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Impacts of 5G on productivity and economic growth

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Contents

Executive summary

Consumers and businesses consider mobile connectivity essential. 5G, the next generation of mobile wireless network technology, which is expected to commence rollout in Australia from 2019, will improve consumer experiences and business utility through faster data transmission and more reliable connectivity.

5G also represents a step change from previous generations of mobile technology by enabling lower latency—the time it takes for signals to travel through the network. This gives it a wider range of applications by providing the responsive digital technology required to support innovations such as robotics and the Internet of Things (IoT).

Digital transformation of this scale has long held the promise of improving economic outcomes, and 5G is the next development in continuing the critical enabling capacity of communications services across the economy. However, as with previous technologies, some investment choices are likely to be made when the broader economic and commercial benefits are still uncertain.

The purpose of this paper is to help support consideration of any changes to regulatory settings that may be necessary to make the most of 5G. The paper builds on the *5G: Enabling the Future Economy* strategy, and provides estimates of the costs and benefits that may stem from 5G and the potential impacts on businesses and consumers.

The focus of this paper is on productivity growth—how more output is achieved per unit of inputs—as the key driver of income growth. This is important for two reasons. Firstly, about 80 per cent of per capita growth in income in Australia over the past 30 years is attributable to labour productivity growth, which is comprised of multifactor productivity (MFP) growth and capital deepening. Secondly, MFP has languished in recent years and is not expected to bounce back—new drivers of productivity growth will need to be found.

5G is likely to improve MFP growth across the economy. This could add an additional $1,300 to $2,000 in gross domestic product per person after the first decade of the rollout.

This estimate of the economic benefit is likely to be conservative in that it does not fully take into account the consumer and non-market benefits that are not captured in economic statistics. These include cost and time savings for households arising from 'smarter cities' and the indirect effects from improvements in health services on participation and productivity—both enabled by better mobile telecommunications. The sharing economy (which harnesses household assets for market production) is also likely to increasingly blur the line between productive and household sectors in terms of the drivers of output, innovation and productivity growth.

As with any transformative digital technology, there may also be distributional effects within and between industries, and across society, as resources are reallocated. This paper has not been able to address these impacts in detail, given the uncertainties about how 5G will affect different industries.

A critical determinant of the economic impact of 5G will be the extent to which it is more than an incremental advance on previous mobile technology, or even a more radical shift to a 'general purpose technology' (GPT)—one typically associated with industrial revolutions.

There are reasons to suggest that mobile wireless technology may itself be closer to the definition of a GPT, with 5G representing a substantial improvement in what that mobile technology can offer. The BCAR has taken the conservative view that—at this stage at least—more evidence would be needed to conclude that 5G is likely to be a GPT.

Why focus on productivity?

Productivity growth—how more output is achieved per unit of inputs—is the key driver of income growth over the long term.

In recent times, productivity growth has been average or slower than average, and there are some reasons to be concerned for productivity growth in the future. An ageing population is expected to slow the growth in the supply of labour, detracting from income growth. The transition of the Australian economy to one based more on services (which usually have a lower level of productivity relative to non-service industries), is also likely to slow labour productivity growth.[1] Furthermore, Australia is unlikely to experience the same boost to incomes that was experienced in the recent mining boom.[2] Productivity growth is not expected to bounce back to where it was in previous decades. This means that new drivers of productivity will have to be found if income growth and wellbeing are to improve in the coming years.

Digital transformation has long held the promise of improving productivity outcomes, and the planned rollout of 5G internationally has been viewed as the next development continuing the critical enabling capacity of communications services across the economy.

5G—faster, better and different

Consumers and businesses consider mobile connectivity essential. Both are becoming increasingly mobile, with faster growth in demand for mobile data relative to fixed-line data, reflecting the shift from a wired world to a wireless one.[3] As the next generation of mobile wireless network technology, 5G will provide a better consumer experience and improve business utility through faster data transmission and more reliable connectivity. For example, 4G technology allows download speeds of 100 megabits per second (Mbps), while 5G could potentially enable speeds of more than 1,000 Mbps. It currently takes about eight minutes to download a feature movie using 4G; people could be able to do this in seconds with 5G.[4]

These features, combined with its lower latency—the time it takes for signals to travel through the network—mean that 5G represents a substantial step change compared to previous generations, with the promise of a vastly increased range of applications (table 1). This reduced latency will, for example, allow the responsive digital technology—particularly for spatial applications—required to support robotics and the Internet of Things (IoT).

While 5G will be an advance on previous mobile technology, the wide array of potential uses means that it may develop as a 'general purpose technology' (GPT)—such as electricity or the internet—that becomes ubiquitous in its own right. In any event, 5G is likely to:

- Support the introduction of new goods and services, with higher data rates and lower latency expected to enable greater use of IoT devices (box 1).
- Improve business efficiency in producing and delivering goods and services, and enable scope for greater innovation and the development of new products. For example, faster download speeds and lower latency will make cloud computing more effective, and allow for better collection and analysis of big data that can lead to more real-time decision making.
- Improve health and social outcomes. For example, wearable technology and IoT devices will help people better access health and education services in a more timely and personalised fashion—the gains from which will have a flow-on effect and will largely accrue to individuals.

Table 1. 5G represents significant improvements in speed and latency compared to previous generations

	2G	2.5G	3G	4G	4.5G/LTE–A	5G
Year introduced in Australia	1993	2003	2003	2011	2014	2019+
Potential download speed	Up to 0.1 Mbps	Up to 0.4 Mbps	Up to ~84 Mbps	Up to 300 Mbps	Up to 1,000 Mbps	Potentially ≥10,000 Mbps
Real world/ expected speeds	~0.0096 Mbps	~0.04–0.05 Mbps	~0.55–20 Mbps	1–24 Mbps	2–160 Mbps	Estimated >50 Mbps on average
Latency	300–1,000 ms		100–500 ms	<100 ms	<50 ms	≤1 ms

Source: ACMA (2016) 5G and mobile network developments—emerging issues; Department of Communications (2015) Mobile broadband trends in Australia, unpublished; Duke (2018) 'Optus to roll out 5G technology to metro markets next year', Sydney Morning Herald, 2 February; European Commission (2014), Mobile communications: from 1G to 5G; Grigorik, I. (2013) 'Brief History of the G's' in High Performance Browser Networking.

Box 1: Some of the terms and technology relevant to 5G

The Internet of Things (IoT) is a generic term describing the practice of adding internet-connected sensors and controllers to objects, infrastructure or locations, and using the data to provide an improved service or capability. It is expected that the use of such devices, which can communicate with one another quickly and reliably, will automate a range of household and business processes. The deployment of IoT sensors is already well-advanced in some sectors[5], but 5G is expected to accelerate the uptake of IoT.

Massive machine type communications (mMTC) is the automatic and real-time communications between IoT-enabled devices. The ability for these devices to communicate between each other is expected to drive productivity growth through the automation of business processes.

Multiple Input Multiple Output (MIMO) refers to the use of multiple antennas in transmitting and receiving devices, which enables more data to be broken down into multiple pieces. This improves the efficiency and reliability of wireless transmissions. Because 5G will enable greater rates of data transfer, MIMO technology will become more important to take advantage of the new standard.

Network slicing refers to the partition of 5G networks to provide dedicated capacity for particular technologies. For example, network slicing of 5G could provide dedicated resources to IoT devices to ensure that they work effectively in particular areas or for particular industries. Network slicing may also allow for sharing of a capital-intensive 5G network between many operators.

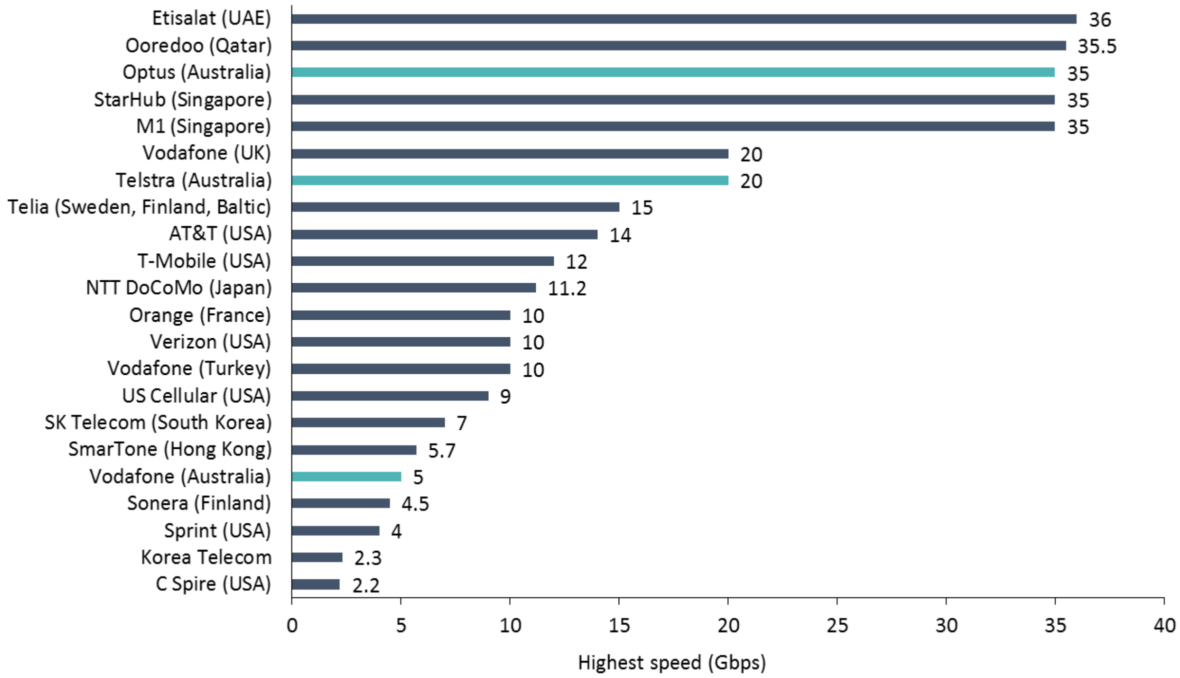
As 5G enables greater sharing of data—such as through cloud computing and IoT devices—there will also need to be a greater focus on keeping those data secure. 5G will lead to an increase in the number of applications and connected devices, and with it the risks from cybercrimes such as identity theft and hacking. Network security architecture will need to adapt to achieve the right balance between security and flexibility of use[6] to address new challenges that could emerge. [7]

Costs and deployment

Greater demand for mobile broadband by households and firms will require greater supply, and telecommunications firms are already considering how 5G may be deployed in Australia and overseas.

Many companies are already trialling 5G (figure 1), with Telstra, Optus and Vodafone conducting lab testing in Australia. Telstra is undertaking field testing as well.[8] Internationally, 5G was trialled at the 2018 winter Olympics in South Korea and is to be trialled further at the 2020 Olympic Games in Japan, which will provide an early indication of its potential capabilities and practical uses[9], and many jurisdictions are in the process of considering the allocation of spectrum for 5G purposes. A recent global survey of telecommunications operators indicated that around 80 per cent were engaged in 5G trials in 2017, compared with around 30 per cent in the previous year.[10]

Figure 1. Highest claimed data speeds reached during 5G trials



Source: Viavi (2017) The state of 5G trials.

The 5G supply response in Australia is likely to occur in phases, with rollout expected more quickly in urban areas and in locations where there are concentrations of businesses that can make the greatest use of the technology. The provision to more rural and remote areas is likely to be slower, reflecting the greater costs of service and (comparatively) lower demand. The speed and location of where 5G is rolled out will depend on the cost of the new technology and likely return, but on the whole the costs of building the 5G network are likely to be significant (box 2).

If it follows a similar path to previous generations of mobile technology, the rollout of 5G will be slow to start and grow as new goods and services supported by 5G are brought to the market. For example, Cisco (2017) suggests that less than one per cent of connections in Australia are expected to be 5G in 2021. The supply of 5G infrastructure will depend on whether suppliers can see a commercial benefit from making substantial investment in the infrastructure.

Telecommunications providers might initially see the investment in infrastructure to support 5G as risky where there are limited use cases, but will ramp up investment once use cases grow. The possible early deployments of 5G have not been fully developed, however to date the industry has assumed that key applications will target cities and transport hubs, with a focus on the outdoor dense urban environments and large indoor public spaces.[11] Decisions about investment will also depend on a range of factors, including how spectrum is allocated for 5G services and how profitable it is to build a network quickly to capture market share.

Box 2: Costs of providing 5G

Mobile network infrastructure requires significant upfront investment. In the case of 5G, the cost drivers of investment will depend on the necessary upgrades to existing base stations, backhaul capacity and core networks. Costs are also affected by the size and concentration of potential users. For example, a study completed for The UK National Infrastructure Commission found that a national deployment would cost a total of £42 billion in capital expenditure, with up to 85 per cent of that investment required to service those in rural areas with lower population density.[12]

Spectrum bands chosen for use by 5G will affect the eventual cost of providing 5G. On 8 March 2018, the Australian Government announced that 125 MHz of spectrum in the 3.6 GHz band will be sold at competitive auction, paving the way for new 5G services in metropolitan and regional Australia. The auction is likely to commence in October 2018.[13] The full range of spectrum bands to be used by 5G are yet to be finalised. Of note, the International Telecommunications Union Radiocommunications Sector (ITU-R) is studying the suitability of a number of frequency bands for globally harmonised use by mobile networks. The wavelength of the spectrum allocated to 5G will directly affect costs—in terms of spectrum licensing fees, the opportunity cost of that spectrum being used for other purposes, and the physical investment associated with different wavelengths. For example, higher frequency spectrum may require more base stations that increase the volume and cost of 5G infrastructure.

Based on previous patterns of deployment, the provision of 5G is likely to require considerable investment, as each generation of mobile infrastructure has cost more to deploy than previous generations, and 5G is expected to enable many more services than previous generations. For example, a study prepared for the European Commission examined how the real cost per capita of delivering each generation of mobile technology has increased through time. It estimated that the cost per capita of providing 5G will be around 4.5 per cent higher than the per capita deployment cost of 4G, when 5G is rolled out in 2020, and 7.5 per cent higher in 2025.[14]

There is the potential for 5G to interact with the supply of other technologies. For example, 5G could be deployed in applications that enhance or extend some networks, while it could replace other networks, especially previous generations of mobile networks. The scope for how 5G affects other technologies will depend on the relative costs of deployment, maintenance and demand for services.

The potential benefits

The potential for new and improved products, and better efficiency in their production, means that 5G is likely to have an economic effect well beyond any short-term commercial return. Depending on the scale and pace of the rollout and the development and uptake of the services it supports, it has the potential to produce far-reaching economic benefits by supporting, and even accelerating, Australia's digital transformation.

If 5G develops consistent with earlier developments in communications technologies, the consumer benefits are likely to emerge early and be significant. While productivity is typically driven in the productive sector of the economy—where businesses compete to make the most efficient use of resources—consumer and household uses of 5G may also have an effect on productivity, as well as wellbeing (box 3). For example, the rise of IoT devices may lead to smarter cities where consumers are better able to avoid, and hence reduce, congestion. This benefits households and improves their ability to supply labour to the economy, but also makes transport services more efficient, which should raise productivity. As the digital transformation of Australia continues, the sharing economy (which harnesses household assets for market production) is likely to increasingly blur the line between productive and household sectors in terms of the drivers of output and productivity growth.

This means that the scale and scope of 5G's economic impact will depend on many factors:

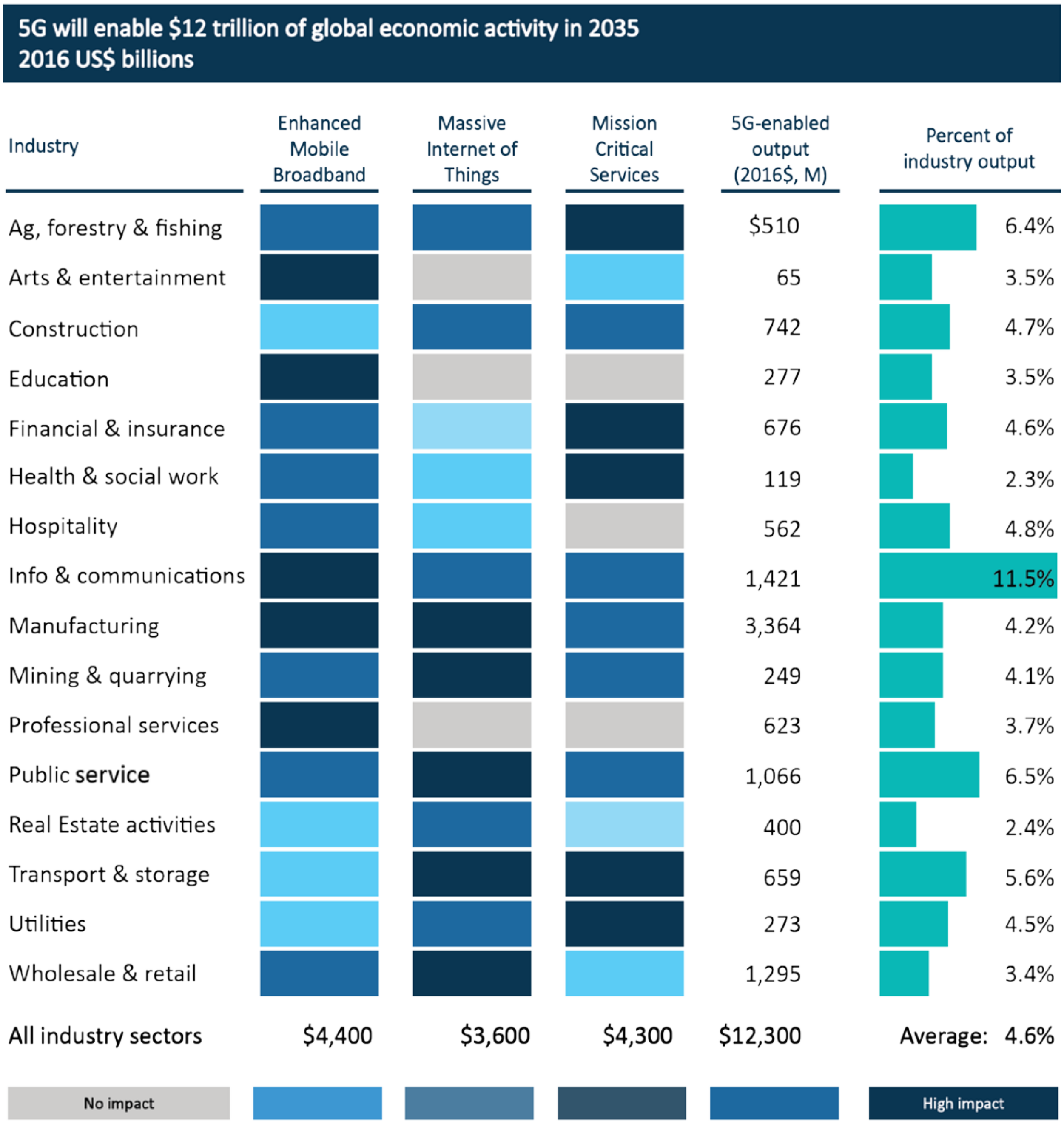
- How transformative 5G is—where it falls within the range of significant advances in mobile technology, ranging from an incremental improvement to a GPT in its own right. Both will have productivity impacts, but the latter could be expected to affect productivity and prosperity over a longer period.
- How quickly 5G is rolled out—which will be affected by investment choices and regulatory settings.
- How quickly 5G is taken up—which will reflect the readiness of businesses and households to make use of the new technology. This includes addressing some of the potential barriers to adopting 5G, such as:
  - a lack of agreed standards for data protection, privacy and security, of both data and devices
  - concerns over safety, quality and reliability of 5G-enabled applications, and resistance to digital change more generally
  - legal and regulatory frameworks that may need adjustment to allow for 5G-enabled goods and services.

All of these factors will be affected by the demand and supply for mobile data and 5G-enabled products.

While much of the expectation around 5G initially focused on consumer use, more technology providers are beginning to see important business use cases that will generate industry demand. In 2016, 90 per cent of telecommunications operators surveyed saw consumers as the central segment in their planning, with only 34 percent focused on specialised industries. But by 2017, the consumer focus had fallen, with 52 per cent of operators viewing consumers as the central segment in their planning, with planning shifting to specialised industry segments and business users.[15]

Some early analysis suggests that 5G may allow a wider scale of additional economic activity. IHS Markit modelling has predicted that 5G will enable $US12.3 trillion of global economic activity in 2035, shared across all industries (figure 2) and that the global 5G value chain will generate $US3.5 trillion in output and support 22 million jobs.[16] While they expect that some of the largest gains will occur in information technology and communications, they also expect large gains for manufacturing and wholesale and retail trade.

Figure 2. Global impact of 5G on various industries



Source: IHS (2017) *The 5G economy: how 5G technology will contribute to the global economy*.
Note: Mission critical services refers to any activity, device or system whose failure or disruption would cause a failure in business operations.[17]

In Australia, mobile-based services already provide a range of benefits to businesses. They help increase productivity by supporting flexibility and innovation, and generating cost and time savings.[18] Over time, 5G has the potential to improve productivity through cost savings across a range of sectors (table 2). Cost savings, directly enabled by 5G or via IoT, are expected in all parts of the economy, such as in industrial applications where automated machines and vehicles are becoming more important.

More efficient use of capital and labour could also arise from the increased use of machine-to-machine (M2M) technologies (which enable networked devices to exchange information and perform actions without human guidance) and m-commerce (electronic commerce conducted on mobile phones).[19]

Table 2. Examples of cost savings in different parts of the economy

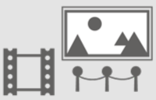
	Transforming Australian Industry
Communications firms	Network improvements could enable lower cost-per-bit for data transmission: an important driver for increased use of broadband applications.
Across industries	Massive deployment of sensors and actuators: these are low-cost devices that only transmit data periodically.
Mining	Smart sensors and M2M communication will improve the performance of automation, and raise efficiency by reducing labour costs and by reducing accidents.
Retail	Online shopping: lower labour costs and reduction in physical outlets.
Delivery of goods	Unmanned aerial vehicles: Reduced fees compared with paid vehicle operators, time saving and better effectiveness. However, regulatory restrictions and infrastructure costs (e.g. reachable recharging stations) could represent a stumbling block.
	Transforming Communities
Healthcare	Remote patient monitoring in rural areas leads to lower transport costs, and lower opportunity costs for patients. Increased outpatient monitoring will reduce in-hospital stays.
Emergency services	Faster spread of life-saving information and better coordination of emergency response. Disaster prevention: awareness campaigns, early-warning messages. Mobile rapid response (e.g. drones used in response to bushfires).

Source: Table compiled by the BCAR.

The automotive industry is also on a transformative path, and some in the telecommunications industry have suggested that 5G could be a major enabler of autonomous vehicles, which are expected to make transport more cost-effective.[20] At the community-level, 5G has the potential to improve healthcare and emergency services. For instance, patients are expected to experience greater quality of care while saving time, and increased outpatient monitoring can reduce hospital costs (which is discussed in more detail later in this paper). 5G can also facilitate more efficient disaster management, and offer more preventive rather than responsive solutions, which ultimately lowers the overall economic and social costs of disasters. For example, drones are currently being used in bushfires response with 4G, but 5G technology could offer a more sophisticated and efficient solution. Drones assist firefighters by providing near real-time images of areas too dangerous to access and enabling rapid damage assessments.[21] The high-speed, low-latency 5G network would allow real-time images and enable faster responses than with 4G. Drones could provide temporary base stations that would form an ad hoc network and help spread the internet to areas that lack reliable connectivity.

Table 3 examines some of the more likely business use cases and target users for 5G in selected industries. As the high speed of 5G enhances business communications, businesses will be able to improve their operations, enhance customer communications and create new applications opportunities. With customer expectations of communications and entertainment experience always increasing, sectors such as Information, Media and Telecommunications (IMT) and Arts and entertainment are expected to benefit greatly from 5G. Thanks to its high speed and low latency, 5G will help support IoT, and various applications such as augmented reality (AR) and ultra-high definition videos. Some innovative retailers are also starting to use virtual reality (VR) and artificial intelligence (AI) tools to enhance consumers' shopping journeys, and better target customer needs and wants.

Table 3. Some industry applications that 5G could help enable

Industry	Potential 5G use cases, benefits and target users
Information, media & telecommunications 	• 5G can help support IoT, which may be a platform for future innovations and inventions. • 5G networks could increase network capacity by 40 times compared with 4G. • Access to a fully wireless and mobile internet: high-speed, high-capacity networking, low latency. *Target users: ICT providers, Consumers.*
Arts & entertainment 	• Mobile broadband in crowded areas, alleviating issues with capacity, interference & reliability. • Video is a key driver of high bandwidth consumption, and 5G could provide improved user experience for watching 3D and 4K movies, and using immersive Augmented Reality (AR) on a mass scale. Lower latency makes it more attractive to provide 'over-the-top' (OTT) services. • High quality of service (QoS) even in challenging network conditions. *Target users: Mobile operators, Pay-TV operators, Broadcasters, OTT providers, Consumers.*
Education 	• Combining tactile internet and VR can remove the physical location constraint for experimental practices, and facilitate the sharing of resources between larger numbers of students. • Virtual delivery of quality education, particularly important in Australian higher education in an increasingly competitive, borderless world. • Real-time interactions, AR without visual delay. • Easier learning for students with special needs, e.g. via cloud-based robots. *Target users: Education providers, Researchers, Governments, Consumers.*
Wholesale & retail 	• Beacons and connected shoppers (e.g. 'smart internet connected bags' that automatically inventory items and initiate transactions). • Better asset tracking due to 5G's better connectivity. • Brands to interact with consumers in a more dynamic fashion. • e-commerce, faster mobile payment. *Target users: Retail industry, Consumer brands.*
Finance & insurance 	• Ability to handle a larger volume of data, better analytics and faster speed that could help with fraud detection, and customer segmentation. • Autonomous vehicles may reduce the costs of insurance premiums, and overall costs of risk. • Improved experience, faster transactions. *Target users: Financial institutions, Insurers, Governments, Consumers.*

Industry	Potential 5G use cases, benefits and target users
Professional, scientific & research services	• Growth of ICT in the form of cloud computing, creation of new software and rise of online information. • More outsourcing of business service functions. *Target users: Scientific R&D, Legal, Computer Systems design, Consulting.*
Public administration	• Superfast internet, analytics and advanced software programs could support smarter, fast-response emergency services. • Predictive analytics to forecast and mitigate the impact of natural disasters. • Changes to systemic behaviours, easier processes. *Target users: Governments, Infrastructure vendors.*
Health care and social	• 5G could help to better enable an ‘internet of medical things’. • Tactile internet and smart interactions between humans and machines. • Health data mining and analytics could grow as the digital infrastructure becomes more powerful, and through predictive modelling, doctors can better anticipate risks to patients. • Connected medicine could help patients get better quality of care (improved imaging, diagnostics and treatment) and better access to care. *Target users: Medical device manufacturers, Healthcare providers.*

Source: Table compiled by the BCAR, from a range of sources.[22] [23] [24] [25]

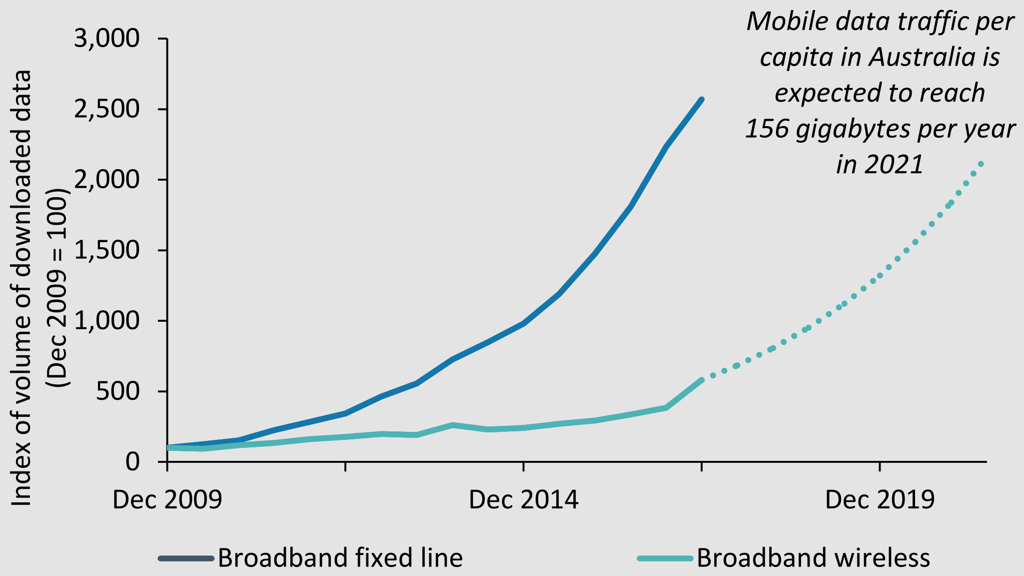
Box 3: Consumer benefits from 5G

Recent trends in the demand for data suggest that demand for 5G will be strong. Consumer demand for data in Australia has grown rapidly since 2012, with most downloads occurring over fixed broadband connections relative to mobile handsets. But greater demand for mobile broadband is starting to occur—reflecting consumer preferences for video ‘on the go’ and evolving workplace policies and practices, as staff increasingly demand mobile solutions that provide greater flexibility over how, when and where they work.[26]

This demand is translating into greater mobile data use, which is expected to grow almost exponentially over the next few years, and is beginning to mirror the exponential growth in fixed-line broadband observed previously (figure 3). It is also reflected in the number and nature of mobile devices that Australian households are using, and the importance of communications services to households.

These expectations could be conservative, as they do not incorporate the additional demand that could arise from 5G-enabled goods and services.

Figure 3. Volume and forecast of data downloads



Source: BCAR (2017) Trends and drivers in the affordability of communications services for Australian households, working paper, July 2017. Forecasts (dotted line) based on data from Cisco (2017).
Note: Data from ABS (2017) 8153.0—Internet Activity, June 2017. Data downloaded is reported for the three month period prior to the reference date. Cisco predicts that mobile traffic per capita in Australia will grow significantly, reaching 156 gigabytes per year (13 gigabytes per month) by 2021, up from 32 gigabytes per year (2.6 gigabytes per month), an average annual growth rate of 37 per cent.

For example, as consumers and firms realise that 5G can provide faster and more reliable mobile internet, they may begin to demand more internet-enabled goods and services, which will further increase the demand for wireless data. In other words, consumers may not be able to realise their 'latent' demand for 5G-enabled products until the network, and the products themselves, become available on the market. Some applications that could lead to additional demand include:

- The tactile internet introduction of haptic devices, which stimulate the sense of touch by applying forces (e.g. based on a virtual 3-D environment). This would allow the transmission of touch and actuation in real-time.
- The use of ultra-high definition video streaming (such as 4K or 8K), and high-definition video calling.
- The rise of IoT devices. While some IoT devices are already available and can function on 4G or fixed-line networks, 5G will enable a higher standard of quality, especially for wearable devices. These might include basic devices (such as fitness trackers or smartwatches) to more complex 'wearables' (e.g. glasses with integrated display).

As well as new products, 5G may mean cost and time savings to consumers (table 4). In the home, IoT devices can better track usage of waste and utilities, which can bring costs down.[27] As IoT devices become more ubiquitous, the additional data collected may enable more efficient usage of infrastructure in cities, which can save households (as well as businesses) both time and money. 5G will connect more devices in a given area and this provides the potential to enhance the benefits from 'smart cities'.

The cost of devices themselves is also important in influencing demand, but 5G may play a role in reducing these costs too. By enabling faster data transmission speeds, information with 5G networks can be processed more centrally or in the cloud, which reduces the complexity—and cost to produce—many devices. All of these factors point to strong demand from consumers for 5G in the coming years.

Table 4. Examples of cost savings for consumers

Creating Smart Cities and Homes	
Smart Cities	• More efficient energy and utilities, e.g. the electricity grid could be expected to use IoT devices to distribute energy on a needs basis (already available, but will allow for new applications and therefore more detailed information). • Fast communication of any faults to minimise disruptions. • Reductions in congestion, as authorities can more reliably track and forecast demand for infrastructure linked to smart devices used by people and their vehicles.
Smart Homes	• Energy and water savings, e.g. remotely change lights and temperature with smartphones, garden sensors connecting to short-term weather forecasts and automated watering. • Time-savings associated with appliances wirelessly connected to the internet.

Source: Table compiled by the BCAR.

Assessing the potential productivity impacts

Key findings

- There is still uncertainty about the investment needed to enable 5G and the scope and scale of benefits that will stem from the new technology. It is difficult to quantify the productivity and economic effects of 5G with certainty.
- Consistent with previous advances in mobile technology, 5G is expected to have a positive effect on productivity, economic growth and incomes. The overall impact on productivity and growth will depend on the extent to which the impact of 5G goes beyond an incremental effect or is more fundamental—such as becoming a general purpose technology (GPT).
- Productivity growth is expected to be slower initially, which reflects the upfront costs of building a network before it is completely utilised. Over the long term, the productivity benefits offset the cost of building the 5G network by a small amount if 5G represents a smaller improvement, and by a more substantial amount if 5G is a GPT.
- While the additional investment could add to GDP initially, longer-term benefits arise where this investment has the potential to enhance productivity.

How 5G will affect productivity

There are two main ways in which new technology can influence productivity.

The first is by changing the efficiency in the production and distribution of existing goods and services; for example, mobile technology that allows businesses to better access information, and consumers to better access entertainment services while 'on the go'.

The second is through the efficiency of new goods and services brought to the market (relative to the efficiency of any goods and services they displace). For example, if 5G allows the production and use of autonomous vehicles, these may enable the more efficient use of transport infrastructure if such vehicles are better at navigating and clearing congestion.

The overall productivity effect of 5G will stem from how inputs and outputs change as a result of the technology. On the outputs side, the benefits from 5G are expected to lead to more efficiently produced goods and services—a greater volume of production for given inputs. On the inputs side, there will be additional investment and costs to build the physical infrastructure of the network (upgrading new and existing base stations, and upgrading backhaul capacity) as well as purchasing access to spectrum.

The Government's 5G strategy details the actions that are to be taken to allow for the introduction of 5G in line with international developments, including:

- Making spectrum available in a timely manner
- Actively engaging in the international standardisation process
- Streamlining arrangements to allow mobile carriers to deploy infrastructure more quickly, and
- Reviewing existing telecommunications regulatory arrangements to ensure they are fit-for-purpose.[28]

The scale of the inputs and resulting outputs will vary with the extent of the rollout. Mobile technology is more readily deployed in areas of high-population density, where fixed infrastructure can serve more users. This is likely to be the case where 5G-enabled applications rely on scale of use to be profitable, such as M2M applications in automated transport, warehousing and retail.

One mechanism that examines the flow of outputs and inputs is called ‘growth accounting’, which breaks downs economic growth into changes in productivity, inputs and outputs.[29] This approach assumes that output growth can be explained by multifactor productivity (MFP) growth and growth in labour and capital, in proportion to their relative importance to each industry. By accounting for how labour, capital and output change, productivity growth can be calculated as a residual measure.

Many factors will affect this productivity measure—including the effect of technology in raising efficiency, if there are economies of scale (that is, an increase in inputs leads to an even larger increase in outputs), and if there are dynamic effects where resources are allocated to more efficient industries and uses. It can also be affected by measurement error, such as in determining the quality of inputs and outputs.

What this approach enables is to test whether the expected returns—in terms of greater efficiency and output—from investment in 5G are likely to lead to a net improvement in productivity.

Using different scenarios to test the productivity impacts

Consistent with the very early stages of the development of 5G technology, there is a fair degree of uncertainty about the extent and scope of the technology’s impact. Reflecting the uncertainty of the rollout and take-up of 5G, the BCAR modelling approach does not incorporate any ‘dynamic’ or ‘behavioural’ responses by firms to 5G. For example, an increase in productivity caused by 5G could be expected to change the allocation of resources in the economy, which in turn would have a further impact on productivity. The BCAR’s modelling is intended to get an ‘order of magnitude’ impact on productivity and incomes.

For the purposes of growth accounting, the key areas of uncertainty include:

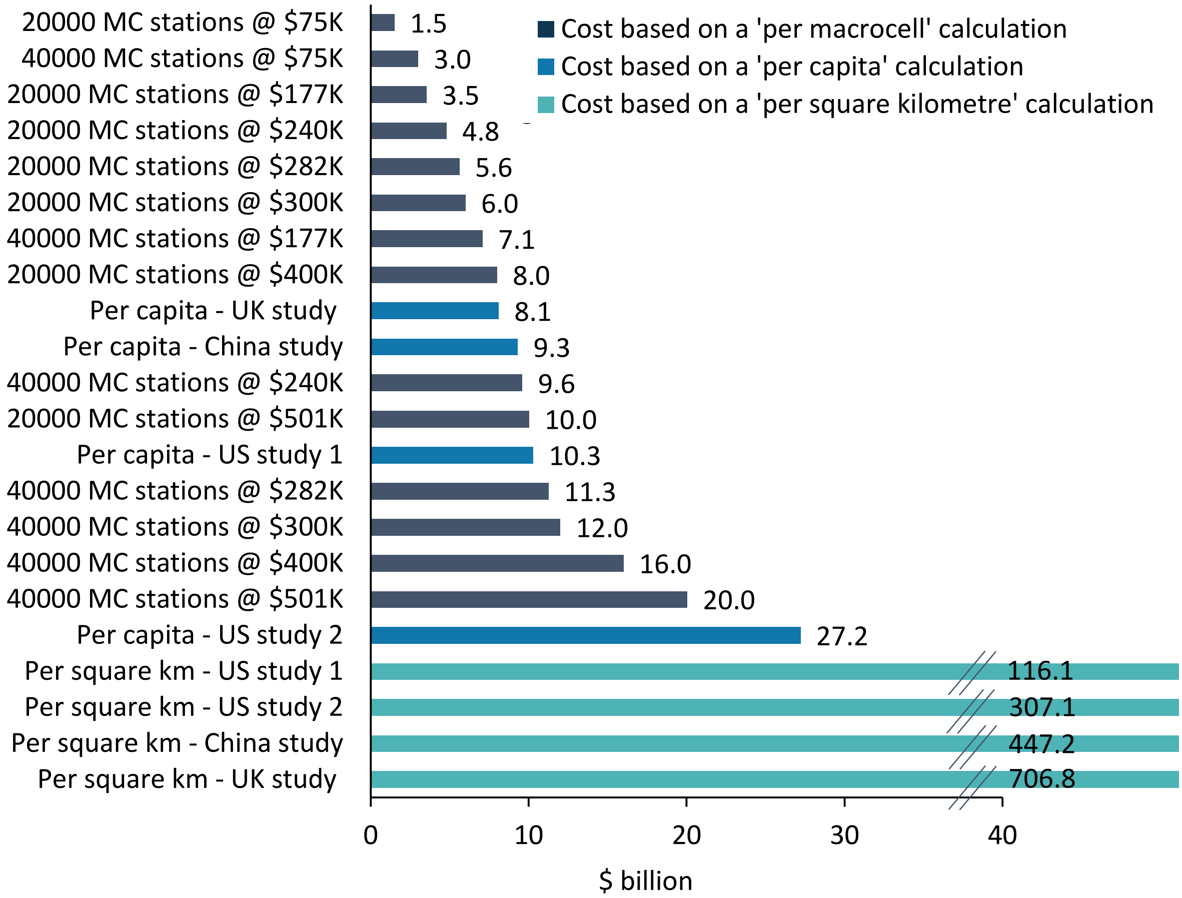
- The output effects of 5G—specifically the extent to which the technology represents a larger improvement on previous generations or whether it is a more of a GPT.
- The inputs required to enable 5G—specifically the infrastructure costs of building the network, the costs of acquiring spectrum, and the costs that businesses and consumers will pay in order to gain access to 5G (such as purchasing new equipment that is 5G-compatible).

The BCAR has sought to overcome this uncertainty by modelling a range of different scenarios, each of which uses a set of different assumptions around the costs, outputs and timing.

Costs

To date there has been limited assessment about how much it will cost to build 5G networks and purchase relevant spectrum, and those assessments undertaken vary substantially depending on whether they are on a per capita or per area basis (figure 4). On a per person or per base station basis, these data suggest that the costs of building the network could be around $2 billion to $27 billion. On a per area basis, the estimated costs are substantially higher, reflecting Australia’s large area and low population density.

Figure 4. Costs of building 5G networks in Australia, as implied by different sources



Source: BCAR analysis based on a range of sources.[30]

Note: 'MC' refers to macrocell stations. The number of MCs that will be required for 5G networks is uncertain at present. The BCAR has used 20,000 and 40,000 MCs as a range of potential MCs needed, based on previous trends detailed in the *Mobile Network Infrastructure Forecasts* final report made to the ACMA in June 2015—however, this range is purely indicative at present and may change as providers' investment decisions become clearer. To make the costs presented in each study comparable, the BCAR has adjusted values to Australian dollars in current price terms and applied the result on a per capita, per cell tower, or per square kilometre basis as appropriate.

Major telecommunications providers have announced significant investment to improve mobile networks. Last year, Telstra pledged to spend $3 billion over three years to improve its networks and customer experience.[31] Optus recently announced its intention to spend $1 billion to improve and expand its mobile network and coverage in regional areas by the end of June 2018.[32] Vodafone recently reported it spent $2 billion on its mobile network and technology to increase coverage, capacity and performance.[33] Other recent commentary suggests that total mobile investment in Australia will be in excess of $5.7 billion per year as operators invest in building 5G networks.[34] Although Australian telecommunications providers are expanding their networks, the details of how much investment will go towards 5G alone have not been confirmed.

On the basis that previous rollouts have focused on user access rather than geographical location, the BCAR has used per capita and per base station estimates in its modelling and examined potential low, medium and high cost scenarios.

A 'low cost' case assumes that there would be:

- $5 billion in non-dwelling construction investment and $0.5 billion in R&D for the Information, Media and Telecommunications Sector (reflecting the costs of building the network).
- A 5 per cent increase in investment in electrical and electronic equipment in all industries (reflecting the costs of purchasing new 5G-enabled equipment).

A 'medium cost' case assumes that there would be:

- $10 billion in non-dwelling construction investment and $1 billion in R&D for the Information, Media and Telecommunications Sector (reflecting the costs of building the network).
- A 10 per cent increase in investment in electrical and electronic equipment in all industries (reflecting the costs of purchasing new 5G-enabled equipment).

A 'high cost' case assumes that there would be:

- $25 billion in non-dwelling construction investment and $2.5 billion in R&D for the Information, Media and Telecommunications Sector (reflecting the costs of building the network).
- A 20 per cent increase in investment in electrical and electronic equipment in all industries (reflecting the costs of purchasing new 5G-enabled equipment).

However, the differences in costs should not be equated with the likelihood of expected returns—a higher cost or greater investment does not mean that the likelihood of 5G being a GPT is increased.

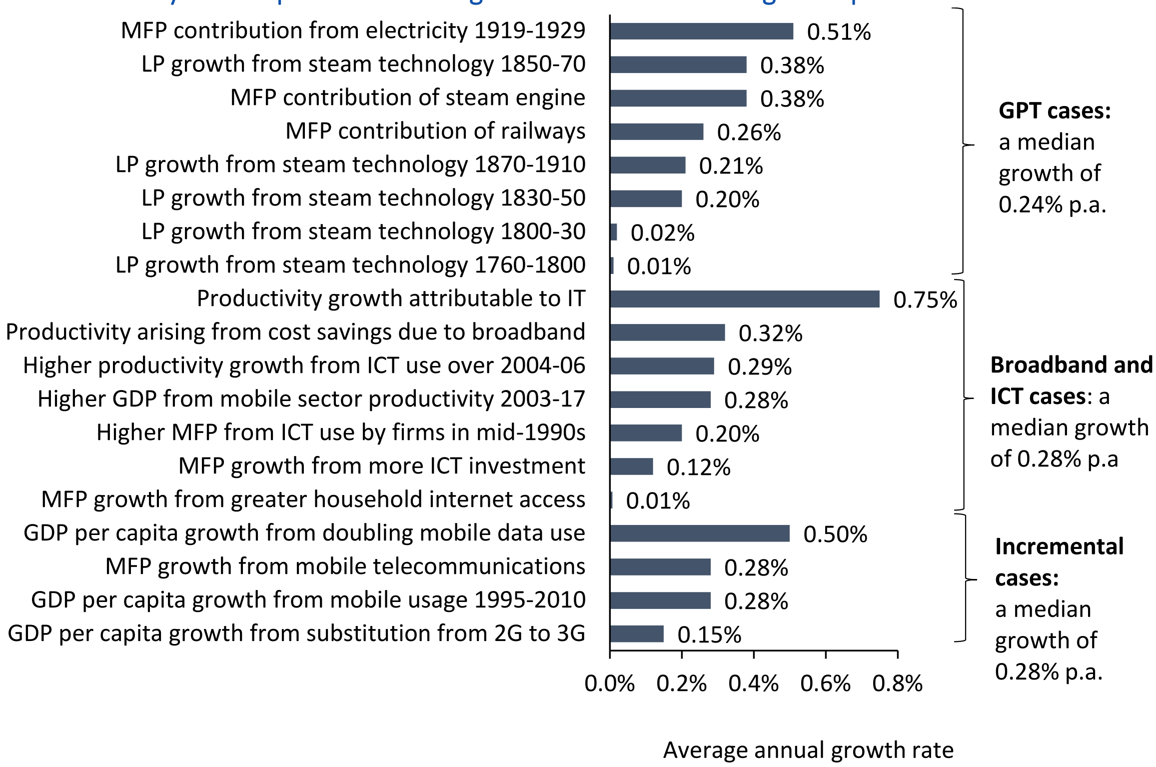
Given the commercially sensitive nature of future spectrum auctions, the BCAR has not included any *explicit* provision for spectrum costs in its modelling, rather it has captured this in total infrastructure spending as infrastructure without spectrum is functionally useless.

Outputs

The benefits accruing from 5G are harder to evaluate, given uncertainties of who will use 5G and when—especially given the expectations of the technology enabling a wider range of new goods and services than previous generations of mobile technology. The BCAR has based its assessment on how output and productivity have been affected by incremental advances in mobile technology and more fundamental shifts in technology (including GPTs) (appendix B).

These studies indicate a range of different productivity and output effects for different changes in technology (figure 5). While GPTs tend to provide longer periods of productivity growth, the rate of this growth is not necessarily faster than that for more incremental technologies.

Figure 5: Productivity and output effects arising from different technological improvements



Source: Studies listed in appendix B.
Note: The studies use different measures to examine the effect of different technologies, such as labour productivity (LP), multifactor productivity (MFP) and gross domestic product (GDP). To the extent that labour productivity and multifactor productivity each contribute to GDP, the effect of the growth rates are presented for comparison.

Reflecting this, the BCAR has modelled two cases for output growth associated with 5G. Each assumes a 0.3 per cent increase per year in output in market sector industries, with one case assuming that increases occur over 10 years, and the other assuming 30 years (which reflects a more transformative technology).

While this is a very long period in the context of mobile technology, and does not preclude further generations being rolled out in that time period, it is the contribution of 5G to *cumulative* productivity growth that is assumed to be ongoing and sustained.

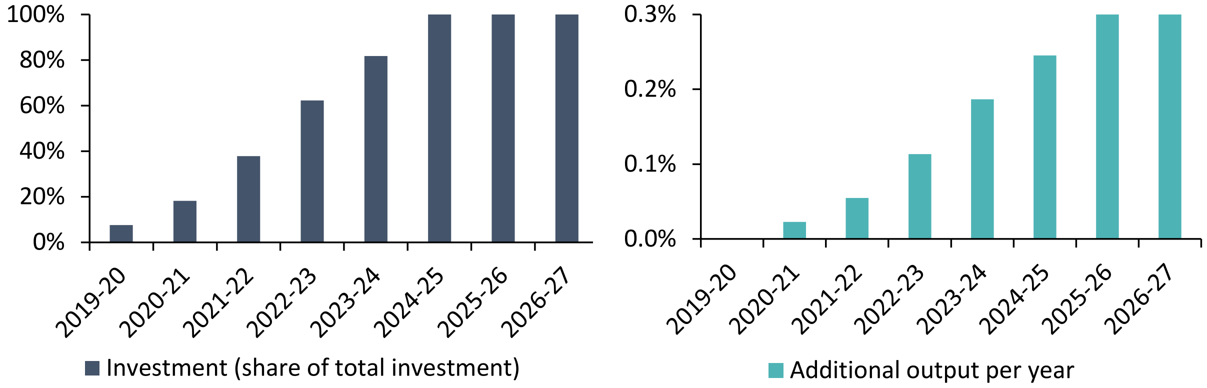
Timing

Productivity is also affected by the timing of 5G. It is not clear how long it will take to build the network, nor how quickly the technology will be taken up. The longer it takes to build the network and for its enabled technology to be adopted, the longer it will take to see the associated productivity benefits.

To reflect this, the BCAR used two different timing cases to compare the relative impacts. The first assumes that the network is built very quickly and that benefits are able to flow shortly after the investment. In this scenario the investment occurs in one year and the benefits flow the next.

In the second case the investment and initial benefits are staggered (figure 6). Investment and outputs increase slowly in the beginning of the rollout (reflecting early adoption and testing of business cases), then increase faster in the middle of the rollout (as the technology becomes mainstream), and then increase more slowly at the end of the rollout (where there are diminishing returns to further investment).

Figure 6. How investment and outputs evolved in the lagged timing cases



Source: BCAR estimates.

The scenarios tested

The BCAR has modelled different scenarios that reflect the combinations of cost cases, output cases and timing cases, as well as a baseline scenario that has no shocks at all (equivalent to no additional investment for 5G where productivity growth rates continue at their long-run averages).[35]

Each of the scenarios showed a similar pattern relative to the baseline.

Initially, there is a fall in productivity reflecting the additional inputs to build the network and for businesses to purchase 5G-enabled or compatible capital goods before productivity growth increases at a faster rate. The overall productivity impact depends on how large the cost and how long the period of faster productivity growth are, relative to the baseline.

Where costs are high or the period of faster growth is short, the productivity effect for the economy will be small, and could even be worse than if there had been no investment in 5G. Conversely, the productivity effect will be greater when costs are low and any resulting output growth is prolonged.

Results from the scenarios

The productivity effect in the communications sector is driven by the size and flow of costs and benefits

Because the output and input shocks are different for the communications (IMT) sector compared with other sectors, the results for IMT are quite different to the rest of the economy. The additional inputs to build the network initially reduce productivity growth in the communications sector sharply, before the output dividend from 5G occurs and accelerates productivity growth back towards the baseline. This is reflective of the ‘capital lag’ effect observed in some capital-intensive industries (such as mining[36]) where investment occurs before output flows—leading to an initial measured productivity decline.

Lower costs yield a stronger positive productivity dividend—greater than the baseline—regardless of whether the output dividend from 5G is over a shorter period or longer period. Where costs are high, the productivity benefit needs to be over a longer period for there to be an overall positive productivity impact compared with the baseline.

This is because where costs are high, the commercial incentive would be to build the network in fewer places, or implement a more delayed rollout that concentrates on where the output dividend may be greatest and longest.

This is most likely to be in urban areas, where users are concentrated, and where there is a greater concentration of IMT-intensive industries. Such findings are consistent with international analysis by Nokia that examines business cases for communications services providers, which finds that positive return is contingent on a more concentrated number of households per base station.[37] The implication is that in high-cost cases, the incentive to invest in areas with lower population densities is more muted.

Alternatively, if costs are high, then 5G providers may seek to extract a price margin from users. This could affect the potential take-up of the technology and focus activity on the most profitable business uses.

On the other hand, if costs to build the network are low, then the modelling suggests that 5G could be a worthwhile contributor to IMT productivity. It also makes clear that, if costs are low, it could be expected that providers would roll the network out on a scale similar to previous mobile networks. However, this will depend also on commercial decisions about whether to replace their existing previous generation networks.

The productivity effect more broadly

The productivity effects across the economy are likely to be positive. Because other industries are only assumed to require a more modest additional investment to become 5G-ready (relative to the costs in IMT of building the network), their additional inputs are far outweighed by the additional outputs that occur. This result holds regardless of whether the cost is high or low, the productivity effect is short or long, or whether the timing is quick or lagged.

That said, there are still some implications from the different outcomes between the scenarios.

- The capacity to influence costs and timing will affect the productivity outcome as the productivity benefits are more muted in the higher cost and lagged cases. This means that the adoption profiles of 5G will affect the benefits of 5G, however the nature of the adoption profile is uncertain—but likely to be faster if the technology is more transformative.
- Cost factors may be harder to address than timing. Australia is not a major manufacturer of the capital needed to enable 5G, and is more of a 'price taker' as a result.

Potential implications for incomes

Ultimately, the goal of faster productivity growth is a higher standard of living. The BCAR has used the Australian Treasury's *Intergenerational Report* (IGR) to assess the magnitude of additional income that may arise from the rollout of 5G. Because the productivity effects vary by cost, output effect and timing, so do the resulting income effects. (The results of key scenarios are presented in table 5, with all scenarios presented in appendix A.)

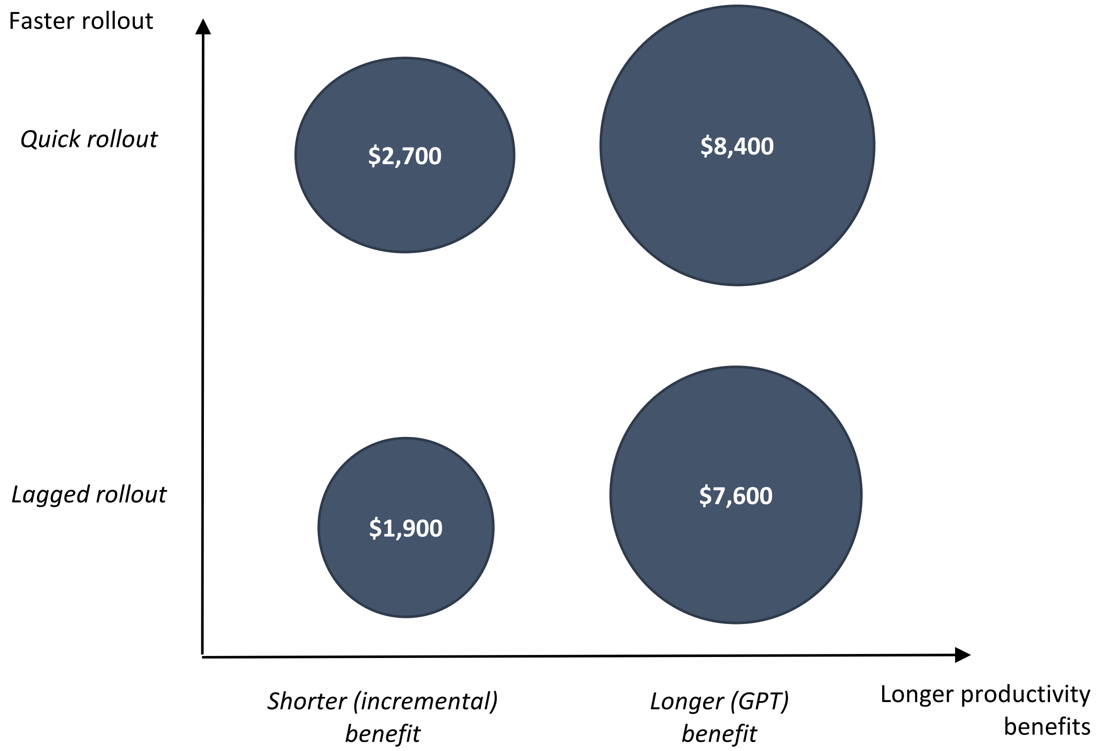
Table 5. Results from the different scenarios under the medium cost cases relative to the baseline

Scenario	Effect on IMT MFP (p.a) to 2030	Effect on IMT MFP (p.a) to 2050	Effect on total economy MFP (p.a) to 2030	Effect on total economy MFP (p.a) to 2050	Additional per capita GDP (relative to baseline) in 2030	Additional per capita GDP (relative to baseline) in 2050
Shorter output effect, quick rollout	0.16%	0.06%	0.21%	0.08%	2,000	2,700
Shorter output effect, lagged rollout	0.06%	0.02%	0.15%	0.05%	1,400	1,900
Longer output effect, quick rollout	0.16%	0.28%	0.21%	0.23%	2,000	8,400
Longer output effect, lagged rollout	0.06%	0.25%	0.15%	0.21%	1,400	7,600

Source: BCAR estimates based on ABS and Treasury data (appendix A).
Note: The effects shown are relative to the baseline case, where long-run productivity growth is assumed to continue through to 2050 (detailed in appendix A). Additional GDP per capita figures in real 2015–16 terms.

Holding costs fixed, figure 7 shows the effect on GDP per capita by 2050 depending on whether the rollout is quick or slow, and whether the productivity effects are short or long. The longer-term productivity effects (to reflect a ‘GPT-like’ effect) have a much larger effect on GDP per capita than the shorter-term ones, reflecting the compounding effect of continuous productivity improvement over a longer period of time. The timing of the rollout also has an effect, with delays yielding smaller benefits—regardless of whether it is a shorter (incremental) benefit or longer (GPT) benefit.

Figure 7: Impacts of rollout speed and length of 5G's productivity benefit on real GDP per capita in 2050



Source: BCAR estimates based on ABS and Treasury data (appendix A).
Note: Figures are real GDP per capita in 2050 expressed in 2015–16 prices. Cases presented are for the 'low' cost scenarios in appendix A.

In the most favourable circumstances—where costs are low and output effects are high—GDP per capita is raised by around $8,400 per person by 2050 (in 2015-16 prices). In less favourable circumstances—where the costs are high, the output effects are more reflective of a smaller gain rather than GPT, and the rollout is lagged—GDP per capita is raised by a more modest $1,900 by 2050 (in 2015-16 prices).[38]

At this stage, it is too early to tell the extent to which 5G will go beyond an incremental advance or is a GPT. But past experience has suggested that movement between generations of mobile technology has tended to be more incremental than transformative. There are reasons to suggest that mobile wireless technology may *itself* be closer to the definition of a GPT, with 5G representing a substantial improvement in what that mobile technology can offer (box 4).

Previous experiences also suggest that mobile networks are not built quickly. There are periods of fast rollouts, particularly in areas where the costs are smallest to deploy and the commercial benefits are greatest, but the rollout may be more lagged or partial in other areas. Based on this, the BCAR has taken the more conservative view that the smaller benefit and lagged rollout scenarios—at this stage—are the more likely outcomes. While these generate smaller returns than some of the other cases, the important factor is that they still improve productivity.

Box 4: Is 5G a general purpose technology?

5G may be part of an industrial revolution, but it may not be the industrial revolution itself.

Past experience has suggested that movement between generations of mobile technology have been relatively more incremental rather than transformative. Improvements to mobile technology have occurred more frequently 'within Gs'—with improvements like 3.5G, 4.5G and 4.9G all building on existing technology. Some of these improvements 'within Gs' have been considerable—for example, the increase in theoretical download speeds between 4.5G and 4G was greater than the increase between 3G and 4G (table 1).

The applications enabled by new generations of mobile technology, too, have been incremental in many ways rather than transformative. Banking applications have improved the efficiency of accessing financial services, but not always the efficiency of financial services. Mobile technology has improved the efficiency of consumers' lives, but not always the underlying efficiency of the production of goods and services that they use. While this is of value to consumers it is not necessarily transformative.

If 5G were to buck previous trends and become a general purpose technology (GPT) that enables an industrial revolution, then it would have to satisfy different characteristics that GPTs exhibit:

- Pervasiveness—in that it should spread to most sectors
- Improvement—GPT should get better over time and reduce the cost of the technology to its users
- Innovation spawning—the GPT should make it easier to invent and produce new products or processes.[39]

While a range of use and business cases have been and are being developed, it is still too early to say with confidence that 5G represents a GPT. At this stage, it might be more accurate to say that mobile technology itself is the GPT—in that it now reaches most of the population and has spawned many new products and processes—and that 5G represents a substantial improvement that has scope to reduce costs to firms and consumers in the production of goods and services. In these circumstances, investing more or changing regulatory settings are unlikely to make 5G more or less likely to become a GPT, but could have other effects on productivity and income.

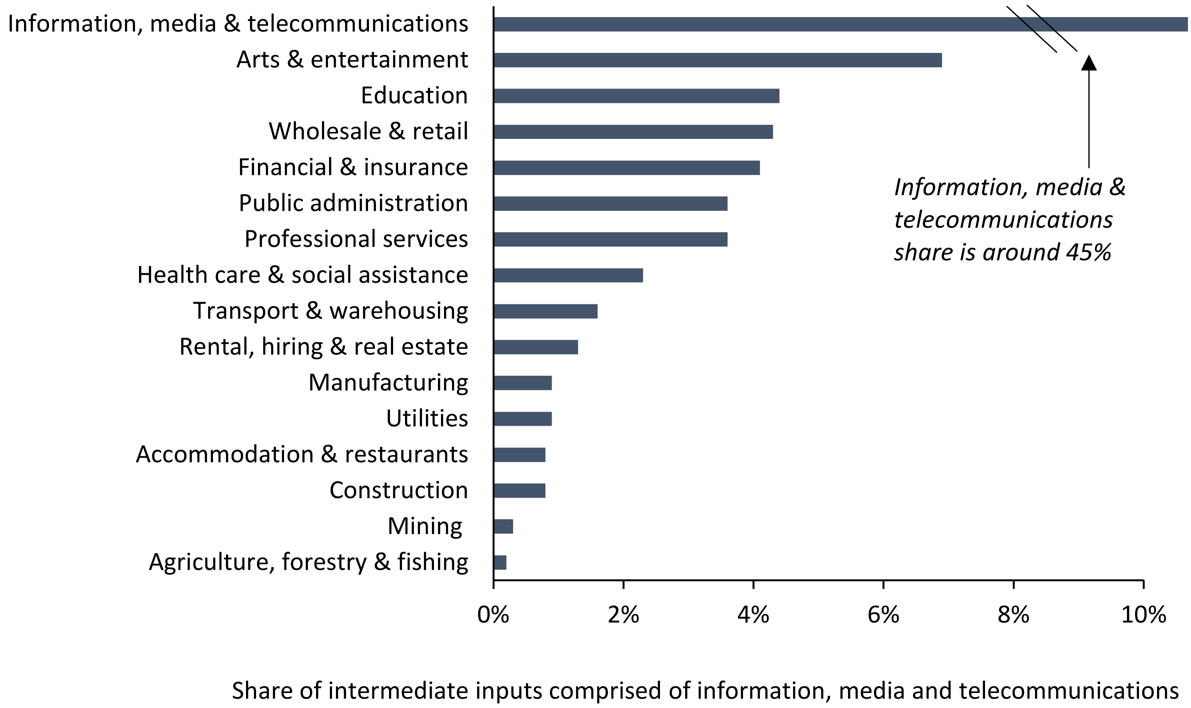
Sectoral impacts

While the applications of 5G could be expected to transform the way that Australians live and work, the economic benefits will depend on Australia's use of telecommunications services, and the extent to which particular industries will be able to make the most of the new technology. Some industries are likely to benefit more than others.

Because 5G is intrinsically linked to the delivery of telecommunications services, examining the value of telecommunications services used by businesses to produce goods and services across industries provides a metric for how much of an impact 5G will have. Put another way, those industries that use telecommunications services more intensively as inputs to production are more likely to benefit from improvements to telecommunications services, such as 5G.

Figure 8 shows the proportion of IMT inputs as a share of all inputs used by firms in different industries. The IMT sector itself is a very intensive user of IMT goods and services, suggesting that 5G will deliver the most gains to that industry. Arts and entertainment, education, wholesale and retail trade, and financial and insurance also have a significant proportion of IMT inputs currently used in their production of goods and services. In contrast, Agriculture, forestry & fishing, and Mining have a much smaller share of IMT inputs—less than one per cent. While these results reflect existing telecommunications intensities, they provide a means to consider which industries might be early beneficiaries to changes to telecommunications technology.

Figure 8. Industries with more intensive telecommunications use could be the biggest initial users of 5G



Source: BCAR estimates derived from ABS Input-Output data for 2014–15 (Cat. No. 5209.0.55.001).

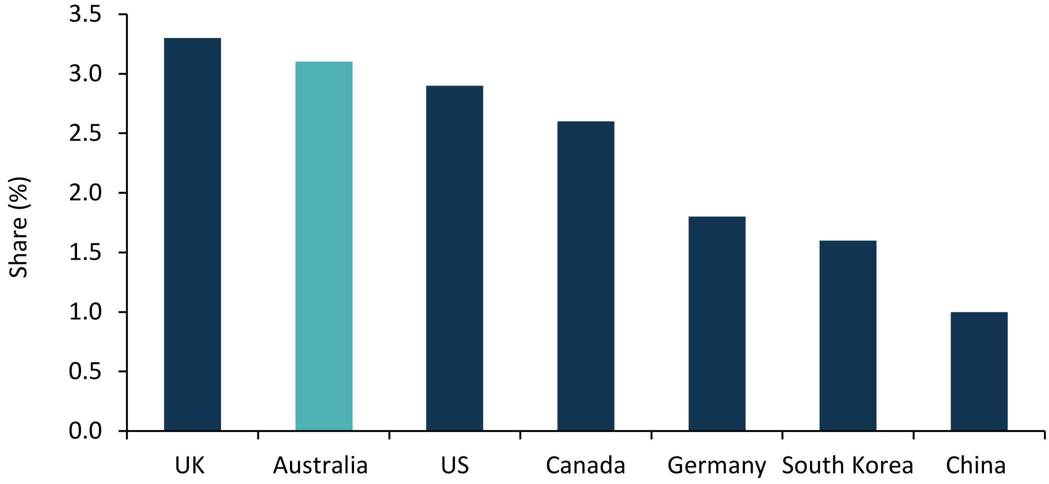
These data suggest that the impact of 5G is likely to be uneven—some industries are better-placed to take up the new technology and integrate it into their supply and production chains. But as 5G becomes more pervasive—particularly if it does become a GPT—then it could reasonably be expected that the telecommunications intensity of all industries could rise as they take advantage of the new technology.

Will Australia benefit as much from 5G as other countries?

The same sort of analysis can be conducted between Australia and other countries to determine which jurisdictions will be more affected by 5G than others. Countries that presently use more telecommunications inputs to produce and deliver goods and services to other businesses and households could be expected to benefit the most from 5G. As such inputs are delivered more efficiently, those benefits accrue to the firms that use telecommunications inputs and the households that consume telecommunications-intensive goods and services.

Using the OECD Structural Analysis database, the BCAR has looked at how intensively businesses use telecommunications services (figure 9). These data suggest that, on average, Australia is a fairly intensive user of telecommunications services in production, and so stands to benefit as much (if not more) than some key OECD nations.

Figure 9: Post and telecommunications inputs as a share of total industry inputs, by country, 2011



Source: BCAR analysis of OECD STAN (2011).
Note: Postal services are included in the analysis as they form part of the 'postal and telecommunications' industry classification used in the OECD data.

These data can also be used to compare telecommunications intensity between industries in different countries. Table 6 summarises the industries where Australia is more or less telecommunications-intensive in the production of those goods and services compared to some other countries. The implication with the rise of 5G is that Australia could be well-placed to take advantage in those more telecommunications-intensive industries, but perhaps less so in those with lower telecommunications intensity.

Table 6: Relative telecommunications intensity in production compared to the UK, US and Canada

Industries where Australia is more telecommunications-intensive	Industries where Australia is less telecommunications-intensive
Wholesale and retail trade	Agriculture, fisheries and forestry
Transport and storage	Mining
Renting of machinery and equipment	Textiles and apparel
R&D and other business activities	Rubber and plastics products
Public administration	Basic metals
Education	Real estate activities
Arts, entertainment and other community, social and personal services	Financial intermediation

Source: BCAR analysis of OECD STAN (2011).

A qualitative approach—5G & healthcare

Key findings

- Growth accounting can be used to derive productivity measures, and it provides a useful framework to estimate the productivity impacts of 5G. However, other significant observable impacts of 5G (consumer and society-wide benefits) are not measurable in the traditional sense, and are therefore not included in measures like Gross Domestic Product. A more qualitative approach can help better understand the changes on quality and wellbeing that 5G may bring, including how 5G will affect different groups. This is particularly relevant to goods and services that directly affect wellbeing, and will be affected by 5G—such as healthcare.
- Healthcare is an example of a sector becoming more reliant on the internet, and digitally-delivered healthcare is expected to be more important in the future as new technologies emerge. 5G could have the potential to change the way healthcare is delivered thanks to fast connectivity and lower latency than previous mobile technologies. 5G can help reduce costs and improve patient outcomes and experiences.
- However, this will require significant upfront investment and parts of the healthcare sector may be slow to adapt, especially in the early days when business cases are limited.

Productivity analysis alone does not tell the full story of 5G's impact

Growth accounting is a useful tool, but it cannot tell the full story about how 5G will affect people's lives and work. For example, growth accounting does not directly identify any benefits that accrue from higher *quality* goods and services such as improved consumer convenience, greater product choice, or impacts on the environment. Nor does growth accounting measure gains to businesses and households from the provision of more reliable or tailored products. The economic impacts of 5G reach beyond national accounting measures such as GDP. These includes the:

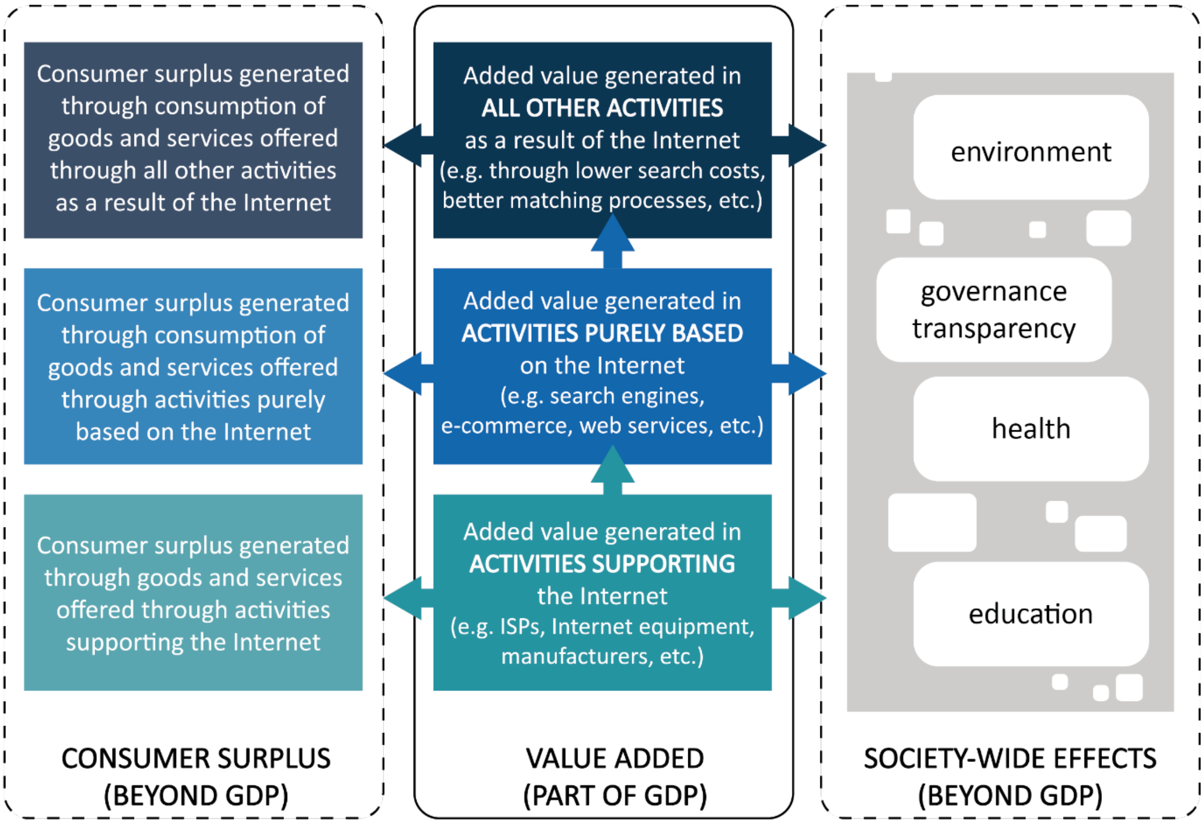
- positive impact of 5G for consumers, and
- broader, society-wide wellbeing gains generated due to 5G, derived from non-monetary transactions.

5G can deliver better goods and services that consumers value more highly. What consumers value more may not be 5G itself but the added value generated in additional activities that result from 5G (e.g. entertainment). Furthermore, competitive effects that reduce the prices of goods and services increase value to consumers. Apart from the benefits for individual consumers, other impacts of 5G are the broader, society-wide effects—for instance the expected positive impacts on education, scientific research or transport.

Although the internet's impact on market transactions has been far-reaching, its impact on non-market interactions have also been profound—including, for example, the effects of social media and user generated content. These interactions and indirect impacts of the internet contribute to individual benefits and the wellbeing of society, and are not directly captured in national accounts and are therefore difficult to quantify.[40]

Figure 10 illustrates how only some parts of internet-enabled goods and services are considered in measuring GDP. The indirect benefits of the internet are shown on the left-hand side (consumer surplus) and the right-hand side (society-wide effects). These indirect impacts also have a value in themselves (e.g. wellbeing, environmental amenities), which can have an impact on productivity. For instance, smart electricity grids will positively affect firm efficiency and benefit electricity providers (captured in GDP) as well as provide environmental benefits (not captured by GDP).

Figure 10. Limits to growth accounting—impacts can be broader than measured value added



Source: OECD (2013) Measuring the Internet Economy: A Contribution to Research Agenda, OECD Digital Economy Papers, No. 225.

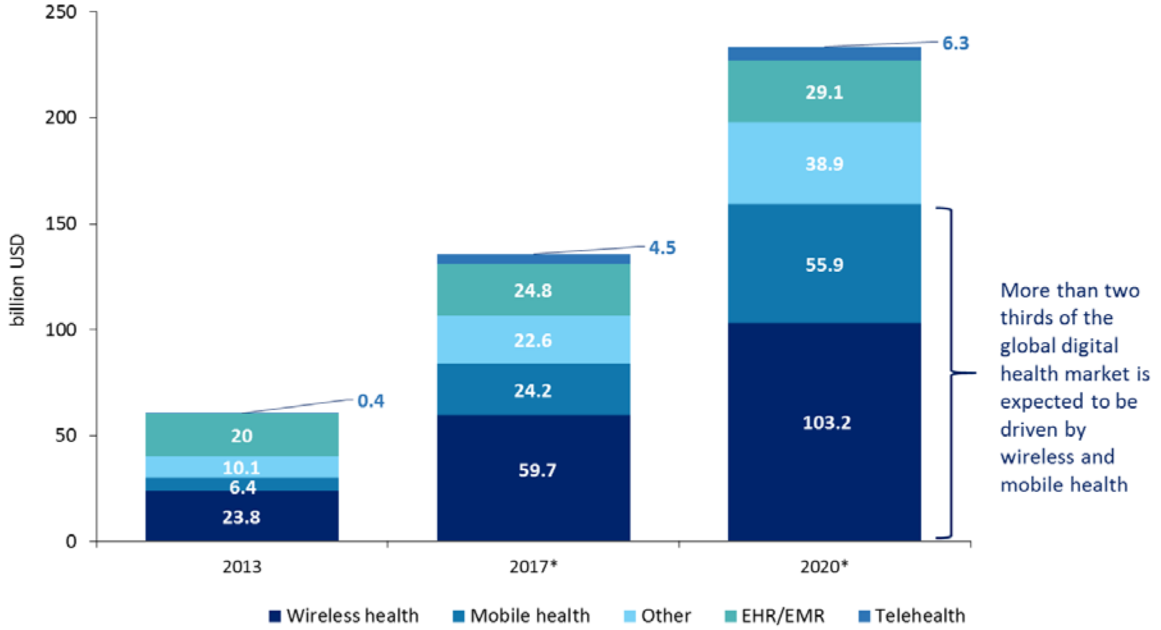
A more qualitative approach is required to better understand the impact of such quality and wellbeing changes that 5G may bring, including how 5G will affect different groups. To that end, the BCAR has developed a case study for the application of 5G to healthcare, with some of its likely impacts on patients, doctors and the economy more broadly.

A qualitative assessment of 5G and healthcare

Healthcare is a fast-growing sector, and digital technology is changing the way that healthcare is delivered. As consumers demand better accessibility to their medical practitioners, and better value, mobile health worldwide has experienced rapid growth, which is expected to continue (figure 11). By 2020, the mobile health segment of the global digital health industry is expected to generate the second largest revenue share. In Australia, the healthcare IT market was estimated at $1.20 billion in 2015 and is estimated to grow to $2.21 billion by 2020.[41]

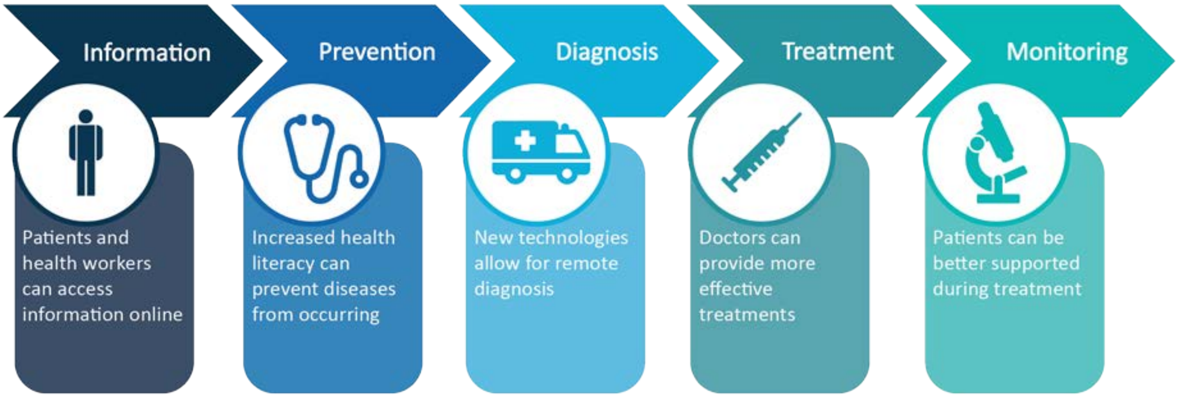
Healthcare is becoming increasingly reliant on the internet to support and provide medical services (figure 12), and digitally-delivered healthcare is expected to be even more important in the future as new technologies emerge.

Figure 11. Global digital health market from 2015 to 2020, by major segment



Source: Little, A. D. (2016) Global digital health market from 2013 to 2020.
Note: EHR: Electronic Health Records; EMR: Electronic Medical Records. An EMR refers to a single practice's digital version of a patient's chart, whereas an EHR is a more inclusive snapshot of the patient's medical history, designed to be shared with other providers.

Figure 12. How improved internet services lead to better health outcomes



Source: Deloitte (2014) Value of Connectivity: Economic and Social Benefits of Expanding Internet Access.

5G is likely to improve the capability of delivering services when compared against those currently available. Four features mean 5G will have more potential uses in delivering healthcare: fast and intelligent networks, connected devices, back-end services[42] and extremely low latency.[43] For example, some have suggested that the lower latency of 5G will offer applications such as tactile ('haptic') medicine using mobile technologies. The benefits of 5G will depend on how much healthcare is delivered via mobile technologies, and how much via fixed networks—often the main medium of delivery.

5G has the potential to bring productivity benefits to healthcare in several ways (table 7). 5G is expected to expand the availability of healthcare, by allowing for greater speed and lower latency to support more effective video conferencing and remote diagnostics. 5G is also expected to improve the reliability of healthcare, by enabling more reliable networks and using smart machines that may be less susceptible to breakdowns or downtime. The quality of healthcare may also be improved by 5G, as it could enable more wearable technology that provides better data for treatments and preventative care.

Some wearables have more stringent requirements in terms of data transmission capacity and latency than others, because some medical applications can be delay-sensitive. 5G may also lead to reductions in the cost of healthcare over the longer term as chronic disease is treated more effectively.

Table 7. Productivity benefits of 5G on mobile healthcare

5G will affect…	…by building on existing mobile health applications…	…which will have impacts on patients, providers and the economy
Availability of healthcare services	The greater speed and lower latency of 5G will allow for more effective video conferencing and remote diagnostics. It may also allow for remote procedures to be carried out in areas that lack access to health professionals.	• Patients and their families may no longer have to travel as far for some health services, and may be able to choose from a wider range of health professionals. • Health professionals may be able to better reach patients. • Greater availability of health services may enable a healthier, more productive workforce.
Reliability of healthcare services	5G is expected to be more reliable than existing mobile technology. The use of 5G to enable the 'internet of medical things' will also allow medical equipment to be more effectively monitored and maintained, avoiding breakdowns and down time.	• Patients and providers may be able to more frequently use telehealth solutions, without fear of dropouts or outages. As medical technology proves more reliable over 5G, more cost-efficient procedures may be carried out remotely as a matter of routine away from more costly hospital settings. • More reliable access to healthcare means that medical interventions can be timely and targeted, which could reduce overall costs on health budgets.
Quality of healthcare	As 5G allows for more ubiquity of fast, mobile internet connections, practitioners will have better access to patient data and tests. As wearable technology becomes more widespread, a greater wealth of more timely medical data will become available.	• Patients will contribute to their own wellbeing by collecting medical data, which should shift medicine towards more early intervention solutions rather than treatments. 5G devices can monitor and remind patients of treatment—potentially reducing repeat visits to doctors and insurance premiums. • Health professionals will have better access to richer data, enabling better treatment of patients as well as more information to improve medical research. • Higher quality healthcare leads to better health—an important determinant of wellbeing.

5G will affect…	…by building on existing mobile health applications…	…which will have impacts on patients, providers and the economy
Costs of healthcare	5G can help save costs for hospitals, with fewer admissions, and for patients, with self-management approaches. The cost reduction will depend on how quickly practitioners and patients are prepared to adopt 5G-enabled healthcare. There will be initial costs to purchase new 5G-enabled technology, which will vary depending on the technology.	• Despite the costs of upgrading technology, the pervasive healthcare provided by 5G will result in less expensive hospital-based care and fewer readmissions, and therefore be more cost-effective. • As 5G enables a better management of chronic diseases, this will lower the economic burden and social costs associated with these diseases.

Source: Table compiled by the BCAR.

The benefits from 5G will depend on a number of factors

While the productivity promise of 5G to enable better healthcare is attractive, the benefits of 5G will depend on a number of factors, for instance whether rolling-out 5G to remote and very remote areas is a viable option, and whether this can be done in a timely manner. The long-term economic and social benefits could be significant, however one of the main barriers is the cost of providing 5G access to all Australians, especially those in rural and remote areas. Given the way that standards are expected to evolve for 5G, it seems likely that the new technology will require a greater number of base stations and other physical infrastructure than current generations of wireless technology, which will be costly. This requirement makes rolling out such infrastructure less attractive in areas of lower population density.

There are also other potential barriers to the take up of digital health, including[44]:

- lack of agreed standards for data protection, privacy and security— both for data and devices
- concerns over patient safety, quality and liability
- lack of clear legal and regulatory frameworks
- poor interoperability and a need for common interoperability standards
- cultural resistance from healthcare practitioners.

Furthermore, parts of the healthcare sector may be slow to adapt, especially in the early days when business cases are limited. According to a survey of medical practitioners, one of the main concerns about using technology such as mobile health is the limited evidence on outcomes, including cost savings.[45] Other concerns included that the volume of medical data generated might be too complex to manage, less trustworthy, and could undermine clinical judgment.[46]

The Internet of Medical Things: Changing the way healthcare is delivered

These barriers are considerable, but if they can be overcome then 5G may enable a much wider range of medical technology that improves health outcomes.

5G will be part of the so-called ‘internet of medical things’ (i.e. IoT with medical applications). Wearable devices, remote sensors, and devices that electronically monitor and transmit data such as vital signs, will provide a better context for interpreting information, and deliver better diagnoses and treatments.[47] Although these services already exist, existing technologies are still not mature. Several constraints limit the clinical possibilities, and 5G is expected to enable new, improved functionality. For instance, the current monitoring of patients is based on one-way communication, with sensors sending information from patients to doctors. In the future, wearable sensors are expected to support many lifesaving functions that require two-way communications, such as drug delivery systems, neurostimulators[48], and pacemakers.[49]

5G and IoT will upgrade patients' experience, as virtually everything is connected. Access to online consultations will become more common with 5G and help provide the immediate, attentive care that patients are demanding. Currently, some patients are frustrated by long waiting times[50] and their inability to get a convenient appointment with the doctors of their choice.[51] More advanced applications such as robotic surgery could reduce wait times for surgeries, and move care closer to where patients, their families, and their carers live. Furthermore, with more devices and sensors deployed with 5G, it will be possible to store recorded medical data in the cloud, making data available to medical practitioners and researchers who need them around the clock.[52]

Patients will also become more involved in the monitoring of their own illnesses. For example, enhanced mobile technology and health applications could remind patients of treatments and to take medications, as well as send data to their doctor. This can potentially increase compliance with treatment, and play a role in improving patients' life expectancy.[53] For imaging and diagnostics, patients can gain access to medical expertise domestically or overseas, which may mean fewer travel costs or calls upon health infrastructure.

5G could be a cost-effective way of managing patient care in urban settings, where coverage is ubiquitous, and in some regional areas. Mobile telecommunications are part of Australian digital health capabilities[54] and are especially valuable for communities in remote and very remote areas, who may be at a disadvantage in terms of healthcare access.[55] Transferring health information via mobile applications can save travel time and service costs, and help the healthcare system to better overcome any geographic, income or other disparities.[56]

Because there is uncertainty about the investment needed to enable 5G, and what the benefits will be, it is difficult to quantify precisely the productivity effects that 5G will have on healthcare. Furthermore, the benefits from 5G could be diminished if it takes time to be rolled out to all areas. However, as 5G may offer more applications and greater benefits, there is a stronger case to roll out mobile-enabled healthcare more broadly than previously might have been expected. Despite the large technology costs, remote healthcare has the potential to generate revenue for rural hospitals, while incurring substantial patient savings. For instance, a study in the US found that by staying in their local hospital and avoiding transfer to a larger hospital elsewhere, patients save about $5,600 a year in avoided transportation and other related patient expenses.[57]

Digital health applications have the potential to change the course of healthcare as it is provided today. As 5G is rolled out, more attention will need to be paid to regulatory and policy settings to address issues such as safety and privacy. The right environment to optimize the benefits of 5G to consumers, businesses and society will be crucial, and effective government frameworks and appropriate regulation are necessary.

Appendix A: Methodology

The BCAR has used a growth accounting approach in order to estimate the potential effect on multifactor productivity (MFP) from the introduction of 5G in Australia. It does so by assuming different changes to investment (the inputs needed to build and enable use of the 5G network) and output growth (reflecting the additional goods and services that can be generated more efficiently by 5G). These assumed changes are based on reviews about how much it might cost to build the 5G network and output growth associated with previous generations of ICT technology, the internet and more fundamental general purpose technologies (GPTs).

By deriving the effect of 5G on MFP, the result can then be used to assess the potential effect on GDP per capita, which in turn enables an assessment of the magnitude of income growth that might be expected from the introduction of 5G.

An overview of the approach

Growth accounting is an approach used to decompose economic growth into changes in productivity, inputs and outputs. Typically, this involves an assumption about how different inputs—labour and capital—are used to produce output. By examining the movements in measured inputs and outputs, a residual measure can be calculated, which reflects changes in productivity.

One of the most common approaches, and the one used in this paper, is to assume that output growth in the Australian economy is based on labour input growth (the number of hours worked), capital input growth (changes in 'capital services'—a measure of the flow of output from the capital stock in the economy) and MFP. Growth accounting can also be used at the industry level—allowing the calculation of inputs, outputs and productivity by different industries, and their contribution to the total economy over time.

The BCAR has used growth accounting consistent with the way that the Australian Bureau of Statistics (ABS) approaches calculating MFP.[58] However, the BCAR has made some extensions to this:

- To get a data series long enough to consider fundamental changes, the average annual growth rates in inputs and outputs by industry have been forecast out to 2050 using a simple exponential trend based on data from 1995–96 to 2016–17 (the period over which all market sector industries have available data).
- The way that labour and capital are weighted to form inputs in the growth accounting are held at their long run averages through time. For example, if the importance of labour means that it comprises 40 per cent of inputs on average between 1995–96 and 2016–17, then this proportion is used out to 2050. While this sort of weight does not change much at the aggregate level, it may not be accurate for rapidly changing industries that are becoming more labour or capital intensive, or for those industries where the different *types* of capital are changing.

More details on the approach used by the BCAR are provided below.

Growth accounting approach

The growth accounting approach used by the BCAR is consistent with chapter 19 of the ABS *Australian System of National Accounts: Concepts Sources and Methods* publication.[59]

Data for each of the market sector industries is sourced from the ABS' *Estimates of Industry Multifactor Productivity* release for 2016–17. (Market sector industries include all ANZSIC divisions except Public administration and safety, Education and training, and Health care and social assistance.) To derive a total economy measure of MFP, the individual industry MFP series are aggregated. The BCAR has used a different approach to the ABS in that non-market sector industries are included in the aggregate—however, these industries are assumed to have no MFP growth, consistent with ABS practice. The income share data to aggregate total economy MFP are sourced from the *Australian System of National Accounts, 2016–17* release.[60]

Forecasting

Because the BCAR modelling takes place over a long period, the BCAR has forecast the relevant series to generate productivity estimates to 2049–2050:

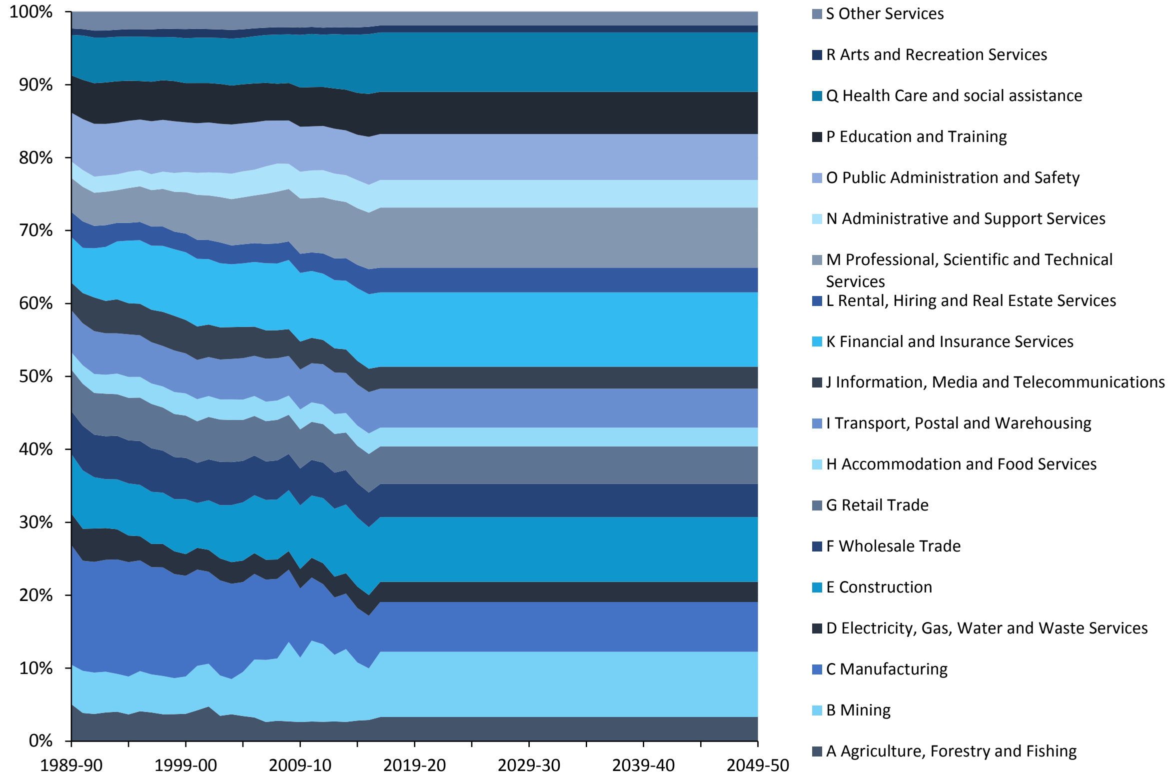
- Output growth and labour input growth for each industry are forecast using the average annual growth rate from the ABS *Estimates of Industry Multifactor Productivity* publication from 1995–96 to 2016-17.[61]
- Productive capital stock growth for each asset in each industry is forecast using the average annual growth rate from the ABS *Estimates of Industry Multifactor Productivity* publication from 1995–96 to 2016–17.
- The productive capital stock series are aggregated to capital services—the capital input for the growth accounting—for each industry using fixed rental price shares from the ABS *Estimates of Industry Multifactor Productivity* publication for 2016–17.
- Value added shares, gross operating surplus and gross mixed income, and compensation of employee shares across industries—used to calculate total economy MFP—are based on the 2016–17 shares from the ABS *Australian System of National Accounts, 2016–17* publication.

This approach incorporates some simplifying assumptions made by the BCAR:

- The assumption that value added shares, gross operating surplus shares, and compensation of employee shares are fixed through time means that there is no long-run change in the structure of the economy.
- The assumption that rental prices are fixed through time implies that the relative prices between different capital goods do not change.

This means that, to the extent that structural change is occurring over the forecast period, the analysis will not truly reflect the change in MFP from 5G as modelled. (The true effect could be more or less than what the growth accounting might suggest.) This includes any structural change that 5G *itself* may drive.

Figure A.1: Value added shares assumed through time for each ANZSIC division



Source: BCAR estimates based on ABS *Australian System of National Accounts, 2016–17, Cat. No. 5204.0* (to 2016-17).

The scenarios

The scenarios tested by the BCAR all involve additional capital inputs to be modelled. Adding additional investment to the growth accounting model occurs in several steps:

- Any additional investment is added using a perpetual inventory method—consistent with chapter 14 of *Australian System of National Accounts: Concepts Sources and Methods*[62]—which yields the additional productive capital stock (PKS) by year, and by industry.
- This additional capital stock by year by industry is added to the existing PKS by year, and by industry to get the new value for PKS, which forms the input to capital services.
- Investment trends are assumed to be persistent, so growth in PKS is then assumed to be at the same rate as previously, but with the new level of PKS forming the base. (Without this assumption, growth in capital services after the shock is lower, as changes take place from a larger base of productive capital stock. Conceptually, the assumption is consistent with a higher level of investment required to maintain the new investment in line with previous investments.) This is then used to calculate a capital services index, which forms the capital input for the growth accounting.

In terms of additional investment made to enable 5G, the BCAR has considered three different cases, based on a literature review of costs to build 5G networks in Australia and overseas:

- A ‘low cost’ case assumes that there would be:
  - $5 billion in non-dwelling construction investment and $0.5 billion in R&D for the IMT sector (reflecting the costs of building the network).
  - A five per cent increase in investment in electrical and electronic equipment in all industries (reflecting the costs of purchasing new 5G-enabled equipment).

- A ‘medium cost’ case:
  - $10 billion in non-dwelling construction investment and $1 billion in R&D for the IMT sector (reflecting the costs of building the network).
  - A 10 per cent increase in investment in electrical and electronic equipment in all market sector industries (reflecting the costs of purchasing new 5G enabled equipment).
- A high cost case:
  - $25 billion in non-dwelling construction investment and $2.5 billion in R&D for the IMT sector (reflecting the costs of building the network).
  - A 20 per cent increase in investment in electrical and electronic equipment in all market sector industries (reflecting the costs of purchasing new 5G enabled equipment).

On the output side, the BCAR has considered three different cases as well (reflecting the findings outlined in appendix B):

- a case where there is no productivity effect (which provides some guidance as to the degree of productivity gain needed to offset the additional investment)
- a ‘short’ period of productivity growth that allows for faster output growth of 0.3 per cent per year in all market sector industries over a 10 year period (reflecting an advance on previous technology)
- a ‘long’ period of productivity growth that allows for faster output growth of 0.3 per cent per year in all market sector industries over a 30 year period (reflecting a GPT case—where 5G enables an effect more akin to an ‘industrial revolution’).

There is also a timing dimension to the growth accounting with two cases considered: an instantaneous case (where investment in the network happens in one year, and benefits flow thereafter) and a lagged case (where investment is staggered over a 5 year period, and benefits flow more slowly over these years before ramping up to the full 0.3 per cent thereafter). In the staggered cases, a logistic function is used to reflect the slow initial and final stages of a mobile network rollout with a faster middle stage (figure 6).

This yields 19 scenarios, including the case where no change is made to investment or output, which is used as a common ‘baseline’ scenario for comparing different scenarios.

Table A.1. The different combinations of assumptions used by the BCAR to derive each scenario

Investment cost	Productivity effect	Speed of rollout	Scenario Number
None	None	None	0—NNN
Low	None	Instant	1a—LNI
Low	None	Lagged	1b—LNL
Low	Shorter	Instant	1c—LSI
Low	Shorter	Lagged	1d—LSL
Low	Longer	Instant	1e—LLI
Low	Longer	Lagged	1f—LLL
Medium	None	Instant	2a—MNI
Medium	None	Lagged	2b—MNL
Medium	Shorter	Instant	2c—MSI
Medium	Shorter	Lagged	2d—MSL
Medium	Longer	Instant	2e—MLI
Medium	Longer	Lagged	2f—MLL
High	None	Instant	3a—HNI
High	None	Lagged	3b—HNL
High	Shorter	Instant	3c—HSI
High	Shorter	Lagged	3d—HSL
High	Longer	Instant	3e—HLI
High	Longer	Lagged	3f—HLL

Graphical results of the different scenarios

Because much of the investment activity is assumed to be in IMT, it has different productivity trends as a result of the shocks compared with other industries.

Figure A.2 shows MFP in IMT for the high cost case of building the network with no output effect, a short output effect and a long output effect, respectively. In each scenario, there is a fall in MFP growth in 2019–20 reflecting the investment made to build the 5G network. In the short output effect case, the additional output almost perfectly offsets the additional investment, leading to almost no productivity effect. In the case with a longer period of output effects, this additional output well exceeds the additional investment, leading to higher MFP growth.

Figure A.3 shows the total economy MFP aggregate for the high cost case of building the network with no output effect, a short output effect and a long output effect, respectively. While difficult to see, there is a fall in MFP growth in 2019–20, again reflecting the additional investment to build the 5G network, and the additional capital needed to ‘enable’ its use in each market sector industry. However, because the scale of the output effect in the shorter and longer output effect scenarios is much larger relative to this investment, productivity growth is stronger than the baseline case.

The figures for the other cost scenarios are not shown, but these simply represent a 'level' shift increase in the patterns shown in figures A.2 and A.3, as the output effects are the same, but the assumptions about the volume of additional capital input requirements are reduced.

Linking growth accounting to incomes

GDP per capita growth can be disaggregated into labour productivity growth (value added per hour worked) and labour utilisation growth (hours worked per person). Labour productivity growth itself can be decomposed into growth of MFP and capital deepening (the growth of capital per unit of labour input).

The BCAR growth accounting provides an indication of the *additional* MFP growth that might be expected from 5G on the basis of different assumptions. This additional MFP growth is added to the GDP per capita growth assumed as part of Treasury's 2015 *Intergenerational Report.*[63]

Table A.2 shows the differences from the baseline cases for the different scenarios on IMT and total economy MFP. The latter is then used to calculate the additional income. For example, to calculate the additional GDP per capita in the case of the scenario with low costs, longer output effect and lagged timing ('1f—LLL'), an additional 0.21 per cent is added to the growth rates estimated in the intergenerational report. This yields around an additional $7,580 per capita by 2050 (in real 2015–16, undiscounted terms).

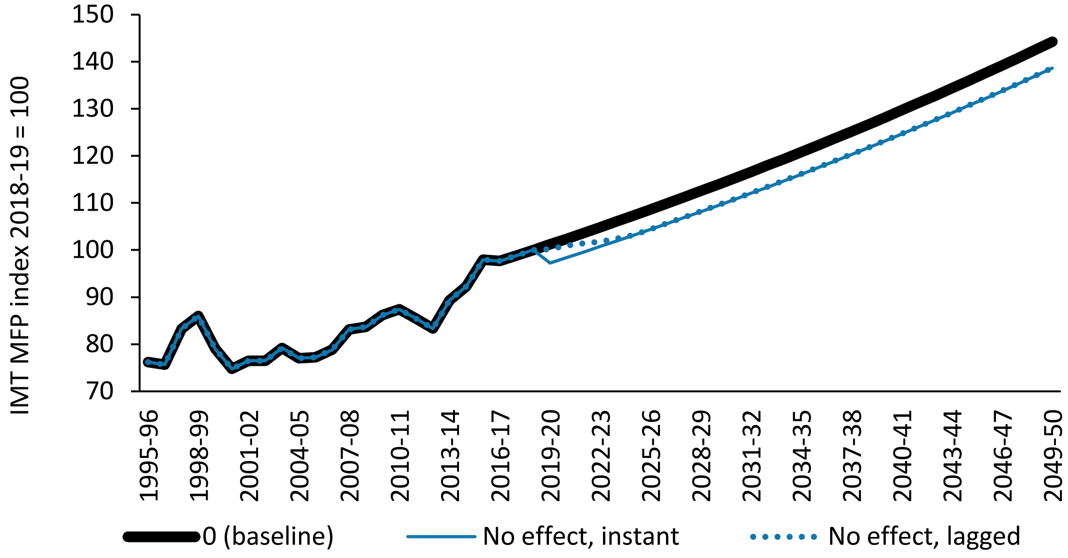
Table A.2. Results from the different scenarios

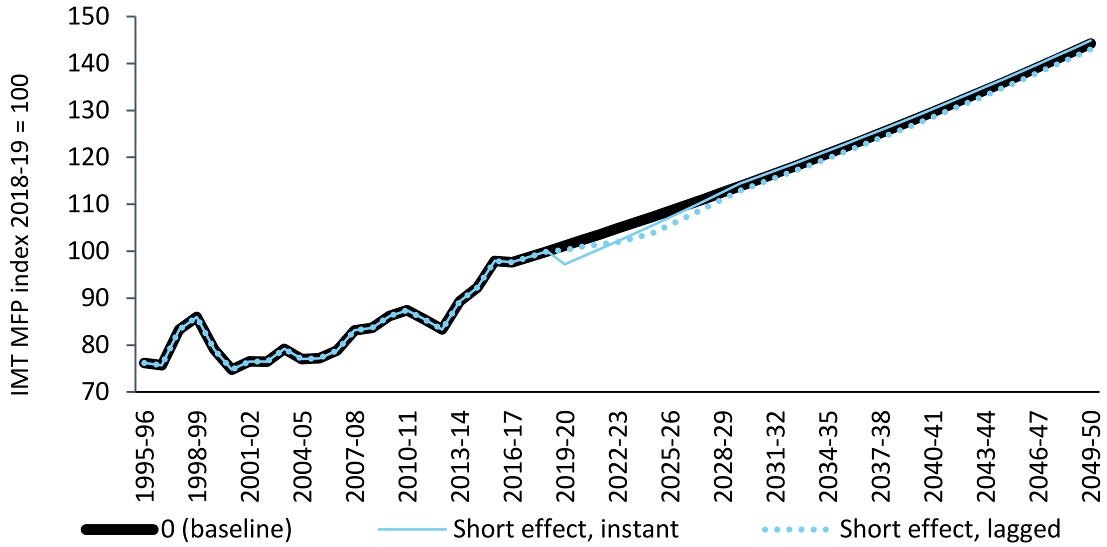
Scenario	Effect on IMT MFP (p.a) to 2030	Effect on IMT MFP (p.a) to 2050	Effect on total economy MFP (p.a) to 2030	Effect on total economy MFP (p.a) to 2050	Additional per capita GDP (relative to baseline) in 2030	Additional per capita GDP (relative to baseline) in 2050
0—NNN	0.00%	0.00%	0.00%	0.00%	0	0
1a—LNI	-0.14%	-0.05%	0.00%	0.00%	-29	-4
1b—LNL	-0.13%	-0.04%	0.00%	0.00%	-36	-5
1c—LSI	0.17%	0.06%	0.21%	0.08%	2,025	2,739
1d—LSL	0.08%	0.03%	0.15%	0.05%	1,412	1,929
1e—LLI	0.17%	0.24%	0.21%	0.23%	2,025	8,425
1f—LLL	0.08%	0.21%	0.15%	0.21%	1,412	7,576
2a—MNI	-0.16%	-0.06%	-0.01%	0.00%	-58	-8
2b—MNL	-0.23%	-0.08%	-0.01%	0.00%	-83	-9
2c—MSI	0.12%	0.04%	0.21%	0.08%	1,996	2,735
2d—MSL	0.02%	0.01%	0.15%	0.05%	1,378	1,925
2e—MLI	0.12%	0.24%	0.21%	0.23%	1,996	8,421
2f—MLL	0.02%	0.21%	0.15%	0.21%	1,378	7,571
3a—HNI	-0.36%	-0.13%	-0.01%	0.00%	-123	-20
3b—HNL	-0.36%	-0.13%	-0.02%	0.00%	-149	-23
3c—HSI	0.04%	0.02%	0.20%	0.08%	1,929	2,723
3d—HSL	-0.08%	-0.03%	0.14%	0.05%	1,297	1,911
3e—HLI	0.04%	0.23%	0.20%	0.23%	1,929	8,408
3f—HLL	-0.08%	0.20%	0.14%	0.21%	1,297	7,556

Source: BCAR estimates based on ABS and Treasury data.

Note: The effects shown are relative to the baseline case discussed above. Additional GDP per capita figures in real 2015–16 terms.

Figure A.2: The high cost cases for IMT productivity by different output effects





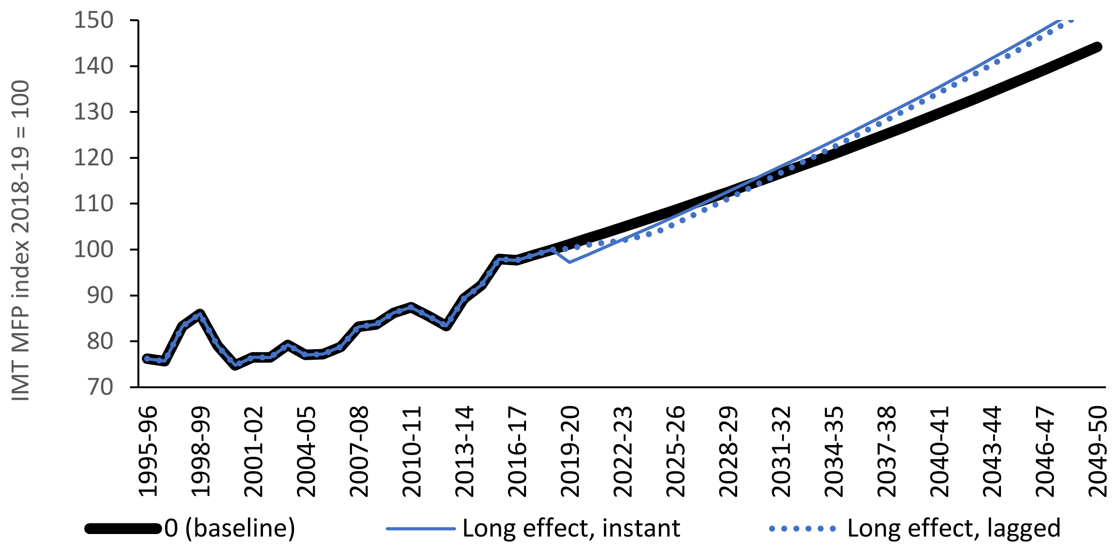
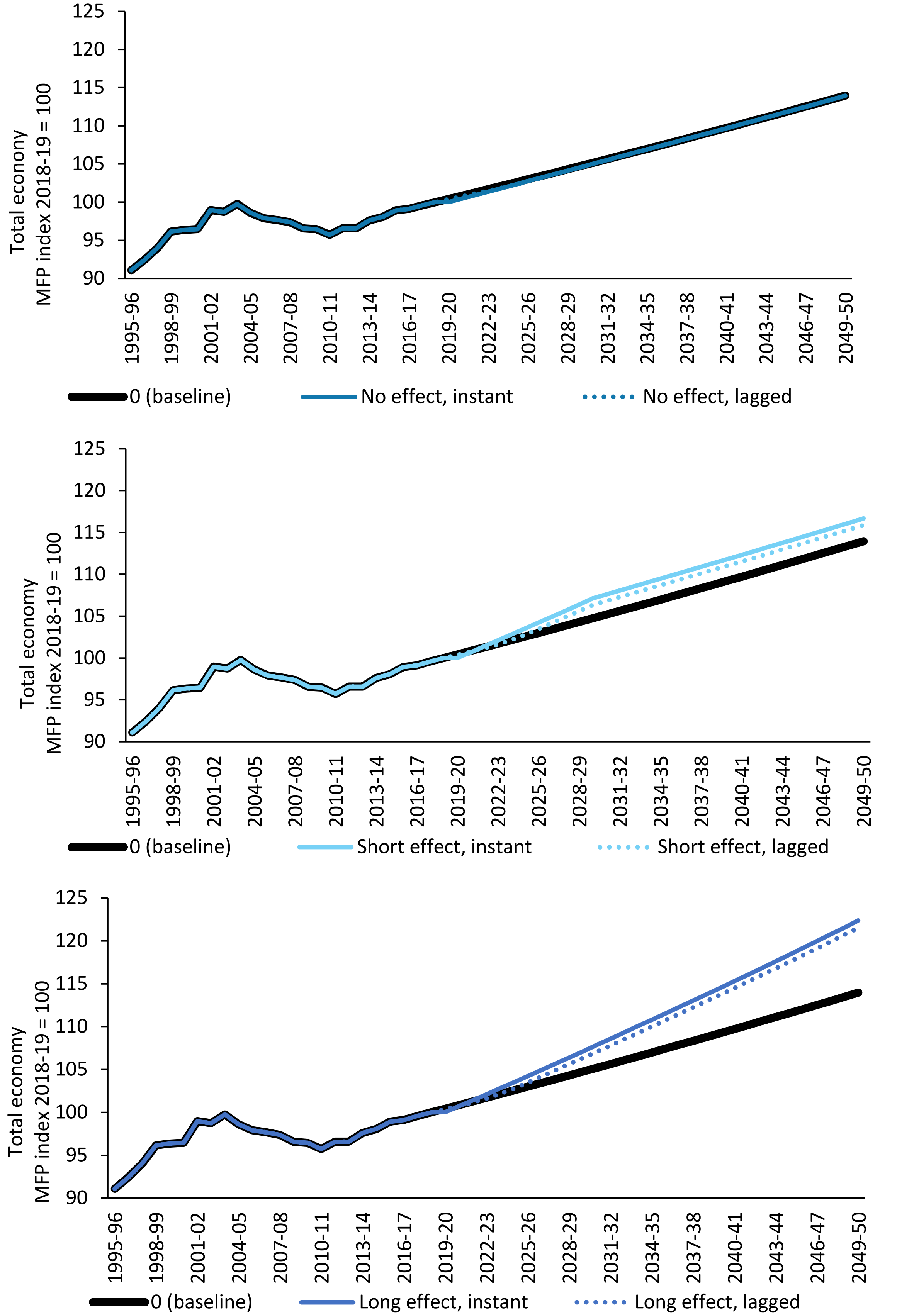


Figure A.3: The high cost cases for total economy multifactor productivity by different output effects



Appendix B: ICT, internet and GPT studies

Table B.1 How previous ICT, internet and GPT advances have affected productivity

Key studies	Findings	Methodology
	Mobile technologies adoption	
Deloitte (2016)[64]	Real GDP higher by $8.9 billion from 2008 to 2015 as a result of enhanced labour participation from mobile devices.	Dynamic CGE model, using shocks derived from Deloitte's workforce forecasts, survey data and ABS data.
Deloitte, GSMA and Cisco (2012)[65]	10% substitution from 2G to 3G increases GDP per capita growth by 0.15%	Econometric analysis, 96 developed and developing countries (2008–11)
Deloitte, GSMA and Cisco (2012)[66]	Doubling of mobile data use leads to a 0.5% increase in GDP per capita each year	Econometric analysis, study using data from Cisco's VNI Index for 14 countries (2005–2010).
Deloitte, GSMA and Cisco (2012)[67]	If countries had had a 10% higher mobile penetration between 1995 and 2010, MFP would have increased by 4.2 percentage points	Stochastic Frontier Analysis (SFA), study of 74 countries (1995–2010).
Gruber and Koutroumpis (2011)[68]	Productivity growth higher by 0.28% p.a. in Australia over 1990–2008. Productivity growth higher by 0.31% in Nordic countries (Finland, Norway and Sweden), 0.30% in UK, 0.24% in US, and 0.18% in Canada	Econometric analysis of the contribution of mobile telecommunications to productivity growth in Australia.
GSMA (2017)[69]	Mobile technology contributed 5.2% to real GDP of Asia-Pacific economies in 2016	Unspecified.
	Broadband Internet, Information and Communication Technologies	
CIE (2014)[70]	Real GDP higher by 0.28% p.a. (over 2007–2013). (Does not account for the infrastructure costs of building mobile networks.)	Dynamic CGE model of the Australian economy estimating economy-wide benefits from higher mobile sector productivity.
Allen Consulting (2010)[71]	MFP higher by 0.07 percentage points for a 20% increase in household internet connectivity in Australia	Dynamic CGE model of the Australian economy, the Monash Multi Regional Forecasting Model (MMRF).
Micus (2008)	Productivity 0.29% higher (over 2004–06), EU27 average. Business services had the highest annual improvement (0.58%), whereas the manufacturing sector was only 0.14%.	'Community survey on ICT use in enterprises', to estimate the macro-economic broadband-related productivity improvement in Europe.
Productivity Commission (2004)[72]	Acceleration in MFP growth higher by 1 to 2 tenths of a percentage points. Findings within the same range as estimates from previous studies.	Firm-level econometric analysis of firm ICT use in the mid-1990s in Australia.
Allen (2003)[73]	6.3% cost savings from broadband internet (1.5% for dial up), resulting in productivity gain of 0.32%	Survey of Australian businesses.
Bean (2000)[74]	Uplift in ICT investment in Australia contributed 0.12 percentage points to MFP growth in the 1990s	Cross-country regression, OECD countries
Toohey (2000)[75]	Australian productivity growth attributable to IT is 0.75% p.a.	Growth accounting framework.

Key studies	Findings	Methodology
	Other General Purpose Technologies (GPTs)	
Allen (2010)[76]	Contribution to productivity growth during the Industrial Revolution: railways (0.26%), steam engine (0.38%)	Unspecified.
Edquist and Henrekson (2006)[77]	Electricity: estimated compound growth rate in labour productivity and MFP were 5.5% and 5.1% respectively, over 1919–1929.	Review of secondary sources and authors calculations (unspecified).
Crafts (2004)[78]	Total contribution to British labour productivity growth from steam technology (combined impacts of steam engine and railways) was, in percentage p.a.: 0.01% over 1760–1800; 0.02% over 1800–30; 0.20% over 1830–50; 0.38% over 1850–70; and 0.21% over 1870–1910.	Growth accounting framework.

Source: Table compiled by the BCAR.

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