DEPARTMENT OF SCIENCE, TECHNOLOGY,
ENGINEERING AND PUBLIC POLICY

# 5G Technology – A Demonstration of How Innovation is Political

3

STEaPP Working Paper Series

# 5G Technology – A Demonstration of How Innovation is Political

**Abstract:**
Government funding for science and innovation has fundamental political and economic repercussions. To demonstrate this point, this paper looks at how the UK can achieve its mission of becoming a world leader in 5G. It begins by exploring the history of previous generations of telecommunications, and how leaders of this industry have emerged with government support. It then identifies what problems the UK might face in achieving its goal of becoming a world leader in 5G, and uses the cases of China and the United States to provide a more detailed exploration of how they have developed or lost their leadership. Finally, it uses these cases to formulate a series of recommendations that the UK should consider in response to the problems we identify.

**Key words:**
5G, Telecommunications evolution, United Kingdom

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3

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# Table of contents



"This paper reveals how deliberate government action has shaped each country's leadership in previous generations of telecommunications."

# Executive Summary

Government funding for science and innovation has fundamental political and economic repercussions.

Neoclassical political theorists have advocated for a laissez faire approach by the government, protecting property rights and occasionally correcting market failures, while they suggest that the private sector decides where to invest in science and innovation. However, for countries that want to lead in the next generations of technological development, and fully unlock the social and economic rewards, this neoclassical approach does not work.

To demonstrate this point, this paper looks at the development of 5G telecommunications technology and the cases of China and the United States (US) to help inform decision makers in the United Kingdom (UK). This paper reveals how deliberate government action has shaped each country's leadership in previous generations of telecommunications. This deliberate action is particularly patent in China, where leadership in 5G has been articulated in government documents since 2013. This remarkable case shows how a country with few existing capabilities in telecommunications technology managed to become a world leader through government support for science and innovation. In the US case, when the government stopped funding certain areas of science and innovation, its global influence in telecommunications shrank. The US is now scrambling to reassert its dominance in 5G, as policymakers from across the political spectrum are advocating for more state involvement.

In addition to opening up new debates regarding the political nature of science and innovation funding, 5G reveals the political nature of technologies themselves. In an emerging global political paradigm, new alliances are forming around the development and adoption of 5G. Where a country aligns itself today will have long term repercussions that will be hard to undo.

The UK has announced it wants to be a world leader in 5G, but first it has a number of questions it needs to answer when looking at 5G, 6G and beyond. Whose technology will it adopt for this generation? What role should the government play in developing its science and innovation capabilities? How does funding for science and innovation interplay with political and economic concern?

To respond to these questions, we have a series of considerations across three areas:

1. **Science and innovation – developing future generations of telecommunications technology**
   - 1.1. Support an 'Airbus model' allegiance with the US and the EU to grow Western telecommunications champions that benefit the participating countries
   - 1.2. Support OneWeb's 5G and possible 6G research, and consider taking an equity stake in it to retain its capabilities in the UK
   - 1.3. Publish a strategy on telecommunications areas the UK would want to lead on to provide more direction to its companies
   - 1.4. Take a leading, proactive role in standard setting for 6G
2. **Political – decide if the UK will use Huawei technology in its 5G networks**
   - 2.1. The UK needs to make a decision on whether or not it will use Huawei technology, and then leverage its allegiance with the Chinese, EU or US to build its own capacity
3. **Economic – how to fund 5G deployment and the development of new UK champions in 5G and 6G**
   - 3.1. Use capital cost allowances to speed up the deductions firms receive for building telecommunications infrastructure
   - 3.2. Use existing funding to engage all parts of the triple helix through a more targeted approach for priority areas of 5G and 6G telecommunications

# Introduction

How does innovation occur? Neoclassical economists suggest that the risk of investing in innovation is taken by entrepreneurs and then markets determine whether or not these investments yield profits (Lazonick and Mazzucato, 2013). They support a laissez faire approach, where a government only supports the framework conditions, like protecting intellectual property (Borrás and Lundvall, 2009). When a laissez faire approach is taken, countries, like the US has done, technological leadership has been lost in areas of strategic importance.

In reality, the innovation process is much more complex and involves the interactions of a set of interdependent actors, or a 'triple helix' of universities, industry and government (Etzkowitz and Ranga, 2013). Telecommunications technology is a perfect example of how these three parts of the triple helix have come together to drive innovation in different countries. To support early stage research and development (R&D), governments have used a combination of funding government labs and universities, and then supported commercial efforts through procurement, challenge prizes, and regulations.

As part of this triple helix, it is the role of government that has been particularly misunderstood in theories about innovation. It is not just markets that determine an innovation's success, but also how government support shapes markets for different technologies, derisks early-stage science, and provides a direction to innovations (Schot and Steinmueller, 2018). This approach has been covered extensively by Mariana Mazzucato (see Mazzucato (2013), Mazzucato (2015a), Mazzucato and Penna (2015), and Kattel et al. (2018). This paper delves into how it has market-shaping policies have affected the telecommunications industry.

The ways in which governments support science and innovation cannot ignore the interplay of politics and economics. Winner (1980) says that it is obvious how "technical systems of various kinds are deeply interwoven in the conditions of modern politics", and goes on to suggest that technologies themselves can be political – beyond the social and economic system that they are embedded in.

Again, the telecommunications sector provides an excellent example of how this notion is manifest, as international standards play an ever-increasing role in the development of technology – helping firms and countries protect and increase their competitive advantages (Egan 2003). These standards determine the "specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose" (ISO, no date). As a result, they can benefit existing products and processes from different countries. Many countries are trying to lead on standards regarding 5G to support their domestic interests, while Japan, China and Finland are all openly looking into 6G standards (Mobile Europe, 2020). In explaining the market-shaping approaches of different governments, this paper shows how innovation is political.

To explore these issues regarding the governance of science and innovation funding more closely, this paper looks at how the UK can achieve its mission of becoming a world leader in 5G. It begins by exploring the history of previous generations of telecommunications, and how leaders of this industry have emerged with government support. It then identifies what problems the UK might face in achieving its goal of world leadership and uses the cases of China and the US to provide a more detailed exploration of how they have developed or lost their leadership. Finally, it uses these cases to formulate a series of recommendations that the UK should consider in response to the problems we identify.

"It is not just markets that determine an innovation's success, but also how government support shapes markets for different technologies, derisks early-stage science, and provides a direction to innovations."

# Policy Problem

## 5G development timeline

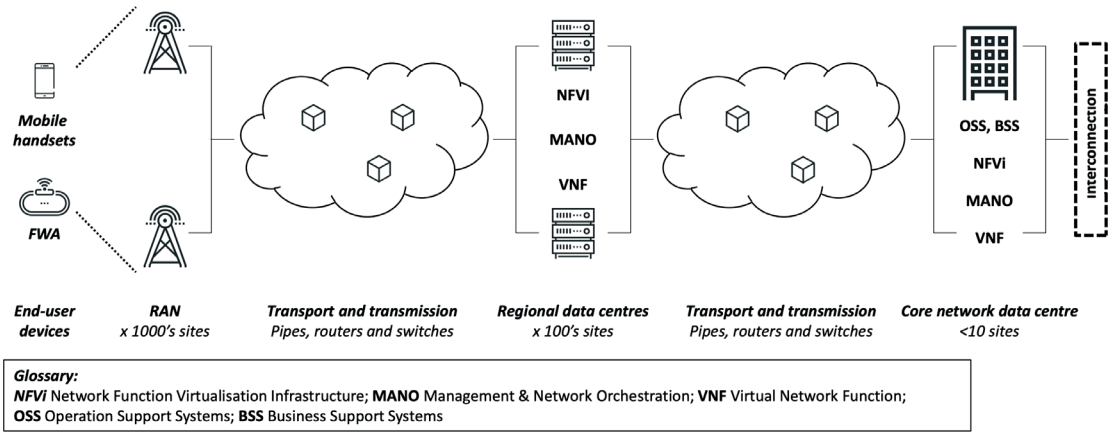
This section explains the different generations of telecommunications technology, their linkages to public policy, and their repercussions for the UK. To get an overview of what is involved in telecommunications infrastructure, **Figure 1 (below) provides an overview of a 5G network.**

Going back in time, the underlying technology for the first generation of telecommunications, or 1G, was developed by AT&T's Bell Labs in the US, which had received significant government support for its research, and protection from competition (Freidenfelds et al., 2002). Following this discovery, countries around the world worked with their domestic companies to develop various standards for 1G networks, and to build the infrastructure to support them (Greevan and Kaa, 2016). The first 1G network was launched in Japan in 1979 by a government owned-corporation, Nippon Telegraph and Telephone Corporation (NITT) (NITT, no date). This launch was followed by AT&T and Motorola, who co-developed a US standard and network (United States International Trade Commission, 1993).

**Figure 1. Parts of a 5G network. Source: adapted from DCMS, 2019.**

The Swedish company Ericsson emerged as the other leader in telecommunications standards and network infrastructure for 1G. Although the Swedish government acknowledges there were no linear linkages from the lab to the market for this early technology, Sweden did shift its industrial and research agendas to allow universities to focus on "problems whose solution in theory and in industrial development enabled Ericsson's huge success". Universities also played an important role in increasing the supply of technical talent Ericsson needed (Arnold, Good and Segerpalm, 2008). Evidently, all of the initial 1G companies were supported by the government or their university research system. These relationships demonstrate the importance of the triple helix approach to supporting new technological development and the government in shaping markets.

The UK did not have a 1G company to build its infrastructure so had a difficult decision to make regarding which company, and, to an extent, which country, they wanted to align themselves with. There are records of this internal debate within the UK government, showing what a political choice this was, not just a technological one. The predecessor of Vodafone ultimately chose Ericsson, while British Telecoms (BT) worked with Motorola. Their networks launched in 1985. Other companies eventually also took part in developing the UK networks. Foreign firms set up subsidiaries in the UK, and this built capacity to start up some UK firms that entered the telecommunications supply chain.



However, the UK never developed a company with the capacity to develop the technology for some of the core infrastructure (University of Salford, no date, a).

The development of wireless connections for sending text messaging, pictures and small amounts of data is what defined 2G. The deployment of this generation was enabled by a coordinated effort by governments across Europe, where their joint funding and new standards helped grow new leaders in the telecommunications space. This is demonstrated by the first 2G network in the world being developed by the Finnish company Nokia and German company Siemens, who launched it in Finland in 1991 (University of Salford, no date, b). 2G also led to notable new entrants into the UK's telecommunications infrastructure space – including the Chinese company Huawei, which played a limited role after opening an office in the UK in 2001 (Tomaschek, 2020).

3G introduced some internet browsing and data downloading capabilities, while 4G was 500 times faster and allowed for all of the modern capabilities we enjoy today with our phones. Who was responsible for these generations? It was a mix of actors, but the partly-government-owned spinoff of Japan's NITT, NTT Docomo, launched the first 3G network in 1998, while 4G was the brainchild of the Defense Advanced Research Projects Agency (DARPA) in the US (GTI, 2013). 4G also demonstrated Huawei's leadership and growing global reach, as it launched the world's first 4G mobile network in Oslo in 2009 (Huawei, 2009). Again, these generations of telecommunications show the important role the state has played in shaping markets.

Over these two generations, the telecommunications industry saw some consolidation, including "Nokia/Siemens (2006), Nokia/Motorola (2010), Ericsson/Nortel (2011) and Nokia /Alcatel-Lucent[Bell Labs] (2015)" (DCMS, 2019). This meant that the US no longer had a domestic leader for all core telecommunications network infrastructure, although Cisco retained some market share in the space but its technologies are less applicable for 5G (Nuttall, 2020). Today, Ericsson, Nokia and Huawei now account for 60% of telecommunications equipment revenue worldwide, while Korea's Samsung and China's ZTE have emerged as smaller players. Huawei is now the biggest telecommunications network provider in the world and has seen its global share of telecommunications equipment revenue rise from 20% in 2014 to 28% in 2019 (Pongratz, 2020). For the UK, this also meant that 3G and 4G telecommunications infrastructure had to rely on technology developed by companies from abroad.

## 5G Benefits

The core reason why every country in the world is in this race to develop 5G technologies lies in its superior speed, capacity and latency (Duffy, 2020). For instance, with 4G, the average latency is around 50 milliseconds (ms), while 5G's average is around half of that time and can even go as low as 1ms. This change in speed is insignificant for the average internet user, but it makes a big difference for things like high frequency trading or autonomous vehicles where every ms counts (SETsquared, 2016). 5G affects many things – from phones to smart cities – but the real international technological competition is playing out regarding the network infrastructure that everything else connects to, which will be discussed in the case studies in this paper.

Each new generation of telecommunications has created huge economic benefits. For example, in 2016, mobile technologies and services generated 4.4 percent of GDP globally, or about US$3.3 trillion in economic value. This is expected to grow to 4.9 percent of global GDP by 2020, or over US$4.2 trillion (Harris, 2018). For the UK, Barclays (2019) found that a "5G mobile telecommunications network could increase annual UK business revenues by up to £15.7bn by 2025".

To unlock this opportunity, the UK is looking to use all parts of the triple helix. In 2016, the UK government claimed it wanted to be a world leader in 5G technology and announced £1 billion for broadband investment to support fibre networks and 5G across Britain, and £41m for a 5G Testbeds and Trials Programme (5G strategy for the UK, 2017). In the same year, BT and Huawei announced their joint partnership to 'lead the global development of 5G mobile technologies' opening up a 5G emulator, which was partly funded by the Enterprise M3 LEP growth fund. This emulator is expected to enable local businesses to access 5G across the UK (SETsquared, 2016). Finally, in 2015, the University of Surrey opened a 5G Innovation centre to foster global collaboration. This technology will then be commercialised in 2020 to drive economic development and research in the UK (Computerworld UK Staff, 2019).

## Problem Framing

Although there are many benefits that 5G technology can bring, it also presents some science and innovation, political and economic hurdles for the UK to overcome if it seeks to truly become a world leader.

### Science and innovation

Firstly, 5G cannot just use the infrastructure from previous generations because it requires a greater number of base stations (Hutton, 2019). New infrastructure and new technology will be required to power this generation. The question here is about who is responsible for the development – is it taking a neoclassical approach and leaving it to the markets, or does the government need to take a leadership role in supporting new innovation for 5G? And then what about supporting 6G, which includes the incorporation of space satellite technologies – an area that the UK has some leadership in?

### Political

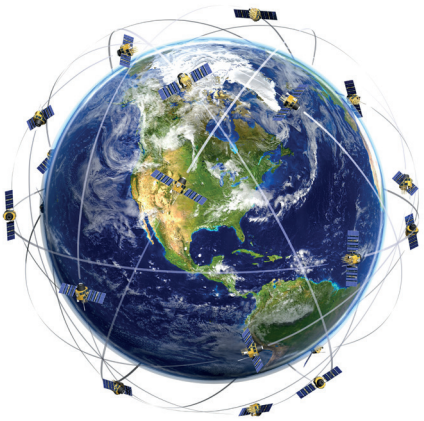
Secondly, and maybe most importantly, is the ongoing concern regarding the political implications of investment in different 5G technologies. The UK does not have enough domestic expertise to build its 5G network infrastructure without technologies from foreign owned companies. This has possible security implications. For instance, the UK Government's Huawei Cyber Security Evaluation Centre, which tests the cyber vulnerabilities of Huawei's technology, released a condemning annual report of the company in 2019 of using its technologies. The UK Government's Telecoms Supply Chain Review Report (2019) also highlights the vulnerabilities of the future involvement of Huawei. Additional pressure is growing from the US, who is threatening to not share intelligence information with countries that use Huawei in their 5G infrastructure. At the same time, how China might retaliate if the UK banned Huawei is still unclear. For instance, in response to German legislation, China has threatened to retaliate against Germany's automotive sector (Bennhold and Ewing, 2020).

### Economic

Thirdly, there is the economic feasibility. Developing domestic capabilities will cost a lot more than £41m for developing 5G testbeds – particularly as Huawei is already spending nearly £15 billion a year on R&D (DCMS, 2019). In addition, Huawei's technology is cheaper, and, because it has been used by service providers in their 4G networks, BT alone says it would cost £500m over five years to switch to a different provider for 5G (Sweney, 2020).

To answer these difficult problems, the next sections will look at what China and the US have done to build-up, or lose, their 5G capabilities.

"5G affects many things – from phones to smart cities – but the real international technological competition is playing out regarding the network infrastructure that everything else connects to… "



# Case analysis: China

## Setting the stage

For a long time in the twentieth century, China had been economically isolated from foreign countries and was far behind the world in technology development (Yu et al.,2018). However, Deng Xiaoping's reforms and market opening policies in the 1980s saw China introduce a market economy and change some of its socialist policies. As a result, China's economic and technological development began to accelerate.

In the field of 5G, China's R&D capabilities and its global presence have become so vast that it has competed with the US for technological hegemony. As of March 2019, China had filed for 34% of Standard Essential Patent (SEPs) for 5G communication systems, an increase of more than 50% compared with its share of 4G patents (iPlytics, 2019). In terms of the amount of investment, China's 5G infrastructure investment since 2015 has exceeded the US's by more than US$24 billion, building 350,000 5G base stations, including 30,000 in the US (CNBC, 2018). Looking ahead, China plans to make another US$400 billion worth of 5G infrastructure investment (Medin and Louie, 2019).

But how has China made such significant progress and established this position in the field of 5G after being a later starter?

There is no doubt that China has benefited from economic growth in recent years and the population's onus to achieve rapid advances in technological development; however, that alone does not explain this tremendous and rapid progress in 5G. The answer is the market-shaping approach the Chinese government has taken. The government has set a series of economic plans, which clearly define investment focus areas, and then state-owned companies have invested substantially in R&D following that plan. Furthermore, the Chinese government has been actively involved in international standard setting, including for 5G, and related international conferences and dialogues, to advance its Chinese technologies.

To grow its two domestic champions in 5G, Huawei and ZTE, the Chinese government has played an integral role. For instance, Huawei "won a government contract to provide telecoms equipment for the People's Liberation Army… sometime in the early 90s", and in 1996 it was named a 'national champion', which meant the government closed much of the market to foreign competition (Vaswani, 2019). The know-how of Chinese telecommunications companies was propped up by forced technology transfer of foreign firms. To get government approval to do business in China, foreign firms had to enter into joint ventures with companies like Huawei, and were "obliged to hand over technology and knowhow to state research labs and business partners". Once they built up domestic capacity, Chinese telecommunications companies pledged to "localise their technologies and production basis", and ended many of their partnerships with foreign companies (Fields and Kynge, 2020). As a result of this foreign support, Huawei quickly became a leader in providing affordable telecommunications equipment around the world, making more sales from outside of China than within it by 2005 (Vaswani, 2019).

In 2006, the Chinese State Council published the "Summary of the Medium to Long-Term Science and Technology Development Regulations (2006-2020)," which is the long-term plan for science, technology and innovation policy. This plan aims to transform China's economy into one that is innovation-led, with world-class science and technology by 2020, by expanding R&D investment and strengthening priority areas. In 2015, the Chinese government formulated the Made in China 2025 plan to promote high-tech manufacturing. The plan identified ten industries to focus investment on, including next-generation information technology like semiconductors, 5G and AI. It has gone on to set a series of more specific technological capabilities it wishes to advance under these industries, which further demonstrates the market-shaping approach it is taking. With the Made in China initiative, the central government provided preferential tax reductions, subsidies, and low-interest financing to the ten industries. In addition, colossal funding was provided through sovereign funds. By taking advantage of this huge amount of government support, Huawei and other Chinese companies rapidly increased their investment in 5G-related technologies around 2016. The telecommunications equipment maker is reportedly spending US$10 billion a year on R&D related to 5G base stations, much more than Sweden's Ericsson or Nokia of Finland, its main rivals – see **Figure 2** (Medin and Louie, 2019). ZTE, a Chinese competitor to Huawei, has also increased its market share in base stations and other equipment (Medin and Louie, 2019).

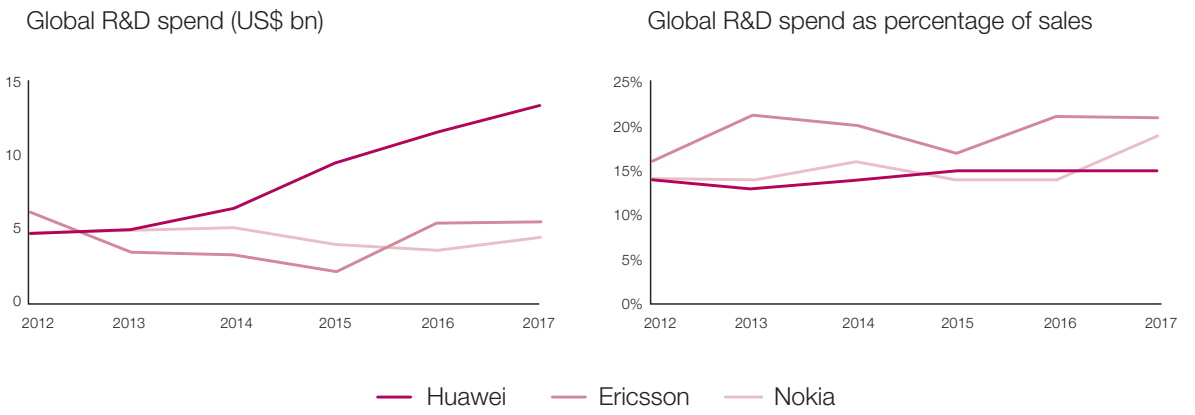



**Figure 2. Total R&D spend. Source: DCMS, 2019**

One of the keys to China's success in this area is the first-mover advantage, which means that before 4G technology was rolled out, it was already embarking on 5G development. In 2013, the Chinese government launched the IMT-2020 (5G) Promotion Group – revealing its focus ahead of other countries. The Group is the primary platform for the Ministry of Industry and Information Technology (MIIT) to promote 5G technology research in China. According to the MIIT introduction plan, 5G demonstration experiments were conducted in China from 2016 to 2018 in three stages: verification of key technologies, verification of technology solutions, and system-level verification. In early 2016, the formal verification of 5G technology began, establishing an open development platform. This Chinese government led initiative has supported science and innovation in a linear model, from the early stages of technology development to commercial success in 5G (Schot and Steinmueller, 2018).

In addition, telecommunication companies like China Mobile, China Unicom, and China Telecom, are already looking to deploy 5G network infrastructure, and are focused on developing a standalone 5G network in China. These companies have plans to deploy the pre-commercial application in 2019 and formal commercial application in 2020 (Medin and Louie, 2019). Through this effort, China already has ~350,000 5G-operable base stations deployed, which is nearly ten times as many as in the US (Medin and Louie, 2019).

In recent years, the Chinese government has been playing an active role, not only in the formulation of investment plans and investment support as described above, but also in discussions on international standardization. Needless to say, this is contributing to the increase of its presence and influence in the field of next-generation communication standards such as 5G. For example, the Chinese government is sending a public-private delegation, consisting of Huawei, ZTE, China Mobile, China Unicom and the China Academy of Information and Communications Technology, as a representative to the International Telecommunication Union (ITU), and actively submits comments on technical specifications. Also, in 2015, Zhao Houlin, a former Chinese government researcher, was elected as a Secretariat for the International Telecommunication Union (ITU), and in 2018 he was re-elected for another five years (ITU, 2018).

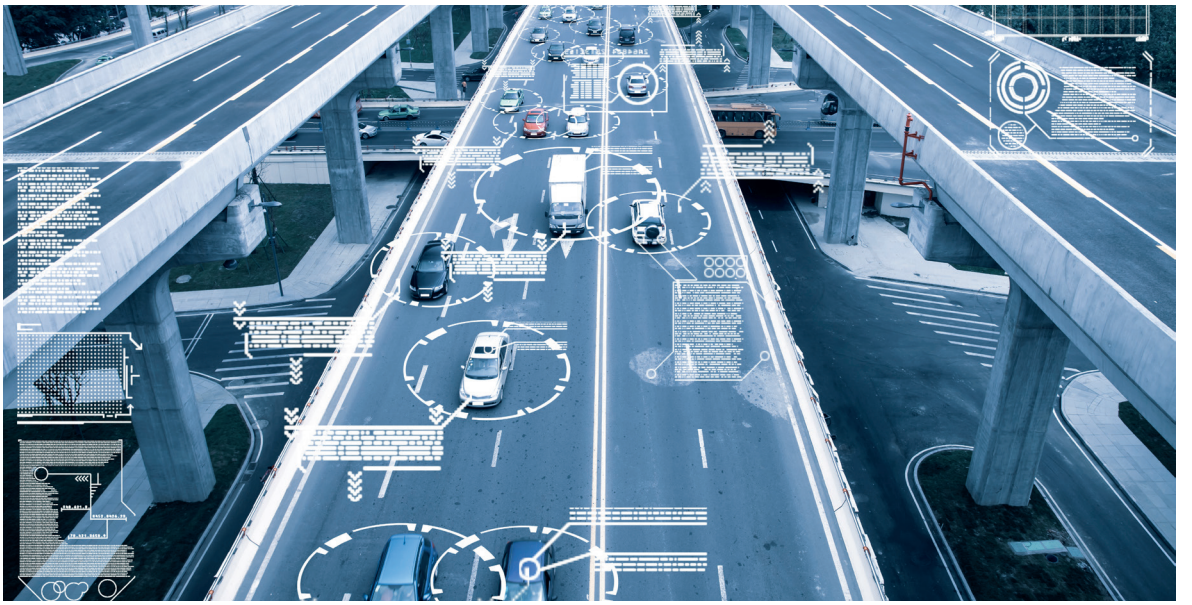
China's success is supported not only by the government and companies, but also by the third player in the triple helix: universities. Many universities across China are researching different applications of 5G, including the first 5G connected university campus, Shanghai University of Engineering Science, which is exploring the use of 5G in artificial intelligence (Jun, 2019). Fostering this research and talent pipeline will be important if China wants to retain its advantage in the telecommunications space.

## Moving forward

As a part of the Belt and Road strategy proposed by the Chinese government, the Digital Silk Road strategy is creating partnerships with countries around the world to encourage the use of Chinese companies in the development of their telecommunications infrastructure. As part of this, Huawei has emerged as a leader in the 5G field, particularly because its equipment is considerably cheaper than its competitors and it was already a key player in the deployment of 4G. However, countries around the world are debating about whether Huawei equipment can be trusted, because the Chinese government might force it to turn over data from these other countries or conduct surveillance due to obligations under the 2016 *China Internet Security Law* (Atkinson, 2020a).

Another debate that is playing out around the world is to what extent China should be allowed to participate in international research activities with foreign universities. For instance, 5G research partnerships already exist between Peking University and LSE in the UK, and Huawei and the University of British Columbia in Canada. China's use of foreign researchers has been instrumental in developing its capabilities in the past – such as Germany's Siemens, the US's Lucent and Canada's Nortel in helping China develop its unique 3G standards and previous generations of telecommunications infrastructure. With growing competition for the next generation of patents, as well as growing national security fears, it is unclear what the future of these partnerships will hold. There is evidence of changing times already, with universities, including Oxford in the UK and University of California, Berkeley and Stanford University in the US, banning grants or donations from Huawei (Davies, 2019 and Sharma, 2019).

Ultimately, through a suite of initiatives that have engaged all parts of the triple helix, China has grown to have comparable R&D capabilities in the 5G field to the US and the EU. From the market-shaping approach by the Chinese government, it has created leading companies in this field, such as Huawei and ZTE. The reason for this success is that top-down socio-economic planning, such as Made in China 2025, has enabled companies with strong government support to make significant investments in 5G R&D. Another factor is the international recognition of Chinese technology through activities at the ITU and technical dialogue with Africa and ASEAN countries. As it moves forward, there is no doubt that the Chinese government will continue to play a strong leadership role in investing in domestic 5G innovation and science capabilities, helping it to reap the benefits of this important technology.



# Case analysis: United States of America

## Setting the stage

The US is a champion of many 5G technologies, with American companies representing 23 of the top 30 most important companies in the world for the roll out of 5G networks (BlueStar Indexes, 2019). The main issue it faces is that, although many of these firms are leaders in 5G chips and integrating 5G into consumer products, it does not have a company to research and develop some of the core network infrastructure. This is important because it is the infrastructure that other technologies work on and data ultimately passes through.

This lack of leadership in any aspect of telecommunications technology is a new phenomenon for the US, as it has led on almost every aspect of preceding generations of telecommunications by supporting innovation in all parts of the triple helix. For example, Bell Labs – a subsidiary of AT&T – had conducted research on radio in the 1910s, which it turned into early-stage radio technology, on 1G cellular technology in the 70s, which it turned into the original cellular networks, and on 2G technology in the 80s and early 90s (Freidenfelds et al., 2002).

How did Bell Labs succeed at leading telecommunications research for 80 years? AT&T had a monopoly on telecommunications in the US for almost 100 years, which it was allowed to keep by the government until the 1980s because it continued to reinvest its profits into radical innovation through Bell Labs (Mazzucato, 2015b). Bell Labs was also supported by the American government through funding innovation missions in a market-shaping approach, such as support from DARPA for researching the predecessor of cloud computing (Cardinal, 2011). This same story plays out with over half of the top 23 most important companies in America for the roll out of 5G networks today, as at least 12 of them have received some sort of Small Business Innovation Research (SBIR) or DARPA support.

What weakened America's leadership in 3G and 4G, and now 5G, is that it broke up AT&T in the 1980s and moved away from market-shaping with telecommunications infrastructure. Lucent was spun off in 1996 from AT&T, taking Bell Labs with it to focus on telecommunications and internet infrastructure equipment. Lucent did not maintain its early leadership in 2G and was significantly hit by the tech bubble that popped in 2000 – shrinking from 157,000 employees to 77,000 in 2001 and 31,000 in 2005 (Recon Analytics, 2018). The French telecommunications firm, Alcatel, saw a similar decline over this period and Lucent could have acquired it in 2001 (Lazonick and Edward, 2010). This acquisition might have resulted in a very different 5G landscape globally, but it fell through, Alcatel acquired Lucent in 2006, and Nokia, one of the few leaders in 5G infrastructure today, acquired Alcatel in 2016 (Recon Analytics, 2018).

In hindsight, the US should have continued to try to shape the direction of 5G technology by working with Alcatel. Instead, following its acquisition, DARPA pulled the plug on a Lucent contract (Bach, 2016).

This mistake is haunting America because it now relies on Nokia, Ericsson or Samsung for 5G network infrastructure, while it is trying to find ways to avoid Huawei. The US is wary of using Chinese infrastructure for 5G because it worries that Chinese firms will spy on America, as it sees China as "the dominant malicious actor in the Information Domain" (Fried et al., 2018). This approach supports Winner's (1980) idea that technologies are political because they require a certain set of political and social conditions to operate and are strongly related to a political stripe. Different international trade blocs are now emerging that differ in how favourable they are to Chinese 5G infrastructure, or the US's pressure to not use Huawei, revealing the political nature that this infrastructure operates in.

"This mistake is haunting America because it now relies on Nokia, Ericsson or Samsung for 5G network infrastructure, while it is trying to find ways to avoid Huawei."

## Moving forward

How to avoid Huawei from playing a role in domestic and international 5G infrastructure, while building domestic capacity, is America's next challenge.

Although the US has banned American firms from selling to China in the past, specifically Huawei and ZTE, this does "virtually nothing to help U.S. national security. In fact, it will harm America by weakening the competitive position of U.S. technology firms as their foreign sales erode" (Atkinson, 2020a). The US is now trying to bide time by preventing its firms from buying Huawei products, stopping Huawei from using American banks, and putting pressure on other countries to follow suit – particularly the UK, Canada and the European Union (EU), as Australia, New Zealand and India already have (Shalal, 2020).

In supporting domestic innovation, there is a clash of ideologies going on right now in America, but it is unclear what is political lip service in support of innovation, and what is true. Some White House officials "are considering an unprecedented federal takeover of a portion of the nation's mobile network to guard against China" (Fried et al., 2018), while members of the US cabinet have even suggested taking a stake in Finland's Nokia or Sweden's Ericsson (Kharpal, 2020). These approaches seem uncharacteristically un-Republican and counter to core laissez faire, neoclassical values of avoiding state interference in the economy.

To build up domestic capacity, there are different approaches depending on where policymakers want to place their emphasis on with the triple helix – government-, university- or industry-led research. Some US senators are proposing taking a more market-shaping approach, by investing US$1 billion into 5G alternatives to Huawei. The US Senate has also approved a US$1 billion fund to help smaller, rural telecommunications companies move from Huawei equipment to alternative suppliers (Feiner, 2020).

On the other hand, President Trump has condemned these protectionist and market-shaping approaches, instead advocating for a more linear approach to innovation and seeking to invest in R&D through defence spending, with the private sector taking the lead in commercialization (Fried et al., 2018). The proposed 2020 White House budget, which Congress has no obligations to pass, seeks to invest "over $14 billion in DOD science and technology programs that support key investments in industries of the future", including 5G and other telecommunications technologies (Office of Management and Budget, 2020). At the same time, although the National Science Foundation (NSF) is doing important work on both fundamental and applied research for 5G and wireless technologies, the proposed White House budget is seeking to cut the NSF's funding by 6% (Malakoff and Mervis, 2020). These paradoxical decisions show how the funding of science remains very political in the US.

Aligned with a more traditional neoclassical view, "a group of major wireless carriers has considered another approach that would allow more companies to challenge Huawei. The group is pressing for a common architecture for the software and hardware that run 5G networks" (McCabe and Sanger, 2020). This explicit anti-Huawei approach is an obvious demonstration of how technology is being designed in a political way.

Although new networks and partnerships may not help the US to catch up on 5G infrastructure, a few partnerships are supporting the development and deployment of 6G telecommunications technology – like the NSF supported Platforms for Advanced Wireless Research, and NYU Wireless (NYU School of Engineering, no date). Looking at 6G might be a new opportunity for the US to gain leadership, as it integrates space satellites into the network infrastructure – something where American companies, like SpaceX and Amazon, are already leaders and looking to enhance their space capabilities for 5G (AAAS, 2020).

Moving forward, it will be interesting to see what one of these approaches wins out, how the US and its allies will build their 5G infrastructure, and if it is possible for the US to develop another domestic champion by the time 6G infrastructure begins to be deployed. What is clear is that, to regain its leadership in telecommunications, the US government will need to be more active in supporting science and innovation in all parts of the triple helix.

# Policy Considerations

These case studies provide important lessons that the UK can learn from if it wants to become a world leader in 5G. This section provides recommendations, and reservations to our findings, to address the problems regarding science and innovation, politics and economics.

## Science and innovation

This challenge involves developing future generations of telecommunications technology. Standing up a new company from scratch is unlikely for 5G, especially given the large amount of money Huawei continues to spend on R&D (Brake, 2019). One approach that could be done, building on some of the American suggestions, is providing funding to Nokia or Ericsson. This could be done in a similar approach to the Airbus model – an aerospace company that is supported by countries across the EU and recently Canada. Brexit means that the UK is not on a strong foot to captain this approach but it could join an allegiance if the US and the EU form one.

6G is an area the UK could be a leader in because of its existing space capabilities – specifically with the company OneWeb, which is developing some 5G capacity (Goovaerts, 2018). China and the US have both shown that funding for industry champions can pay off, so the UK should look at how it can support OneWeb and even consider taking an equity stake to retain its capabilities in the UK – as Japan did with NITT and Germany did with its electricity transmission provider 50Hertz (Bryan and Heller, 2018).

To support other researchers and companies, the UK can also take a market-shaping approach, by identifying areas that it wants to lead on in the future and publishing a strategy, like China has, to give stakeholders a clear sense of direction. It can use a suite of existing programs to support science and innovation at each stage of the linear model and/or by convening networks of relevant stakeholders; this is discussed more in the economic recommendations section.

The UK should also work with industry to set international standards in 6G, as a first-mover advantage has paid off for the EU and China in previous generations. Growing new domestic firms aligns more with the current political climate, including a UK-first ideology and innovation-led growth, so may be more favourable than a joint initiative with the US and the EU.

## Political

This challenge ultimately comes down to whether or not the UK will use Huawei technology in its 5G networks. There are four paths that the UK could take here. Firstly, it could use Huawei technology. Secondly, it does not have to make an overt decision, but can make an implied one. For instance, what the UK is doing already is having Ofcom, the UK's communications regulator, "establish a new set of security and resilience requirements for 5G". Thirdly, in a more direct approach, the UK is seeking to establish additional controls over "individual high-risk vendors" (DCMS, 2019). This could involve using Huawei but with tailored checks. Finally, the most heavy-handed approach would be decoupling – stopping "companies from doing business with China, including selling key inputs, in order to cripple China's advanced economy firms" (Atkinson, 2020b). This is what the US has done with temporary bans to ZTE and Huawei. We recommend continuing along the middle two paths, as this seems to be working in balancing American and Chinese favour so far.

Whatever the UK decides, this is a long-term decision, so it must make allies in the space. It can do this by aligning its security requirements with different trading blocs – e.g. the EU, the US or China. Working in a coordinated way may prevent China from retaliating, or create a new ally with China. However, in the light of Brexit, there may be reservations in alignment with the EU, and the lack of reciprocity in science and innovation in the past from China, as well as animosity from other countries towards China, makes it an unlikely ally.

## Economic

This challenge is about how to fund 5G deployment and the development of new UK champions in 5G and 6G. The £1 billion announced in the 2020 budget for next generation digital infrastructure is a good first step (HM Treasury, 2020). However, for 5G to reach the first 90% of the country, it will cost £6 billion, while the remaining 10% will cost £12 billion (Frias and Oughton, 2018). To achieve this additional investment, the UK could learn from Canada and use its capital cost allowances for businesses to speed up the deductions they get for investments in telecommunications infrastructure (Department of Finance Canada, 2018).

In support of 5G and 6G technological development, the UK can use some of its existing funding that has been committed to telecommunications-related areas.

This approach should engage all parts of the triple helix. For instance, it could look at how 5G basic research can be supported through the granting councils under UKRI's multidisciplinary research areas. Following the US approach, the Small Business Research Initiative could be used to issue 5G challenges, and the Grand Challenges program could launch missions under its existing priority areas. The UK could also develop 6G technologies with OneWeb through the existing Industrial Strategy Challenge Fund or the recently announced advanced research agency, which is being modelled on DARPA (HM Treasury, 2020).

A new sector deal could be developed to break down regulatory barriers and develop in-demand skills for the telecommunications sector. Finally, some of the Catapult Centres – including Digital, Connected Places or Satellite Applications – could bring networks together of UK firms to work on areas of shared interest. Ultimately, more funding may not be required, but a more targeted approach to existing funding could give firms direction in their R&D.

"Whatever the UK decides, this is a long-term decision, so it must make allies in the space. It can do this by aligning its security requirements with different trading blocs – e.g. the EU, the US or China."

# Conclusion

Governments that have taken a stronger role in supporting their telecommunications industry have become global leaders in each generation of the technology so far. To showcase this approach, this paper has shown how China has successfully used a market-shaping role to become a leader in 5G. It used partnerships with foreign firms and very targeted government support to provide the market with direction and grow its national champions into world leaders. In contrast, the US left the free market to determine the fate of its domestic telecommunications firms, and, when its champion was sold abroad, lost its ability to steer fundamental aspects of telecommunications technology. The American Government is now exploring how to take a more active role and regain this lost leadership.

The UK has announced it wants to be a world leader in 5G. This decision does not operate in a silo, and how it looks to grow its telecommunications leadership will have serious science and innovation, political, and economic repercussions. Although it may be too late to compete in all aspects of 5G, the UK Government has several support programs to build the UK's telecommunications expertise. Where the greatest opportunity lies is possibly in 6G, where it has leading companies in the space sector. To fully unlock this opportunity, it should learn from China and the US, and take a stronger market-shaping approach.

To successfully achieve its goals, the UK must also navigate political hurdles related to science and innovation – both domestically and on the world stage. Most importantly will be where it aligns itself regarding the development and adoption of 5G technologies, and whether it succumbs to pressures from the US to stop using Huawei's infrastructure. Regardless of its decision, it risks retaliation from either China or the US.

To be a global champion will not be cheap, and, if the UK is truly committed to becoming a leader in this sector, it will need to significantly increase its investments in the technology to date. What is clear is that the decisions it makes today will have long lasting repercussions for the entire innovation system so must not be taken lightly.

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3

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