will need, to keep the UK globally competitive and to support the regional rebalancing of the economy. However, the UK does not currently appear on track to meet this goal.

As seen in Figure 7, the UK already lags behind many other countries in terms of population coverage of 5G. The UK also trails other countries in average download speeds, as shown in Figure 8.

8 WPI Economics, *Levelling up: How 5G Can Boost Productivity across the UK*, June 2020.

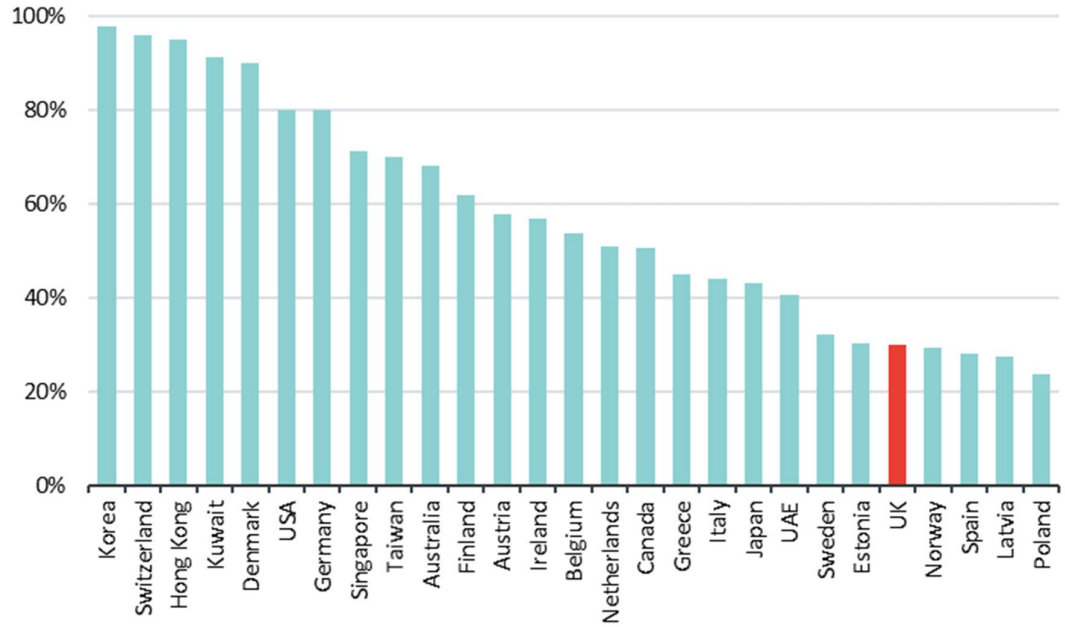
9 Ofcom, *Digital divide narrowed by the pandemic, but around 1.5m homes remain offline*, April 2021. https://www.ofcom.org.uk/about-ofcom/latest/features-and-news/digital-divide-narrowed-but-around-1.5m-homes-offline

10 House of Commons: Environment, Food and Rural Affairs Committee, *An Update on Rural Connectivity*, Appendix: Government response , March 20210.

11 https://publications.parliament.uk/pa/cm5801/cmselect/cmcumeds/153/15306.htm

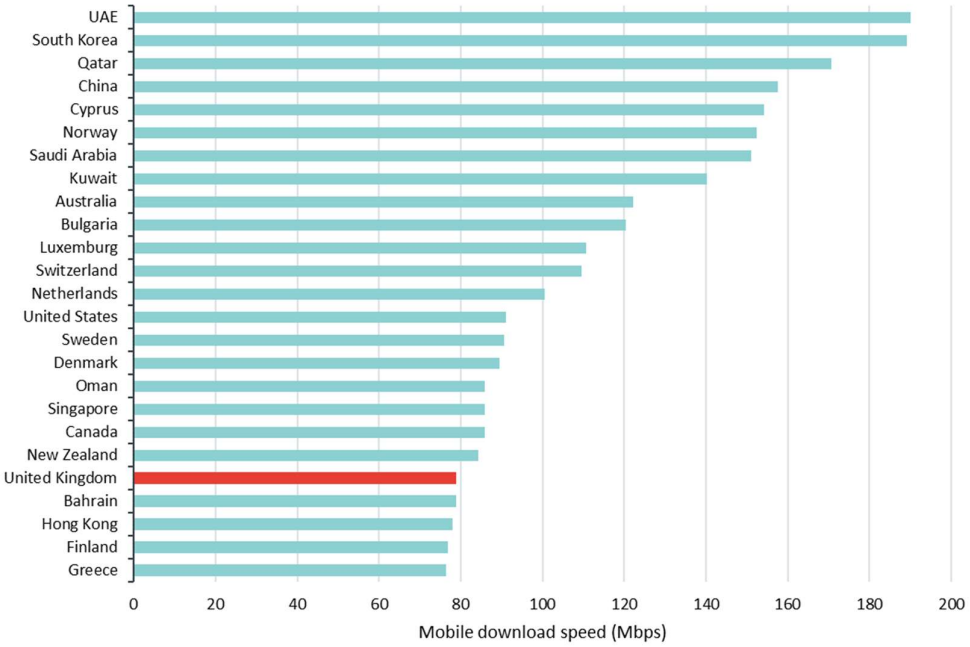
12 DCMS, *Future telecoms infrastructure review,* 2018.

Figure 7 Non-standalone 5G coverage across countries



Source: GSMA Intelligence - 5G Network coverage Q1 2021

Figure 8 Average mobile download speed (Mbps), top 25 nations



Source: Ookla international benchmarking, Mobile download speeds July 2021.

To complement these benchmarks, it is also helpful to be able to compare the latency of the UK network with other countries – which we understand are network measures currently not tracked by Ofcom; this is a metric that should improve with

the ultra-low latency that Full 5G offers.[13] The gap between the UK and leading countries could grow even larger if MNO roll-out plans are delayed and/or if MNOs decide not to deploy Full 5G networks.

Indeed, UK MNOs have not at this point committed to the comprehensive roll-out of Full 5G capabilities, including eMBB, mMTC and URLLC. If deployment is concentrated on high-traffic areas or urban centres, or even just on providing mobile broadband, the UK may fall further behind world leaders.

BT/EE has indicated that it aims to provide 5G connectivity to over 90% of the UK landmass by 2028.[14] However, it is unclear whether this refers to Full 5G capabilities across the UK, or just eMBB, and the stated timescale gives leeway for this aim to be downgraded over time.

✂.[15]

✂

Public statements are likely to be aspirational rather than firm commitments to invest and the decisions MNOs make are likely to reflect changing priorities as new information becomes available.

This optionality is a function of the multiple investment choices that an MNO has each year. An MNO will compare the option to invest in the swift deployment of a Full 5G network with the alternatives. These include mobile-focused options such as a gradual/incremental investment in 5G; bringing Full 5G capabilities only to the most commercially viable areas (e.g. high-traffic urban locations); investing to reduce opex through efficiency improvements; and investing to increase network capacity or to improve reliability. An MNO will also put the investment decision for rapid Full 5G roll-out in the context of the opportunities it has to invest in other jurisdictions or in fixed networks. These decisions and comparisons are particularly in focus now, as MNOs and their investors need to carefully consider their options in light of squeezed market revenues, lower profitability and the burden of consumer-focused regulation in the UK market.[16]

As set out in the following section, there are characteristics of Full 5G investment that make MNOs' potential returns unclear. This could lead to investment being deferred, especially as there may be alternative investments on the table that offer more certain returns.

[13] Ookla international benchmarking data for mobile latency across countries in July 2021 also shows that the UK is lagging behind other countries in terms of mobile latency speed, a key feature which should be improved by investment in Full 5G. In July 2021 the UK's mobile latency was 42ms, double that of top performing nations and outside the top 25 nations in terms of mobile latency.

[14] BT Newsroom, *EE to offer 5G solutions across the entire UK, as BT Group unveil new mobile and convergence ambitions*, July 2021. https://newsroom.bt.com/ee-to-offer-5g-solutions-across-the-entire-uk-as-bt-group-unveil-new-mobile-and-convergence-ambitions/

[15] ✂

[16] ✂

3 THE INCENTIVES TO INVEST IN 5G DIFFER FROM PREVIOUS GENERATIONS

The costs of Full 5G roll-out are significant. Rapid deployment would result in material increases in network expenditure, both capex and ongoing opex.

✂

Competition between MNOs has spurred investment in new generations of mobile technology. This was the case for 4G. Following the 2013 spectrum auction, all four MNOs moved quickly to address latent and growing demand for mobile broadband services in order to remain competitive.

However, there are important differences between Full 5G and 4G. This means the roll-out of Full 5G could more closely resemble the deployment of 3G than 4G.

In particular:

- Full 5G is unlikely to be necessary to retain and grow the existing customer base, given that it provides only a marginal improvement on a 5G NSA for mobile broadband customers.
- Additional revenue streams from new customers and innovative applications using a Full 5G network are uncertain. Most of these use cases are still under development, and it is unclear who in the supply chain will capture what share of this additional value.

We discuss the above points in more detail in the following sub-sections.

3.1 Costs of Full 5G are substantial

The total cost of Full 5G roll-out is set to be significant. As described in Section 2.2, Full 5G investment requires an MNO to upgrade its RAN and core network. Critically, it must also expand its 5G network to provide national population coverage to maximise the benefit for the UK.

Determining the exact bill for Full 5G is difficult. Some costs have already been incurred in laying down infrastructure to support previous technologies, while other costs are still unknown because the configuration and architecture of the network to support Full 5G are still evolving.

✂

✂

3.1.1 5G requires high-cost upgrades to the RAN

Rolling out a Full 5G network requires an MNO to upgrade its RAN sites nationwide. Upgrades are expected to be expensive particularly where they require mMIMO equipment.

3.1.2 5G also requires significant overhaul of the core network and increases in other expenditure

Full 5G also requires significant investment in an MNO's core as well as other parts of the network to unlock the latency and capacity requirements of new 5G use cases.

✂

3.1.3 MNOs face additional costs coinciding with the 5G upgrade

As critical national infrastructure is set to become more dependent on 5G connectivity, network security has come sharply into focus. The Government is introducing new telecoms security requirements (TSRs) that will set out codes of practice and give Ofcom greater powers of oversight and enforcement to ensure industry compliance.

The codes of practice will provide guidance on how, and in what timeframe, certain telecoms providers should comply with their new statutory TSR duties. The Government is consulting on an initial code, which divides providers into three tiers:

- The largest national operators will be considered Tier 1 providers and will be subject to intensive monitoring and oversight by Ofcom.
- Medium-sized Tier 2 telecoms providers will be subject to some Ofcom oversight and monitoring and will have more time to implement the security measures set out in the code of practice.
- Smaller Tier 3 providers will be excluded from the code of practice but may be subject to limited oversight by Ofcom to ensure compliance with the law.

Under these proposals, Vodafone will be considered a Tier 1 provider and so will be subject to intensive monitoring and oversight by Ofcom. Complying with the TSRs is expected to be costly – for instance, it will involve ensuring that the network is backward compatible so that all 5G users have access to 2G for voice calls in remote areas. ✂

3.1.4 ✂

3.2 MNOs' revenues from existing use cases are not reliant on Full 5G deployment

In any investment decision, an MNO has to balance the significant costs of investing in a Full 5G network against the returns it can expect. These will be dictated by the resulting change in profitability from (i) existing users of mobile services and (ii) the MNO's ability to capture the value of new 5G use cases.

This section focuses on an MNO's dependence on revenue from existing users of mobile services. It shows that the change in **revenues from existing use cases**

is likely to be insufficient to justify the significant additional investment required to roll out Full 5G.

This is an important difference from 4G, where the investment case was driven by the need to compete to acquire and retain existing mobile users. The consumer appeal of 4G was more certain, given the perceived poor quality of 3G services. MNOs needed to make a quick switch to 4G or face being unable to meet their existing customers' needs. The same is not true of the transition to Full 5G.

3.2.1 Full 5G would be only an incremental improvement for existing customers

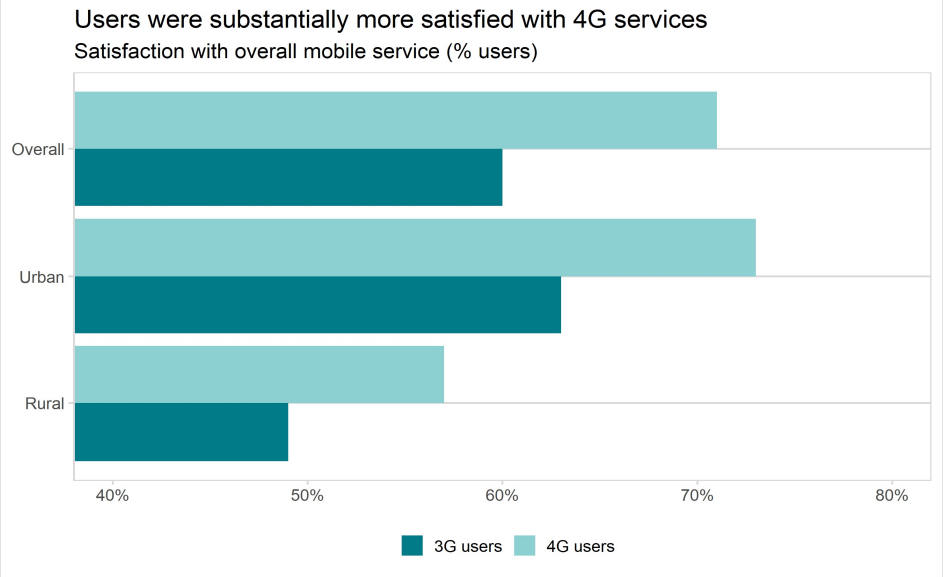
As set out in Section 2.2.1, 5G upgrades to the RAN involve deploying mMIMO antennas in high traffic area that will increase spectral efficiency. The resulting capacity increases will allow MNOs to meet growing demand from existing use cases. This will improve the quality of service to **existing customers**, who will benefit from eMBB. This is the focus of the current roll-out of 5G NSA technology, providing incremental benefits to existing 4G customers.

MNOs began deployment of 4G services at a time when the perceived quality of 3G services was low. 4G offered impressive improvements to a customer base that was relatively dissatisfied. The uptake of 4G was therefore guaranteed. Confident that their investment would meet strong demand and that continuing to rely on 3G networks was not commercially feasible, MNOs had the incentive they needed to press ahead with deploying 4G.

CASE STUDY: 4G INVESTMENT DRIVEN BY COMPETITIVE PRESSURE

- When 4G was rolled out, its primary effect was to make existing (3G) use cases work better. MNO customers experienced a step change in user experience.

Source: Frontier Economics analysis based on data from Ofcom Technology Tracker.



- The step change in quality offered by 4G, particularly given the poor performance of 3G for mobile broadband, meant that MNOs that did not roll out 4G quickly faced losing customers to rivals that did. The investment decision was therefore "do or die" in nature.
- The cost efficiency of 4G roll-out was also improved by the fact that MNOs could migrate their radio networks to 'single RAN' at the same time as the 4G upgrades, therefore minimising site visits.
- The strength of the business case for 4G was further demonstrated by the high valuations for 800 MHz spectrum in the 4G auction – spectrum that was essential for O2 and Vodafone to achieve wide 4G network coverage. The prices paid stand in stark contrast to the relatively modest valuations in the most recent 5G auction.

Things are different now. With 5G, MNOs are rolling out a technology that offers a incrementally better quality of service to a customer base that is already reporting significantly higher levels of satisfaction with 4G. Figure 9 illustrates the positive outcomes for mobile users in recent years – customers have been getting more for less from 4G. This is reflected in overall satisfaction ratings increasing from 89% in 2015 to 93% in 2019.

Figure 9 Estimated spend for average mobile use (excluding handset cost)

	2015	2016	2017	2018	2019
Data (GB)	0.9	1.3	1.8	2.5	3.2
Texts	106	96	83	78	69
Mins	151	159	162	169	166
Overall satisfaction	89%	92%	91%	91%	93%

Source: *Ofcom pricing trends for communications services in the UK, Ofcom customer satisfaction research.*

Note: *To compare prices over time, Ofcom used a pricing model to find the lowest-cost tariff from each mobile provider that met the requirements of a basket of mobile services, excluding the cost of the handset. The basket changed from year to year to reflect changing usage, average calls, texts and data per connection in each year. An average price from these lowest prices was then calculated, weighting it by retail market share.*

This implies that MNOs are unlikely to be able to charge existing users a significant 5G premium. Not only would the improvement in service limited, but competition between MNOs will continue to exert downward pricing pressure.

In addition, research has shown that only 10% of customers are currently willing to pay a premium for 5G mobile services.[17] As a result, MNOs expect to generate **limited additional revenue from their existing customer base** from the deployment of 5G.

3.2.2 Failure to invest quickly in Full 5G would not risk the loss of existing users

For existing users of mobile broadband, MNOs have few, if any, incentives to deploy Full 5G. Crucially, this is because, as set out in Section 2.2.2, incremental deployment of 5G can be used to improve services for existing customers through eMBB, because it does not rely on a 5G core.

Revenues from existing customers are unlikely to increase if MNOs opt for Full 5G instead of rolling out incremental 5G options. MNOs will *not* risk losing existing mobile broadband customers to a rival that opts to deploy Full 5G, since they will be able to offer these customers eMBB.

Therefore, by opting for incremental upgrades, MNOs can continue to compete for existing mobile use cases, which in turn weakens the competitive pressure to rush Full 5G.

[17] Vodafone – Bank of America Global Research, UK customers (December 2020)

Recall that Full 5G will be of greatest benefit for use cases that sit outside mobile broadband (see Section 2.1). This puts the onus on new revenues streams from new user groups to justify Full 5G roll-out. And these sources of revenue, as set out in more detail in Section 3.3, are highly uncertain.

3.3 MNOs' ability to generate returns from new 5G use cases is highly uncertain

The strength of the business case for Full 5G is contingent on MNOs capturing profits from new 5G use cases, given that additional revenues from existing services will be low. These future applications are where the potential revolutionary impact of 5G lies. As set out in Section 2.3, URLLC and mMTC are expected to enhance productivity across industries.

The scope of new 5G services will not be confined to mobile broadband for end-consumers on smart mobile devices, which was largely the case for 4G. Instead, new use cases are likely to be delivered via a range of innovative software and hardware provided to business users as well as consumers. This points to the potential to switch the relationship with the end user away from MNOs to providers of the new services. This could hamper MNOs' ability to monetise their investment.

A further complication lies in the fact that these new 5G use cases are still under development, with no certainty on demand for service. This creates acute uncertainty around MNOs' expected returns from costly Full 5G investment. In particular:

- Inherently risky R&D is required to facilitate the integration needed to ensure seamless end-to-end performance with new 5G use cases;
- Considerable uncertainty remains about the demand for these services, once they are developed, and the willingness to pay for them; and
- Even if users are keen and willing to pay, there is also significant uncertainty around how much of the subsequent value generated will accrue to the MNOs.

We discuss each of these in more detail.

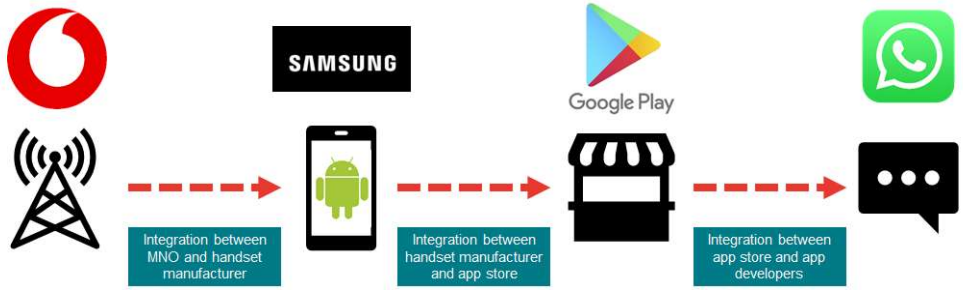
3.3.1 R&D is required for new use cases

As set out in Section 3.2, 4G was an improvement on existing mobile broadband services available to users of smartphones. Consumers enjoyed a seamless end-to-end service across a range of providers at different stages of the supply chain. This convenience is a result of Apple's (and later Google's) development of useable smart mobile devices with app stores. The development of this ecosystem took a number of years after the launch of 3G, which provided the mobile broadband network. This R&D means that relatively little integration is required to deliver new applications that need mobile broadband and no incremental investment is required by MNOs.

Specifically, it makes it possible for a user of a smart mobile device to buy the device from one provider, purchase a network service from another and then interface with different software providers for a range of services, for example

Facebook, WhatsApp and Google Maps. Figure 10 sets out an illustrative example of the integration requirements for 4G use cases.

Figure 10 Integration for 4G use cases was less dependent on MNO-led development



Source: Frontier Economics illustration.

But this will not be the case for new 5G use cases. The proliferation of complex 5G applications comes with a variety of different software and hardware needs. Mobile connectivity will not be limited to smart mobile devices but is expected to also be tightly integrated within a wider set of goods, which are sometimes referred to as 'verticals'. For example, an augmented reality headset with the ability to connect to a 5G network will have specific network requirements linked to the need for ultra-low latency. For example, application compute and storage resources will need to be brought closer to the end user to ensure low latency. This is known as edge computing.

But the business case for this degree of tight integration is unproven, essentially placing MNOs and other stakeholders close to the beginning of the product life cycle of these new services. Extensive R&D is required to develop usable new 5G-delivered services. This is likely to take time, as was the case with the ecosystem for smart mobile devices, which took around a decade to fully evolve after 3G networks were first deployed. Consequently, there is uncertainty as to who should develop this integration capability, with the proprietary nature of any solutions likely to impede use case development.

MNOs are supporting R&D on a small scale. Vodafone, for example, has built a 5G standalone MPN at Coventry University to trial virtual reality learning technology. Healthcare students at the university can take immersive, real-time augmented reality and virtual reality tours of the human body, relying on the network's ultra-low latency. Such trials are important showcases of the capability of Full 5G, but widespread, MNO-led use case R&D would require a major shift in the dynamics of the industry, bring it closer to industries such as pharmaceuticals, as described below.

CASE STUDY: INCENTIVISING INVESTMENT IN R&D

- Many industries are characterised by very high R&D costs. It is generally accepted in these industries that government intervention is needed to compensate for these high costs and resulting risks. This usually takes the form of patents that effectively grant a company monopoly rights.
- As an example, consider the pharmaceutical sector. Absent government intervention, a pharmaceutical company that discovers a new product is not guaranteed to be able to recoup its sunk costs. This is because the outcome of R&D (knowledge in this case) is a public good. Once the knowledge is created, copycat producers can free-ride on the R&D investments of a competitor, with the result that any profit margins on new products are quickly competed away.
- This creates a market failure. The incentive and the ability to invest become sub-optimally low, as investors are unable to recover the substantial costs of R&D, even when the potential demand for a new product is high. In the pharmaceutical industry, patents correct this market failure by allowing the extraction of monopoly profits from the sale of the new drug. The recapture of sunk R&D costs in this way ultimately increases the flow of future innovations.
- There are parallels here with the R&D required to develop integration methods for Full 5G. At present, there is some uncertainty around the MNOs' ability to monetise their solutions via patent protection. This uncertainty blunts investment incentives and hampers the development of new use cases.

3.3.2 The provision of and demand for new 5G use cases are still unknown

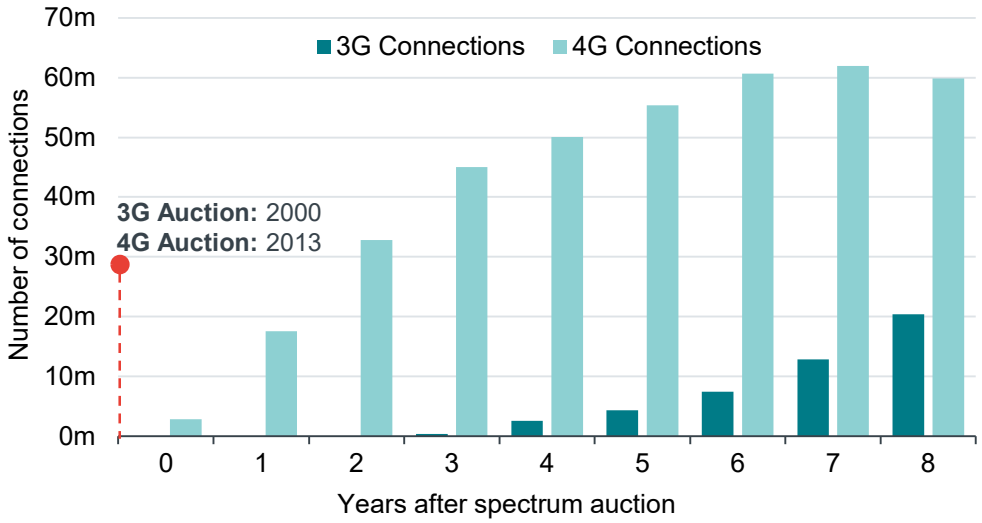
The R&D problem is compounded by considerable uncertainty around the take-up and willingness to pay for new 5G use cases once they are market-ready.

This is a different challenge from 4G, where the key revenue source was MNOs' existing customer groups. As already set out in Section 3.2.1, demand for 4G services and the commercial need to make investments were far more clear-cut. For a start, the transition from 3G to 4G marked a step change in quality of service for the same mobile broadband use cases. Moreover, the high level of smartphone penetration – 59% of the adult population was already using a smartphone to access the internet in 2013[18] – all but assured demand for 4G services. Figure 11 shows that take-up of 4G was particularly rapid.

But this is not the case for Full 5G, which will be geared towards new services and user groups. Given the sluggish pace of use case development for Full 5G, take-up is likely to be slower than 4G and may be more comparable with the relatively slow start for 3G. This compounds the uncertainty that MNOs need to account for when making their 5G investment decisions.

[18] https://www.ofcom.org.uk/__data/assets/pdf_file/0023/82265/section-4-digital-media-take-up-and-use.pdf

Figure 11 Number of connections since spectrum auction, by mobile technology



Source: GSMA – Mobile connections

3.3.3 Even if Full 5G use cases are highly valuable, it is unclear how much of this value will accrue to the MNOs

Even if there is considerable take-up and willingness to pay for new 5G use cases, a number of factors could limit MNOs' investment returns.

One plausible scenario is that MNOs support 5G use cases in a similar way to previous generations of technology by providing essentially a homogeneous input which is highly substitutable.

Crucially, in this case, MNOs may have concerns that prices in a competitive market may not support returns needed to fully recover the fixed costs of 5G roll-out. This was the case for 4G: technology premiums on 4G services were quickly competed away, even though consumer willingness to pay was high. Ofcom's own pricing analysis found the impact of 4G technology on prices of post-pay plans was close to zero over the period 2013-2017.[19]

Alternatively, it is possible that MNOs engage in differentiated competition which is R&D led. In this case, MNOs are still not guaranteed returns that will cover their investment as those returns could be stifled by competitive dynamics specific to the Full 5G market:

- Countervailing buyer power from customers of the MNOs' 5G services, as these are no longer end consumers but rather providers of new 5G use cases that may operate on a global scale. This may limit MNOs' ability to capture a sufficient share of the value generated by these new services; and

[19] https://www.ofcom.org.uk/__data/assets/pdf_file/0027/123894/Econometric-analysis-of-pricing-trends.pdf

- Additional competitive pressure from new players offering MPNs in commercially attractive areas. By limiting economies of scope, this may undermine MNOs' incentives to build nationwide public Full 5G networks.

We discuss these points in the next section and explain why they contribute to an investment hold-up problem in 5G that may lead to sub-optimal market outcomes for the UK economy.

4 THERE IS A RISK OF MARKET FAILURE IN 5G UNDER THE STATUS QUO

As outlined in the previous section, MNOs face considerable uncertainty as to how the new and innovative use cases unlocked by Full 5G might be monetised.

This uncertainty reduces investment incentives – as MNOs must incur the sunk costs of network deployment and R&D *before* they have the opportunity to acquire new customers whose demand and willingness to pay are untested. This is different from 4G, when MNOs had an *existing* customer base who clearly valued the new capabilities offered.

The outcome is a potential market failure known as a **hold-up problem**, which could lead to underinvestment in Full 5G. Such an outcome would be sub-optimal for the UK as it would limit the overall benefits expected from the new technology.

In this section, we:

- explain how the hold-up problem applies to 5G investment;
- show that this could lead to sub-optimal investment outcomes and thus potentially justifies policy intervention; and
- illustrate that the hold-up problem could be effectively mitigated by intervention.

We go on to discuss proposed policy and regulatory interventions in the final section of the report.

4.1 Full 5G investment is facing a hold-up problem

WHAT IS THE HOLD-UP PROBLEM?

- The hold-up problem is a classic problem in the economics of investment.[20] It exists where two firms, A and B, mutually benefit from an investment by A but cannot effectively contract for this investment upfront.
- Consider the following simple example:
  - An upfront investment of £60 by A creates an asset that generates a value of £100 when it is used by B.
  - Ex-ante, A will invest if it expects to earn £60 or more from selling access to the asset to B.
  - The hold-up problem arises if A is unable to contract for its share of the value ex-ante. Once the cost of £60 has been sunk, A can no longer threaten not to invest in order to try to secure a higher price.
  - With no alternative but to deal with each other ex-post, bargaining theory says that A and B would expect to split the value of £100 equally.
  - If A expects only a 50-50 share ex-ante, this is not enough to cover its costs of £60, and so it will choose not to invest – even though the investment would generate significant economic value overall.
  - The market failure is that A has no contractual mechanism to ensure that it can capture enough of a share of the total value generated from its upfront investment.
- Hold-up problems can arise for various reasons. For example, it may be that the outcomes of the investment – especially when research-led – are unknown. In this case, contract design is difficult as contingencies related to the investment may be unknown. It can also be a particular problem if B cannot be identified or if there are potentially multiple B firms, making it more difficult for A to share costs.
- This may deter the investor, as there is a potential for renegotiations to be triggered that could leave it in a less favourable position. As such, the investor may choose not to invest in order to avoid this risk.

The theory of the hold-up problem is relevant to the Full 5G investment decision.

An MNO has a choice of whether to make an upfront investment in a Full 5G network at a considerable cost. This choice relies critically on the returns that the MNO expects from its supply of 5G services to players further down the supply chain for the provision of new use cases, as returns from existing users are likely to be limited (see Section 3.2). The returns from new applications, however, will be dictated by the MNOs' ability to extract value from the network services it provides. But once the MNO has invested, there are a number of contributing factors that limit its ability to do that.

[20] Hart, Oliver, and John Moore. 1990. Property rights and the nature of the firm. Journal of Political Economy 98(6): 1119-1158. https://dash.harvard.edu/bitstream/handle/1/3448675/Hart_PropertyRights.pdf

As set out in the box above, an MNO post-investment can no longer bargain for higher returns by threatening not to invest. In addition, there are other pressures on an MNO's returns: it is likely to have to (i) compete with rival MNOs with Full 5G networks as well as potentially with new players offering MPNs using shared spectrum; and (ii) negotiate with customers who have potentially significant countervailing buyer power that limits how much the MNOs can charge (see Section 3.3.3).

In theory one solution could be for an MNO to contract for its investments in advance by securing demand from players further down the supply chain at a pre-determined price. But the MNO is unable to contract with other players in this way because of the uncertainty around new 5G use cases, as they are still being developed (see Section 3.3.2).

4.2 The hold-up problem could prevent effective competition emerging in Full 5G

It follows from the above that, in the absence of being able to contract for a proportion of the value of Full 5G *ex-ante*, MNOs rely crucially on their ability to capture *ex-post* the value created from its Full 5G investment. This, in turn, will determine the 5G outcome in the UK mobile market and the degree to which the significant benefits for the economy set out in Section 2.3 are realised.

An MNO's ability to extract value from its services following its Full 5G investment will depend on two key factors:

- Competitive pressure - The extent of pressure from competing Full 5G networks, which will be determined by the substitutability of rival MNOs' offerings and the ease of switching for customers; and
- Countervailing buyer power - The extent to which other players in the supply chain, e.g. digital gatekeepers and verticals, have countervailing buyer power to challenge the MNOs' appropriation of value.

In the following sub-sections we take various combinations of these two factors and explore different outcomes to the hold-up problem. The takeaway is clear: under current regulatory policies, there is a risk that Full 5G will not meet the UK Government's objectives because of slow roll-out and/or inadequate coverage. This is either because all MNOs decide to hold back on Full 5G until there is more certainty about the commercial prospects of new use cases (Hold-up outcome 1), or because a single MNO invests in Full 5G and becomes a monopoly provider of new 5G services (Hold-up outcome 2). We discuss these in turn below.

4.2.1 Hold-up outcome 1: MNOs hold back Full 5G roll-out

In the first outcome MNOs hold back on Full 5G roll-out. This would occur if there is uncertainty on the timing of demand for new use case and there is a view among competing MNOs that they will be able to invest in Full 5G networks when there is clarity on demand, making the resulting 5G services highly substitutable to players further down the supply chain (which was the case in 4G, see Section 3.3.3).

There is uncertainty in the timing of demand for new use cases

The delayed 3G take-up after the spectrum auction in 2000 provides a good example of what a wait-and-see outcome to the hold-up problem could look like. After the auction, MNOs were slow to build out 3G networks because of weak consumer demand for new mobile broadband services, rooted in the scarcity of compelling applications and in the poor choice of 3G handsets at the time. The conditions were not dissimilar to those facing 5G today. Roll-out and consumer take-up only really took off once use cases developed, in particular applications and smart mobile devices.

Competition reduces the potential upside if demand takes off

If the MNOs consider that they can defer investment until demand becomes more certain, the MNOs would recognise that out-and-out competition (between themselves and with new MPN players) to serve new user groups would ensue, compressing margins and jeopardising the opportunity to earn a sufficient return on investment.

Overall returns are depressed

As a result, MNOs will sit tight, as the risk of low returns from their Full 5G investment is too high:

- If demand for new use cases takes time to develop, for example due to the need for new ecosystems of integrated hardware, software and network capabilities, investment may not generate returns, leading to a downside risk; and
- If demand for new use cases develops more quickly, then competition between the MNOs will limit the upside.

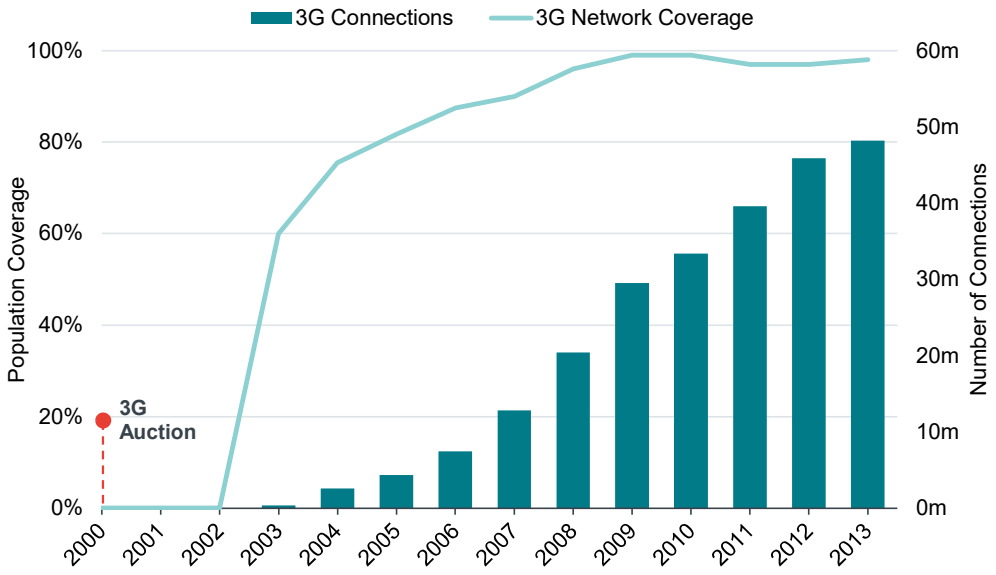
Ideally, MNOs would have certainty that their post-investment returns will cover their costs. But, as set out above, the hold-up problem gets in the way. There is too much uncertainty about these new use cases for contracts to be successfully completed.

MNOs may defer investment delaying the benefits of 5G

With expected returns relatively low and a high degree of demand uncertainty, the rational approach of MNOs would be to defer investment until there is more clarity on demand.

As can be seen below, 3G did eventually spread across the UK and by 2008 there was 96% population coverage. However, delays with 5G like those that dogged 3G would leave the UK significantly short of the Government's aim to be a market leader. A sluggish 5G roll-out could have a greater impact than 3G's slow start because its use cases are set to be ground-breaking and applicable across industries, leaving the UK at risk of losing out on potential productivity gains and reducing the UK's competitiveness internationally.

Figure 12 3G population coverage and connections over time



Source: GSMA

OUTCOME 1: THE UK COULD BE AT RISK OF LOSING LUCRATIVE INDUSTRY DEMAND

MNOs take a wait-and-see approach, exercising the option to invest only incrementally until Full 5G use cases are developed, and demand and willingness to pay are certain.

By the time certainty emerges, other countries may be far ahead in the deployment of Full 5G. Some have already taken a lead as they have the regulatory support to make progress. This may lead to business deals being explored in these countries rather than the UK, which would be a missed opportunity.

4.2.2 Hold-up outcome 2: A Full 5G gatekeeper emerges

An alternative outcome to the hold-up problem under the status quo is a scenario in which one MNO is able to 'escape' competition to become the dominant provider of Full 5G. This could be an MNO player in the UK with a comparative advantage in deploying Full 5G initially.

Once a single provider has invested to a sufficient scale in advance of other players, similar investment by other MNOs could be more difficult. This is for two reasons. First, it is possible that investment by subsequent competitors may not be profitable, given that the resulting competition will drive down prices. Second, owing to the nature of new 5G use cases and the expectation that the key user groups will primarily be industrial customers with complex needs, it is possible that once they contract with a provider they will be locked in for a long time. This is because switching costs are likely to be high.

The emergence of a dominant provider under this scenario would be unlikely to put competitive pressure on other MNOs to invest due to these two barriers to entry.

OUTCOME 2: THE UK RISKS MISSING OUT ON HEALTHY COMPETITION IN FULL 5G

In a scenario where a dominant Full 5G network provider invests and is able to appropriate sufficient returns, there is a monopoly outcome to the hold-up problem, which is itself another form of market failure. This is because a monopolist will have significant market power, enabling it to manipulate the market price and thereby control its profit margin.

In doing so, the monopoly may be able to extract excess rents from providers of new 5G services, in a way that impedes these providers' ability to innovate or develop their services. This would, in turn, slow the growth of new 5G applications, even if they are valuable to end customers.

It is also likely that the monopoly will have weak incentives to invest once it has invested to a sufficient scale. Barriers to entry for rival MNOs are likely to be considerable, so the monopolist's position in the market will be uncontested, resulting in limited, if any, competitive pressure on it to invest.

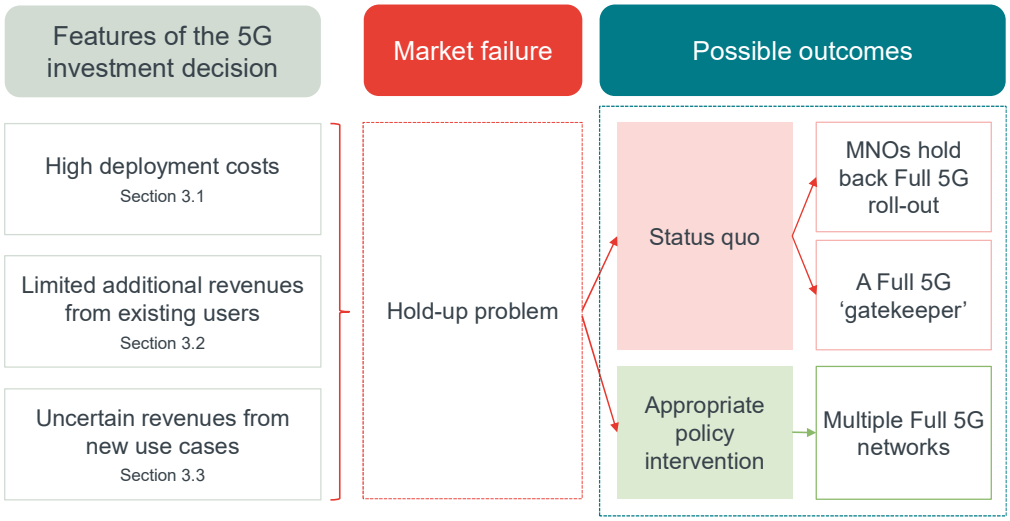
The end outcome for the UK economy is not what it could be. Even though there is a Full 5G network, access to the network will not be on socially optimal terms, giving rise to a misplacement of resources.

The market could tend towards this outcome and market failure as a result of the Government's or Ofcom's decisions or inactions. Ex-post intervention to address this issue will likely be more challenging to implement than acting now to protect existing network competition and ensuring it continues in the Full 5G world.

4.3 The hold-up problem could be mitigated through government and regulatory intervention

It is clear that the features of the 5G investment decision – as set out in Section 3 – contribute to a hold-up problem with the risk of unfavourable outcomes for the UK economy. These are summarised in the Figure below.

Figure 13 Overview of the possible outcomes from the hold-up problem



Source: Frontier Economics.

Rapid investment in Full 5G networks are central to the economic benefits that 5G could generate. The discrepancy between the social value of 5G that the Government expects and the likely market outcomes represents a market failure. This seals the case for policy intervention to create the incentives needed to ensure that MNOs invest in Full 5G and that healthy network competition is maintained for 5G and subsequent technologies. To this end, investors need to have confidence that the regulatory environment is conducive to a profitable business case for multiple competing Full 5G networks, by ensuring that MNOs can realise sufficient value from their Full 5G services.

The specific policy recommendations that could nurture this type of regulatory environment are set out in the following section.

5 A NEW REGULATORY APPROACH IS NEEDED TO MITIGATE THE RISKS OF SUB-OPTIMAL 5G OUTCOMES

As seen in the previous sections, the uncertainty around future returns potentially creates a hold-up problem. There is a role for Ofcom and Government to make regulatory and policy changes to help mitigate this by providing stronger incentives for longer-term investment.

The remainder of this section makes the case:

- that a shift in policy focus towards promoting mobile investment is needed to crystallise the benefits of Full 5G; and
- that Ofcom can pull a number of policy levers to support Full 5G investment.

5.1 Policy interventions should give increased weight to dynamic investment incentives

Ofcom and the Government should rebalance their policy objectives to put more weight on dynamic investment incentives when considering interventions in the mobile industry. This will align the incentives of the MNOs to invest in Full 5G with the Government's ambitions. For it to be effective, such an overarching change in approach should also be reflected consistently across individual policies and impact assessments of new or evolving policies.

In some cases, placing more weight on dynamic efficiency may imply a trade-off with shorter term consumer benefits. The goal of any regulatory/policy changes should therefore be to balance the trade-off between short-term 'static' consumer benefits and the provision of appropriate longer-term 'dynamic' investment incentives. This would increase the chances of rapid Full 5G deployment by multiple MNOs, ensuring that:

- end users in the UK continue to reap the fruits of healthy mobile network competition; and
- the UK economy benefits from productivity gains unlocked by new 5G use cases.

CASE STUDY: INCENTIVISING FIBRE ROLL-OUT

A similar change in policy direction towards longer-term objectives has already been seen in the fixed industry. Fibre networks needed significant investment to meet the growing needs of people, businesses and mobile networks.

This was recognised by Ofcom. As part of its Strategic Policy Position[21] published in 2018, it set out numerous regulatory changes aimed at promoting fibre investment. Some of these changes reflected a clear shift towards dynamic investment incentives. For example, Ofcom:

- Provided longer-term certainty for investors by extending the length of competition assessments from three years to five; and
- Preserved investment incentives by clearly signalling the opportunity to make returns which reflected the risks taken, even if this led to higher prices in the short run.

In doing so, Ofcom accepted that the longer-term benefits of investment outweigh short-term costs. These measures catalysed increases in investment – Ofcom said in its Spring 2020 update that full fibre broadband "*continues to improve at a rapid pace*".[22]

Mobile needs a similar approach as the investment challenge is arguably particularly acute given the uncertainty outlined in Section 3.3.3.

5.2 There are several ways to incentivise Full 5G roll-out

A policy shift towards prioritising investment should be accompanied by more targeted policy changes that address MNOs' current incentives to invest in Full 5G. There are a number of policy changes that Ofcom and Government could make now to ensure a socially optimal 5G outcome, particularly if they are implemented together. Longer-term certainty for investors and clear signals of the opportunity to make returns, like the messaging to investors in the fixed market, are two examples of what is needed. The policy changes could involve the following, possibly in combination:

- Increasing certainty of returns so that MNOs' perceived downside risk of limited returns post-investment is lowered;
- Managing the costs of Full 5G investment so that they are more comparable to the returns MNOs might expect from their Full 5G investment; and
- Ensuring market structures in the mobile (and fixed) industry are conducive to the deployment of Full 5G.

These policies changes are outlined in the remainder of this section.

[21] Ofcom, *Strategic Policy Position: Regulatory certainty to support investment in full-fibre broadband,* 2018. https://www.ofcom.org.uk/__data/assets/pdf_file/0025/116539/investment-full-fibre-broadband.pdf

[22] Ofcom, *Connected Nations Update,* 2020. https://www.ofcom.org.uk/__data/assets/pdf_file/0028/195256/connected-nations-spring-update-2020.pdf

5.2.1 Increasing certainty of returns

As has been discussed thus far, a lack of certainty on a) the value that will be generated by future 5G applications and b) the share of this value that will accrue to MNOs is dampening the incentive to invest. Policy changes on net neutrality and levelling the playing field with private MPNs can help mitigate this.

Addressing net neutrality

Net neutrality is enforced by law in the UK under the Open Internet Regulation, which came into force in 2015.[23] It says that internet service providers, such as MNOs, have to treat all internet traffic on their networks equally and cannot differentiate service quality by, for example, favouring certain content in exchange for higher revenues. But the interpretation of this law is becoming increasingly complicated as it applies to software-defined networks like Full 5G.

The benefits of these networks in both rural and urban settings stem largely from their network slicing capabilities, which require the MNO to have greater flexibility in the services it provides. Under the current net neutrality regime, it is not clear whether these types of services would be prohibited or whether they would be classed as specialised services and treated differently. (We note that Ofcom is in the process of reviewing the current regime).[24]

This uncertainty makes it difficult for MNOs to develop clear business cases for these services. As such, Ofcom/Government should reassess whether current net neutrality laws are fit for purpose for service-driven mobile networks and provide more clarity on its classification criteria for specialised services. This will give MNOs greater certainty in their investment decisions.

Level playing field with mobile private networks

As set out in Section 3.3.3, MNOs will have to compete with rivals *and* new MPN players reliant on shared or unlicensed spectrum.

The cost base of the new players will differ from that of MNOs, potentially allowing them to undercut MNOs. The first-order effect of this is to reduce MNOs' expected returns from Full 5G investment. The second-order effect, linked to the first, is to reduce MNOs' investment incentives, as revenues from industrial uses will be an important source of funds for Full 5G.

Ofcom and Government should therefore make sure that the emergence of new MPN players does not threaten the public deployment of Full 5G networks because, as discussed previously, the more efficient outcome is for a public 5G network to serve the majority of use cases, thereby maximising economies of scale and scope.

[23] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02015R2120-20181220

[24] https://www.ofcom.org.uk/consultations-and-statements/category-2/call-for-evidence-net-neutrality-review

5.2.2 Managing costs

Regulatory 'overheads' are in theory a fixed cost and so should not affect investment incentives or competition. In practice, investors and management take account of these costs and the perceived risk that regulatory action will expropriate some of the value created through investment in the future.

As such, the following recommendations are intended to minimise the costs associated with regulatory overheads.

Annual licence fees

MNOs are required to pay annual licence fees (ALFs) for their spectrum holdings. Ofcom sets the levy on spectrum used for mobile services, other than that which is still within the initial licence term after an auction, to reflect a conservative estimate of its full market value. Ofcom believes that, in doing so, it promotes the optimal use of spectrum, which is in line with its duties. Allowing operators to trade spectrum should in theory be sufficient to ensure its optimal use, but Ofcom considers that the additional step of levying licence fees will in practice produce better outcomes.

However, even if setting ALFs at full market value leads to some efficiency improvement, there is a risk that the current fees methodology will not result in optimal outcomes. Ofcom currently estimates the market value of spectrum based on benchmark auction valuations, combining UK auction data and information from other European jurisdictions. However, auctions of specific bands are infrequent and so, Ofcom's methodology means relying on a small sample of information that is increasingly out of date, as the last auction may have occurred many years ago. The upshot could be excessive ALFs because of sampling errors due to the small sample size, the use of outdated benchmarks or the risk that the use of only limited data introduces a degree of subjectivity in the fee-setting process.

As a result, Ofcom's current approach could blunt incentives to invest if there is a risk that ALFs are set too high now or in the future due to a lack of adequate benchmarks. MNOs may either inefficiently relinquish spectrum for which the ALFs are excessive or may defer investment related to spectrum bands where there is a risk that ALFs may be set too high. This could lead to sub-optimal use of spectrum, worse than if Ofcom relied on spectrum trading between operators to produce the best outcome.

Given the methodological difficulties with its current approach, Ofcom should revisit its framework for setting ALFs to make sure it is consistent with its duties, including promoting investment in 5G.

Consumer protection

Consumer protection is clearly a key objective for Ofcom. It is particularly important for more vulnerable customers. However, Ofcom's initiatives have stretched beyond this group. They have required significant investments by the industry and have reduced revenues. Ofcom's purpose is laudable, but it is not self-evident that its actions are necessary to protect consumers in a highly competitive market. At a time of heavy emphasis on boosting investment, Ofcom should carefully balance

the consumer benefits of each proposal against its potential impact on the ability of MNOs to make future investment commitments and on the ability of operators to differentiate themselves from their competitors.

Ofcom should limit intervention if the market is likely to find a solution. For example, MNOs are able to manage the upcoming 2G/3G switch-off in a way which does not affect customers for the most part. Indeed, MNOs have an incentive to make sure it runs smoothly. Regulatory intervention is not required for most customers, who can easily switch to current technologies. Instead, Ofcom should play a supporting role in the switch-off, just as it did with copper retirement, facilitating coordination between MNOs if needed and at most ensuring safeguards for vulnerable customers.

5.2.3 Suitable market structures

A number of other factors that impact MNOs' incentives to invest have to do with market structure in the mobile and fixed industry. In particular, a business case for Full 5G deployment may rely on efficiencies that result from further consolidation or network sharing by MNOs. The structure of the fixed industry could also play a role because, as set out in Section 2.2.1, MNOs rely on backhaul from fixed providers, who may be vertically integrated with an MNO. The following recommendations aim to address these issues and to encourage Ofcom and relevant authorities to consider the impact that their interventions may have on the incentives to invest.

Approach to consolidation

Ofcom appears to be sceptical of consolidation, given its views and decisions during merger assessments and the discussion paper it published in January 2021 titled '*Market structure, investment and quality in the mobile industry*'.[25]

In particular, it is clear from previous merger assessments that competition authorities place little weight on efficiencies that could arise from network integration. Rather, their priority seems to be to ensure favourable short-term pricing outcomes for consumers, even where there is a reasonable efficiency trade-off. This is in contrast to the view of the European General Court. In its assessment of the blocking of the proposed merger of Telefonica UK and Hutchison 3G UK, the court ruled that the European Commission should have taken more detailed account of the proposed efficiencies of the transaction.

Ofcom's discussion paper concludes that network quality and investment may be lower in more concentrated markets, suggesting that it would assess prospective consolidation in the UK through this prism. However, this analysis is necessarily backward-looking and fails to take account of the dynamics of 5G investment. As noted above, these differ significantly from the dynamics of 4G, which in turn differed from investment in the 3G cycle.

Consolidation may become a more important factor in catalysing necessary future investment. The significant costs of Full 5G (as set out in Section 3.1) mean that it may not be possible for sub-scale operators to invest sufficiently to effectively

[25] https://www.ofcom.org.uk/research-and-data/economics-discussion-papers/mobile-market-consolidation

compete. In particular, as some of these fixed costs relate to R&D, network sharing may not enable smaller operators to compete effectively. In future, UK competition authorities should therefore attach more weight to an assessment of the impact that consolidation could have on investment, bearing in mind that the barriers to Full 5G investment are particularly daunting.

Support for rural roll-out

Network sharing has enabled network operators to reduce fixed costs associated with coverage, while ensuring continued competition both on price and service differentiation. This has delivered benefits to consumers through faster roll out of new technology and better coverage than would have been the case if operators had rolled out networks independently.

While network sharing may not be a key determinant of 5G roll-out in urban areas due to the complexity of 5G networks and the fact that network operators will wish to differentiate their networks, it may continue to be important in rural areas because of the high fixed costs of rural roll-out. Consequently, Ofcom/Government should be supportive of network sharing for rural roll-out.

Faster 5G roll out in rural areas could provide benefits both in terms of rural services and fixed wireless access (FWA). The Government's findings from its 5G Testbeds and Trials Programme[26] found that FWA can be an alternative, lower-cost solution to large-scale fibre installations. But commercial deployment of FWA is unlikely, especially in remote areas. In which case, network sharing could be important if FWA is to become a viable alternative to fibre.

Ofcom and Government should thus support network-sharing agreements to promote the faster roll-out of 5G in rural areas. Network sharing may also bring benefits in other areas, for example where limits on the number of potential cell sites makes competitive roll-out problematic. They should also be open to potential innovative network-sharing arrangements (e.g. spectrum pooling) in other parts of the country if this leads to benefits to end users while still preserving competition.

Backhaul pricing

As set out in Section 2.2.1, fibre-based backhaul has become the preferred option as the volume of data carried over networks has grown, and increasingly holds the key to the resilience of networks.

MNOs' demand for backhaul is expected to rise further with Full 5G. But there are currently only two main fibre backhaul providers: BT Openreach and Virgin Media, both of which are vertically integrated with an MNO. In many areas Openreach is the sole provider. This raises a risk of partial foreclosure, whereby the providers set backhaul pricing in a way that inhibits the ability of rival MNOs to compete in the provision of 5G services, especially in rural areas. While this risk would have been considered in the CMA's assessment of the Virgin Media/O2 merger, it must continue to be monitored as the market evolves, in particular because of the importance of fibre backhaul to future 5G deployment. In addition, any policy

[26] https://www.gov.uk/guidance/5g-programme-findings

intervention should further encourage mobile operators to invest in their own backhaul network to improve resilience.

Figure 14 Overview of policy recommendations

Issue	Policy recommendation
Addressing net neutrality	▪ Reassess whether net neutrality laws are fit for purpose for service-driven mobile networks. ▪ Provide more clarity on the services that are classified as 'specialised services' under the net neutrality laws.
Level playing field compared to MPNs	▪ Ensure that the development of the new MPN players does not endanger the public deploymen of Full 5G networks.
Annual licence fees	▪ Ofcom should revisit its framework for setting ALFs to ensure that they are not excessive and not deter investment.
Approach to consolidation	▪ Pragmatic assessment of consolidation, recognising the importance of efficiencies and th impact on investment incentives.
Consumer protection	▪ E.g. Ofcom should support 2G/3G switch-off in a coordinating role with minimal intervention.
Support for rural rollout	▪ Open to innovative network sharing agreements, as rural and urban needs may differ. ▪ Direct support e.g. through subsidies should be provided where commercial roll-out is not viable.
Backhaul pricing	▪ Ofcom should ensure competitive and fair backhaul access and pricing.

Source: Frontier Economics.


frontier
economics