The 5G Economy in a Post-COVID-19 Era

The role of 5G in a post-pandemic world economy

November 2020

Prepared for Qualcomm Technologies, Inc. in partnership with Omdia

Contents

Executive summary

The early days of 2020 were still heady times for 5G. Rarely had the world so enthusiastically awaited the arrival of a communications technology often described as “disruptive,” “transformational,” and a “general purpose technology.” As its early versions emerged—with much more expected to come over the next 10-15 years—pundits were espousing the ways 5G will change or materially influence almost every aspect of human activity.

Global priorities underwent an unexpected reset starting in February 2020, as the SARS-CoV-2 virus (the virus that causes coronavirus disease 2019—COVID-19) began rapidly cascading from country to country. The world has witnessed catastrophic losses of lives and rates of infection—as of the writing of this report (November 2020), almost 1.3 million deaths from just under 53.0 million infections globally.

The social and economic upheaval caused by COVID-19 has raised questions about 5G’s role in a post-pandemic world. Indeed, the isolation induced by efforts to contain COVID-19 has underscored the importance of communication technology in keeping social networks connected and economic systems resilient. IHS Markit expects the continual and deepening deployment of 5G (and the products, services, and experiences that will likely flow from it) to fundamentally support and enable the emergent requirements of the post-pandemic world for connectivity, flexibility, and resiliency. This will encourage on-going investments in 5G technology in the form of capital expenditures (CAPEX) and research and development (R&D) that will build a communications infrastructure to transform how industries deliver value on a local and global level.

Various mobile network operators (MNOs) have already announced acceleration of 5G deployment and supply chains firmed up as China emerged from its early battles with COVID-19. Smartphone-makers started releasing 5G handsets over a range of price points to attract consumers in different affordability circumstances. Unlike previous generations of cellular technology, industrial requirements are being baked into 5G standards due, in part, to the participation of many industrial companies in the standardization effort. Those use cases will drive value in terms of cost savings and efficiencies, new sources of revenue, more “intelligent” products, and better customer experiences. Many enterprises and industrial companies are taking advantage of 5G’s long-game nature and are currently engaged in trials and proofs-of-concept to validate 5G’s technical suitability for their use cases and returns on investment.

The economics behind the value of the 5G use cases in a post-pandemic world is one reason that investment in 5G technology did not fall off the cliff during the economic downturn that followed the onset of COVID-19; even as many other investment activities saw sharp declines. In fact, IHS Markit’s new forecast shows a 10.8% net increase in global 5G investment and R&D during 2020-35 compared to the 2019 forecast. It is evident that the need for expanded connectivity in the COVID-19 era is invigorating 5G investment growth.

This report presents IHS Markit’s latest assessment of the global economic impacts of 5G in the post-pandemic world (2020-35) and is an update of a similar report issued prior to the onset of COVID-19 (IHS Markit, 2019).

Economic impacts of 5G in a post-COVID-19 world

The key findings explore three measures of the macroeconomic benefits of 5G over the period 2020-35. These are the emerging ***5G value chain***, ***sales enablement***, and the ***net contribution to global GDP***.

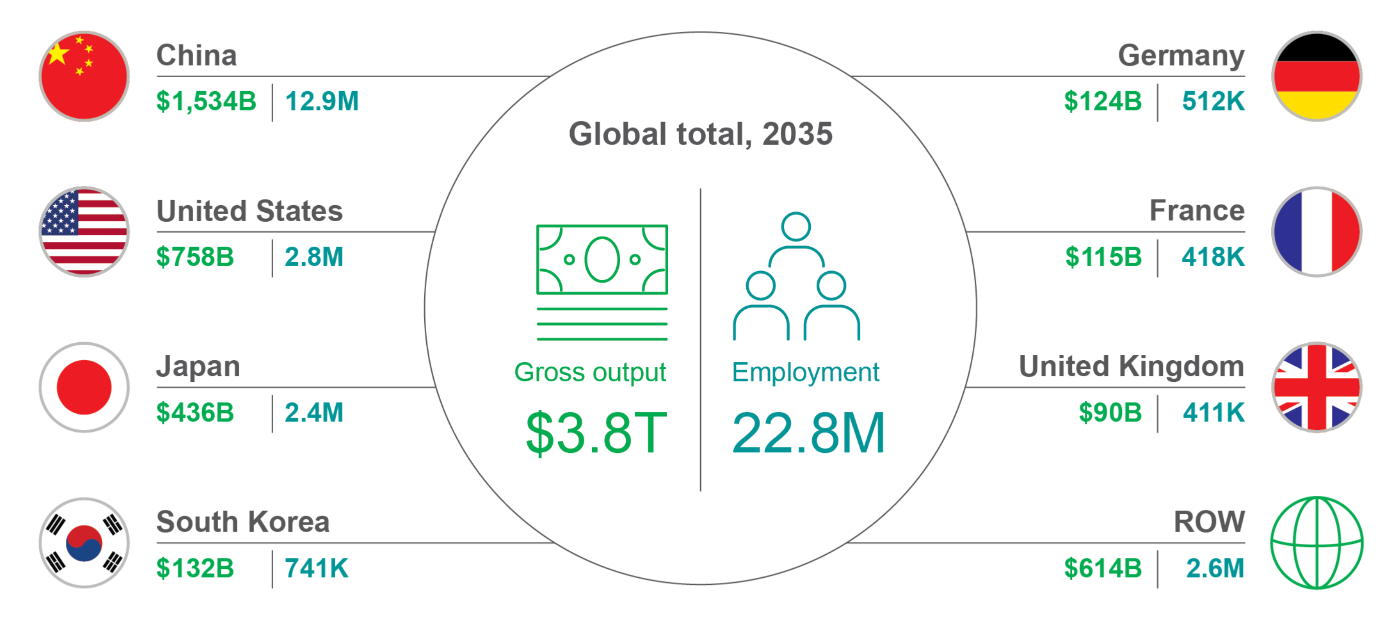
Value chain

Macroeconomic benefits of 5G can be measured by the global contribution of 5G to the value chain around that technology. This reflects the economic impact of investments in 5G infrastructure and associated R&D.

- IHS Markit anticipates that 5G-related investment (both CAPEX and R&D) from 2020 through 2035 by firms that are part of the 5G value chain within just seven countries (China, United States, Japan, Germany, South Korea, France, and United Kingdom) will average over $260 billion annually.
- IHS Markit currently estimates that the 5G value chain will generate $3.8 trillion of gross output and support 22.8 million new jobs by 2035. Moreover, the seven countries will account for nearly 84% of the contribution to global 5G-related gross output and over 88% of the contribution to new employment.

By virtue of a significant ramp-up in 5G related investment (CAPEX as well as R&D), China is expected to capture a higher share of the 5G value chain in 2035—about $400 billion (or 36%) higher at $1.5 trillion than the $1.1 trillion that was forecast in 2019. In contrast, the share of the Rest of the World is expected to be about 19% lower. The slower economic growth trajectory of in the post-COVID world may be felt disproportionally by smaller countries that lack the resiliency to snap back as quickly as larger economies. This will affect their investment priorities and assert downward pressure on 5G-related spending.

The economic contribution of the 5G value chain, 2035



Source: IHS Markit analysis based on data provided by Omdia

Sales enablement

Sales enablement refers to the additional sales that businesses across virtually all industry sectors will realize by exploiting the unique capabilities of 5G (over and beyond existing 4G) to improve their executional efficiency, expand their ability to reach customers, and create unique product or service offerings. IHS Markit believes 5G use cases will fall into three broad categories. **Enhanced mobile broadband** (eMBB) use cases will leverage 5G's extended cellular coverage and improved capacity. By coupling 5G's low power requirements with its ability to operate in licensed and unlicensed spectrum, **Massive Internet of Things** (MIoT) use cases will bring dramatically more scale and flexibility to machine-to-machine and Internet of Things applications. The combination of high reliability, ultra-low latency connectivity, and strong security will be hallmarks of **Mission Critical Services** (MCS) use cases. 5G will enable sales to both end users (final goods and services) and producers (intermediate goods and services). IHS Markit estimates that, by 2035, each of the three categories of applications will produce roughly equal levels of sales enablement (in excess of $4 trillion each for a total of just over $13 trillion).

These applications will, of course, produce the greatest amount of sales in different clusters of industries.

- IHS Markit estimates that, among 16 industries,[1] eMBB will enable sales most in manufacturing, information and communication, professional services, education, and arts and entertainment;
- MIoT sales enablement will be highest in manufacturing, wholesale and retail trade, public service, financial and insurance, and mining and quarrying; and
- MCS will have the highest sales enablement in financial and insurance, transport and storage, health and social work, agriculture, forestry and fishing, and utilities.
- In 2035, the greatest sales enablement in absolute 2016 dollar terms is expected to occur for manufacturing (almost $4.7 trillion), while as a percent of total industry sales, it is expected to be highest for information and communication (10.9%), more than twice the expected overall industry average (5.1%).

IHS Markit anticipates that post COVID-19 global economic growth trajectory will be lower than the pre-pandemic forecasts that informed the 5G economic contribution assessments in the IHS Markit 2019 report. Indeed, the IHS Markit current forecast for global gross output (sales) in 2035 is about 2.8% lower than the pre-pandemic forecast, and the world real GDP forecast is lower by 3.1%. In contrast, IHS Markit's revised forecast for 5G sales enablement, of $13.1 trillion, is a contraction by only about 0.6%, significantly less than the global contraction in gross output and GDP. Furthermore, 5G sales enablement share of overall industry output is forecast to actually increase to 5.1% from 5.0% of global sales in 2035. Both of these indicate that 5G will continue to be viewed as a critical lever for generating sales across a broad range of industries.

5G will enable $13.1 trillion in global sales activity in 2035

	Impact of 5G by industry and use case category			Industry output (sales) enabled by 5G	
Industry	Enhanced Mobile Broadband	Massive Internet of Things	Mission Critical Services	5G-enabled sales (2016$, B)	Percent of industry sales
Manufacturing				$4,771	5.5%
Information & communication				$1,493	10.9%
Wholesale & retail				$1,144	5.2%
Public service				$961	6.4%
Construction				$730	4.4%
Financial & insurance				$646	4.7%
Transport. & storage				$603	5.6%
Professional services				$561	3.0%
Health & social work				$437	4.0%
Ag., forestry & fishing				$416	5.5%
Real estate activities				$360	2.5%
Mining & quarrying				$254	5.1%
Utilities				$289	4.0%
Education				$264	3.6%
Hospitality				$108	2.3%
Arts & entertainment				$62	3.5%
All industry sectors	**$4,257**	**$4,159**	**$4,683**	**$13,098**	**Overall average: 5.1%**

Low Impact — High Impact

Source: IHS Markit

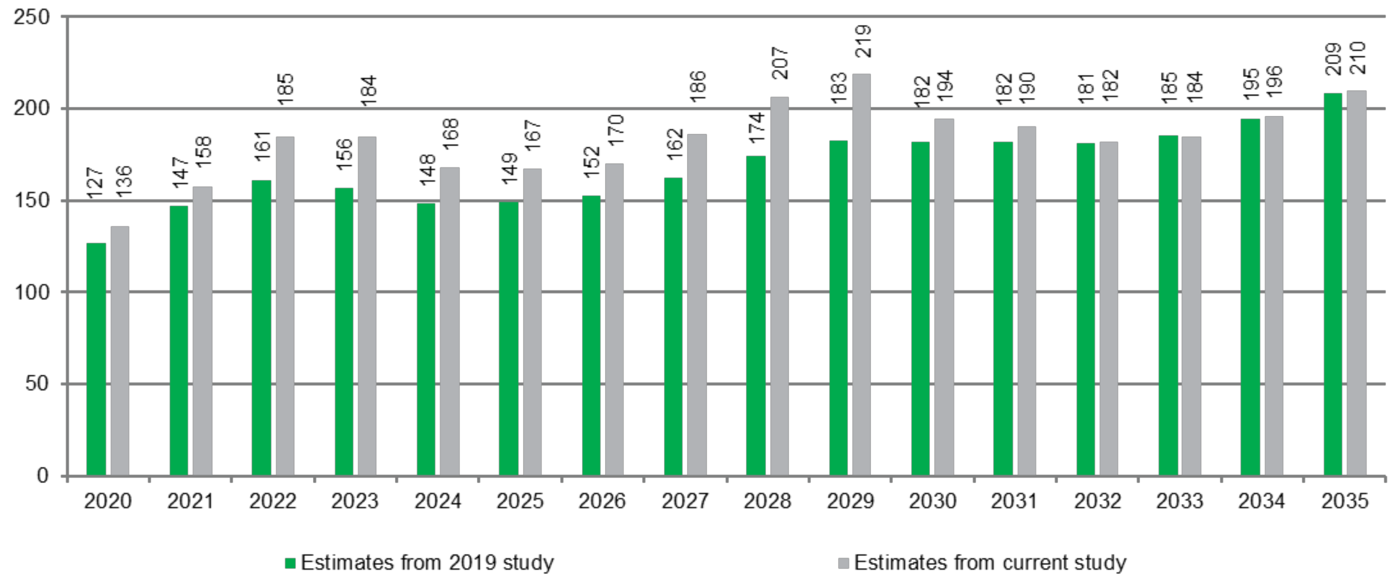
Contribution to global GDP

The third measure of macroeconomic benefits of 5G is the net contribution it makes to global GDP. This net contribution takes into account the possible diversion of investment and R&D spending from non-5G opportunities to 5G and, therefore, the loss of economic benefits elsewhere.

- Based on its proprietary Global Link Model, IHS Markit analysts estimate[2] that the net contribution globally through 2035 (in net present value terms) will amount to about $2.3 trillion in constant 2016 US dollars—roughly the same as France's current GDP.
- Moreover, over that period, IHS Markit analysts forecast that global real GDP will grow at an average annual rate of 2.7%, of which 5G will contribute almost 0.2%. These are both clear indications that 5G will make a significant economic contribution worldwide.

The current estimate of 5G's net contribution to global GDP is slightly higher than that in IHS Markit's 2019 report. Given the excess capacity in the global economy induced by the COVID-19 pandemic, investments can have a slightly higher impact as the opportunity cost of using resources to build out 5G are likely lower than in our previous forecast. In other words, when there is excess capacity, there are more idle resources; therefore, hiring them to build out 5G is not taking them away from another profitable opportunity. The dynamics show that the effects become slightly greater in the medium term in response to a second wave of 5G-related investment.

Annual net contribution of 5G to global growth (billions of 2016 US$)



Source: IHS Markit

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Regardless of any debate over the impact of COVID-19 on 5G, it is hard to argue that the 5G train is already in motion, and the only question is when or how soon it will get to the many destinations along the track. The economic benefits of 5G technology can be realized, but it will require the ecosystem to work together to speed deployment. This includes policymakers and regulators as well as the system integrators, MNOs, etc. The economic impacts can be viewed as the lower bound estimate. Impacts can be higher if the technology is more quickly deployed. Impacts can also be higher if entrepreneurs and innovators harness this technology to solve some of our most pressing challenges. These solutions, particularly those that help bridge the digital divide so that more people can participate in the information economy, will unleash value streams that will help grow the global economy for everyone.

Introduction

These are heady times for the new mobile technology commonly known as 5G. Rarely has the world anticipated with such enthusiasm for the arrival of a communications technology that has been described as “disruptive,” “transformational,” and a “general purpose technology.” Now that its early version is here—with much more expected to come over the next 10-15 years—observers are counting the ways 5G will change or materially influence almost every aspect of human activity.

The arrival in early 2020 of the SARS-CoV-2 virus (also known as COVID-19) and its rapid global spread have been the other big developments of 2020. Over the past 10 months or so, the world has witnessed a catastrophic loss of lives and rates of infection—as of the writing of this report (November 2020), almost 1.3 million deaths from just under 53.0 million infections globally (Johns Hopkins, 2020). This colossal healthcare crisis has dampened expectations in the near term for 5G in some respects. It is also heightening opportunities for 5G to come to the rescue in unexpected ways as lockdowns and social distancing measures pushed people towards virtual interactions; raised the imperative for being able to track supply chains and inventory in real time; and accelerated the behavioral transition for acceptance of e-commerce and telemedicine.

The unwelcome intervention of the COVID-19 pandemic has raised a host of questions about the prospects for 5G’s long deployment cycle (of up to 15 years). Several of those questions, particularly those about 5G’s global economic impacts in a post-pandemic world, are addressed in this report. Both COVID-19 and the availability of 5G (and the products that will likely flow from it) are expected to fundamentally alter behaviors of the 5G user community, from the individual level to whole communities. At the same time, investments in 5G technology in the form of capital expenditures (CAPEX) and research and development (R&D) are expected to change in individual countries with a net result of an increase globally. This report presents the IHS Markit current forecast of the global economic impact of 5G in the post-pandemic world (2020-35), and is an update of a similar report issued in 2017 prior to the onset of COVID-19.

Organization of report

The report has four broad objectives.

It summarizes what is already known about the promise of 5G: namely, the combination of significantly greater speeds and very low latency that can bring forward use cases and products that fundamentally transform the way people live and work.

The report also addresses how COVID-19 has disrupted four important areas of human activity (work, education, healthcare, and retail) and how 5G is already, or will become, a part of the solutions and strategies to cope with those disruptions.

Third, in light of the economic disruption caused by COVID-19, it presents IHS Markit’s best current prediction of 5G’s global economic impacts in the post-COVID-19 world between 2020 and 2035. In addition, it discusses the different ways 5G can have beneficial societal impacts; particularly if individuals, businesses, and governments leverage 5G’s potential to tackle pressing challenges.

Finally, it reviews potential headwinds that 5G may face as it is rolled out.

Historical context for 5G

5G is a fifth-generation mobile communication standard that has followed nearly four decades of evolution through several preceding standards, namely, 2G, 3G, and 4G/LTE. Along the way, mobile telephony has gone from voice communication only to all forms of information flows; first over the early internet and then broadband at different speeds. Because 5G promises so much more than its predecessor standards, questions are often raised as to whether 5G is just an “evolution” from the 4G/LTE standard or a bona fide “revolution” heralding a significant break from the past model of serving primarily the mass consumer market (Lemstra, 2018).

To understand why 5G has brought the world economy to the cusp of major transformational change, and is perfectly positioned to be a part of it, it is instructive to reflect on recent history. In early to mid-1990s, traditional (voice) communication services moved from analog to digital to personal communications services even as the internet was diffusing rapidly thanks to the new-fangled World Wide Web. Soon, “information” was elevated above “communication,” giving rise to information and communication technologies (ICT). The great “convergence” of communication, the internet, and entertainment occurred in the early to mid-2000s with new innovations that allowed people to not only have mobile communication, but mobile information as well.

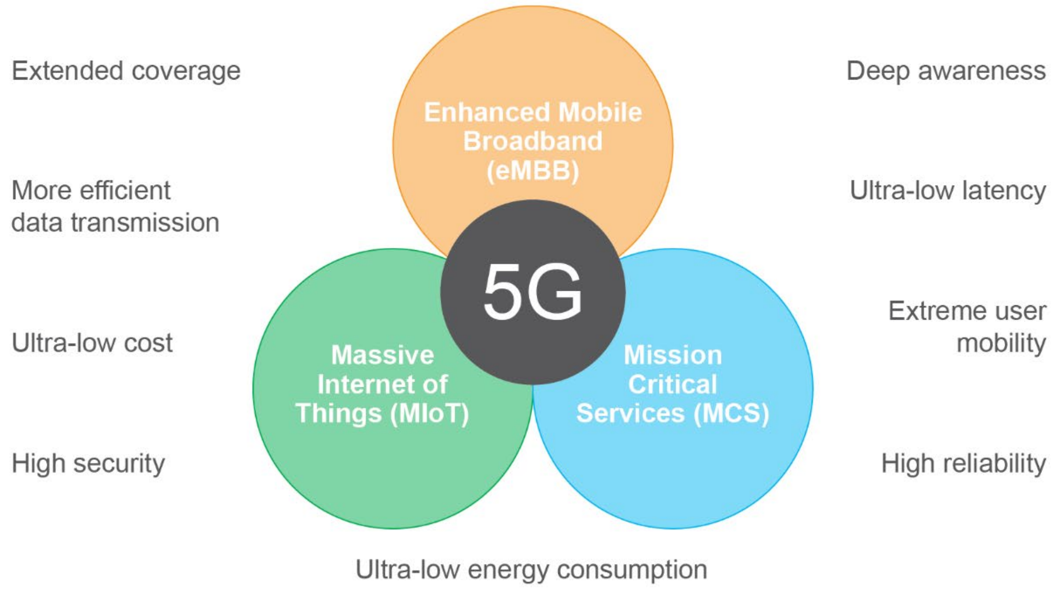
The future of ICT became wireless at that point, followed by a proliferation of portable handsets and devices as 3G and 4G dramatically altered the communication and information landscape. New services ranging from retail and banking to news and entertainment, from email and messaging to navigation, and from music to photography contributed to a dizzying array of ways to use the mobile device. With a decade-long history of increasing consumer acceptance, this set the stage for a substantial breakout in mobile “communications.” 5G is about to deliver on that front; its time has come.

In the industrial space, the information age was also slowly taking over the industrial age. More and more machines were getting equipped with sensors and connected to programmable logical controls (PLCs). These would be the precursors to the IoT. Machines began to have remote troubleshooting capabilities and remote diagnostics over wired communication lines. From there, it was just a matter of time for connections to be wireless. There emerged a growing skills gap for machine operators and engineers that were trained for troubleshooting mechanical operations, not computer-electrical operations that controlled the mechanics. As more and more of these industrial processes become controlled using 5G technology that allows for more cloud, edge computing, and AI and ML techniques to optimize processes, skills training will be a critical piece for the proof of concepts.

The promise of 5G

Following its much-anticipated launch in many countries during the last year, the 5G standard promises unprecedented progress and benefits on several fronts: communication, education, automation, healthcare, connected cars, public safety, productivity, process efficiency, new product development, governance, gaming and entertainment, and many more. Wide-ranging use cases and applications for 5G are envisioned, broadly categorized as enhanced mobile broadband (eMBB), massive internet of things (MIoT), and mission critical services (MCS),[3] with both performance and the range of applications set to expand as the 5G standard itself evolves. IHS Markit expects that 5G will become a mature technology with all three categories of use cases fully deployed by 2035.

The three main 5G use case categories



Source: IHS Markit analysis based on data provided by Omdia

The three main 5G use case categories

eMBB	Two key facets of eMBB will drive adoption and value creation in the 5G economy. The first is extending cellular coverage into a broader range of structures, including office buildings, industrial parks, shopping malls, and large venues. The second is improved capacity to handle a significantly greater number of devices using high volumes of data, especially in localized areas. These improvements to the network will enable more-efficient data transmission, resulting in lower cost per bit for data transmission, which will be an important driver for increased use of broadband applications on mobile networks.
MIoT	5G will build upon earlier investments in traditional machine-to-machine (M2M) and IoT applications to enable significant increases in economies of scale that drive adoption and utilization across all sectors. 5G's improved low-power requirements, ability to operate in licensed and unlicensed spectrum, and ability to provide deeper and more flexible coverage will drive significantly lower costs within MIoT settings. This will, in turn, enable the scale of MIoT and drive a much greater uptake of mobile technologies to address MIoT applications.
MCS	MCS represents a new market opportunity for mobile technology. This significant growth area for 5G will support applications that require high reliability, ultra-low latency connectivity with strong security and availability. This will allow wireless technology to provide an ultra-reliable connection that is indistinguishable from wireline to support applications such as autonomous vehicles and remote operation of complex automation equipment where failure is not an option.

Source: IHS Markit

The Third Generation Partnership Project (3GPP), a standards-setting consortium that develops protocols for mobile communications, completed Release 15, the first full set of 5G standards, in 2018. This release governs primarily eMBB use cases, while future Releases 16 and 17 will do the same for MIoT and MCS use cases (although they will also cover some additional eMBB use cases as well as things such as V2X, private networks, unlicensed spectrum, and industrial IoT).[4] Even though 5G is in its early stages, unlike its precursor 4G, it promises many new industrial use cases. Those use cases will drive value in terms of cost savings and efficiencies, new sources of revenue, more "intelligent" products, and better customer experiences. Many enterprises and industrial companies are taking advantage of 5G's long-game nature and are currently engaged in trials and proofs-of-concept to validate 5G's technical suitability for their use cases and returns on investment

(Blackman, 2019; Business Wire, 2020). 5G, in combination with low-latency edge computing, will play a key role in applications such as smart cities (intelligent transportation, distributed automation switching in electric-power distribution, and public safety), smart factories (motion control and cooperative carrying), and medical (robotic-aided surgery). Making these novel use cases a reality will require extensive planning and stress testing ahead of deployment.

The many use cases and applications within these three categories are well known and have been documented elsewhere.[5]

The enormous breakthroughs promised by a fully developed 5G protocol are not in doubt. First, 5G promises to deliver significantly higher speeds of 20 Gbps downlink or higher in the near future. A Rootmetrics 5G speed test in early 2020 recorded a peak speed of over 478Mbps for the Three network in the United Kingdom, compared to about 20Mbps peak speed for 3G and 90+Mbps for 4G (Rogerson, 2020). Use of the millimeter wave 5G spectrum (mmWave) in the range 6-100GHz (most often 26-39GHz) can, theoretically, be one major contributor to getting maximum speeds up to 10Gbps (McCaskill, 2020). In fact, a 5G speed test in May 2019 on Verizon's network in the Chicago area registered a peak speed of almost 1.4Gbps (Swider, 2019); while only a month later, AT&T mmWave 5G reported achieving a peak speed of 1.8Gbps (Delcourt, 2019). Qualcomm's Snapdragon X60 5G Modem-RF System has been designed for a peak download speed of 7.5Gbps (Qualcomm, 2020). In time, as 5G progresses, speeds of 10-50Gbps could be achieved, which would be several hundred times faster than 4G.

Second, 5G is expected to reduce latency (the network's response time) significantly. A late 2019 Ookla 5G latency test recorded an average low latency rate of about 21ms (on Vodafone) with a theoretical minimum of only 1ms (Rogerson, 2020; Jackson, 2019). The same source compared this to an April 2020 finding by Opensignal of the lowest latency of 58ms on any 3G network tested and 36ms on any 4G network tested. As the deployment of 5G progresses and lower latency rates are achieved, barriers to adoption of cellular-enabled AR/VR experiences—caused by motion sickness and nausea when using those products at current latency rates—will be lowered, Also, MCS services (autonomous vehicles, robotic-enabled remote surgery, etc.) will be powered by ultra-low latency 5G service (Sanders, 2020).

Third, geographic coverage/availability of 5G will greatly surpass that achieved under 3G or 4G. While there are challenges to extending coverage such as site access, eMBB use cases for 5G can extend cellular coverage into areas and structures that were not effectively served by 4G or its predecessors. These include insides of buildings with many walls, densely populated urban areas, and sparsely populated rural or suburban areas. IHS Markit (2019) lists enhanced indoor and outdoor wireless broadband coverage and fixed wireless broadband deployments among the many ways to serve these hitherto poorly served structures and areas. mmWave 5G is particularly well suited for densely populated urban areas with large numbers of devices. While wide-ranging mmWave frequencies provide significant capacity, their signals do not travel far and have narrow wavelengths. These limitations can be mitigated by utilizing micro-infrastructures in those areas consisting of densely packed small cells (McCaskill, 2020). Also, 5G in the lower bands of the spectrum (under 1GHz) are much better suited for rural areas where signals must travel long distances and remain free from interference. Equally importantly, mobile network operators (MNOs) can use the mmWave spectrum—even if temporarily—to provide a wireless alternative to fixed-connection backhaul in rural areas, which may be non-existent or expensive/time-consuming to install. Samsung (2020) and McCaskill (2020) make the case for MNOs to invest in integrated access and backhaul.

Fourth, for seamless wide area coverage, eMBB use cases will deliver medium-to-high mobility (i.e., speed of seamless transfer between radio nodes). 5G devices can potentially connect at speeds as high as 500 Km/hour, compared to around 350 Km/hour on a 4G network (Forge and Vu, 2020).

Finally, 5G promises to revitalize bespoke private networks. That is, enterprises in different verticals (manufacturing, logistics centers, ports, and those providing significant societal benefits such as hospitals and universities) will eventually reduce, if not eliminate, their dependence on public cellular networks and create their own self-contained private networks instead (Lee et al., 2019). This is because public cellular is often insufficient to meet the connectivity needs for indoor cellular or the demanding environments such as ports. In addition to ensuring the required throughput, this will afford them better control over many of their operations—primarily, security, but also sales, monitoring, resource management, and utilization.[6] Private cellular also provides organizations with greater ability to establish performance parameters, scale up as needed, and geofence data. Eventually, as the use cases for MIoT and MCS become available, and standards evolve to allow for, private 5G networks may transcend the current popularity of 4G/LTE and enterprise Wi-Fi or even ethernet-based wired networks (Blackman, 2020). Current private LTE networks can often be upgraded to 5G.

5G in the time of COVID-19

In 2020, it was anticipated that 5G, at least in its earliest (Release 15) version would see MNOs worldwide launch deployment widely within their networks in both rural and urban areas; taking advantage of the move by telecom regulators to free up spectrum in two or three frequency bands. Then the COVID-19 pandemic hit worldwide causing, inter alia, significant supply chain interruptions that stymied the expanded rollout of 5G. As this section explores, while the supply chain issues created some delays, the lasting impacts of the pandemic for 5G technology are likely positive, as the pandemic made clear the importance of connectivity in a socially distanced world.

The history of COVID-19 (a novel coronavirus that is widely believed to have originated in Wuhan, China in December 2019) is relatively brief but replete with twists and turns that have eventually touched all parts of the world. As noted earlier, over the past 10 months or so, COVID-19 has taken a devastating toll worldwide, with a mortality rate of nearly 3% from nearly 53 million infections.[7] In many countries, the virus has spread in multiple waves with no lasting or permanent cure just yet. Almost universally, healthcare systems were unprepared at first to safely administer treatment and care, and are now waiting anxiously for safe and effective vaccines. Billions of people have endured lockdowns, privations, and myriad forced lifestyle changes. Almost every sphere of human activity—work, play, education, health, retail, recreation, etc.—has been affected profoundly. Some of these social and economic disruptions have altered the trajectory of progress in mobile communications as well and, in particular, of the rollout of 5G.

Early in the pandemic, when COVID-19 was least understood, fears about severe disruptions were the greatest. Citing various surveys, a blog post in late March 2020 predicted negative consequences for 5G, brought on particularly by severe economic downturns and dropping consumer confidence and affordability (GSMA Intelligence, 2020). Focusing on supply chains instead, another post in late March 2020 cited investment slowdowns, delays in Release 16 standardization efforts, and “ambiguity” in the 5G supply chain (already brought on by sanctions against Huawei)[8] as reasons for a short-term negative outlook for 5G (Kapko, 2020). Release 17 may also see some delays.[9] This post also saw opportunities for 5G in the longer run as events forced supply chain options, particularly for US MNOs, to become more open and diversified. Some analysts (e.g., Omdia) cited the potentially negative impacts of shutdowns and economic uncertainty on customer willingness to upgrade to 5G (Brown, 2020).[10]

In the months since (and as of October 2020), as countries have learned how public health measures and related policies can better manage, if not completely control, the virus, many of these negative predictions have not been realized. In fact, optimism about an eventual and full recovery for 5G is expressed by several sources, including MNOs themselves. In the United States, all three major networks have reported minimal disruptions in their wireless rollout programs. Also, China has now recovered substantially from its early encounter with COVID-19, and the manufacture of critical network components like base stations has resumed (Wasserman, 2020). While COVID-19 has adversely impacted some industries and limits near-term consumer subscriber growth, according to Omdia, the mobile infrastructure market came out of the first quarter of 2020 in healthy condition. China, where COVID-19 was first felt, reported a slowdown in first part of the quarter but rebounded in March.

Furthermore, emerging use cases for 5G, including need to support increasing numbers of individuals working and schooling from home, are expected to drive 5G investment moving forward. In addition to enabling people to be more efficient in a socially distanced world, 5G technology can be deployed, and in some cases is, to help stop the spread of the virus, including helping in contact tracing, monitoring social distancing behavior, monitoring symptoms, and monitoring COVID-19 patients.[11] Existing wired and wireless technologies are playing a crucial role in areas such as remote patient monitoring, contract tracing, building capacity utilization monitoring, social distancing enforcement, contactless access control, hygiene management, detection of airborne diseases, and many others.

Other recent examples of innovation and increased use of connectivity technologies during the COVID-19 pandemic include:

- The monitoring of the distribution of COVID-19 test kits through the “cold chain” using cellular-enabled data loggers (Controlant).
- The development of an ethernet/Wi-Fi-connected wall-mounted unit that detects airborne diseases in small-to-medium-sized indoor settings (Kontrol Energy Corp.)
- A 150% increase in cellular device usage on Hologram’s IoT platform between September 2019 and September 2020. Hologram cited two key trends behind this growth: the shift from public transportation to e-bikes and scooters (e.g. Cowboy) and proximity tracing in the workplace (e.g. Eyrus, Kepler Analytics, and Visibyl).

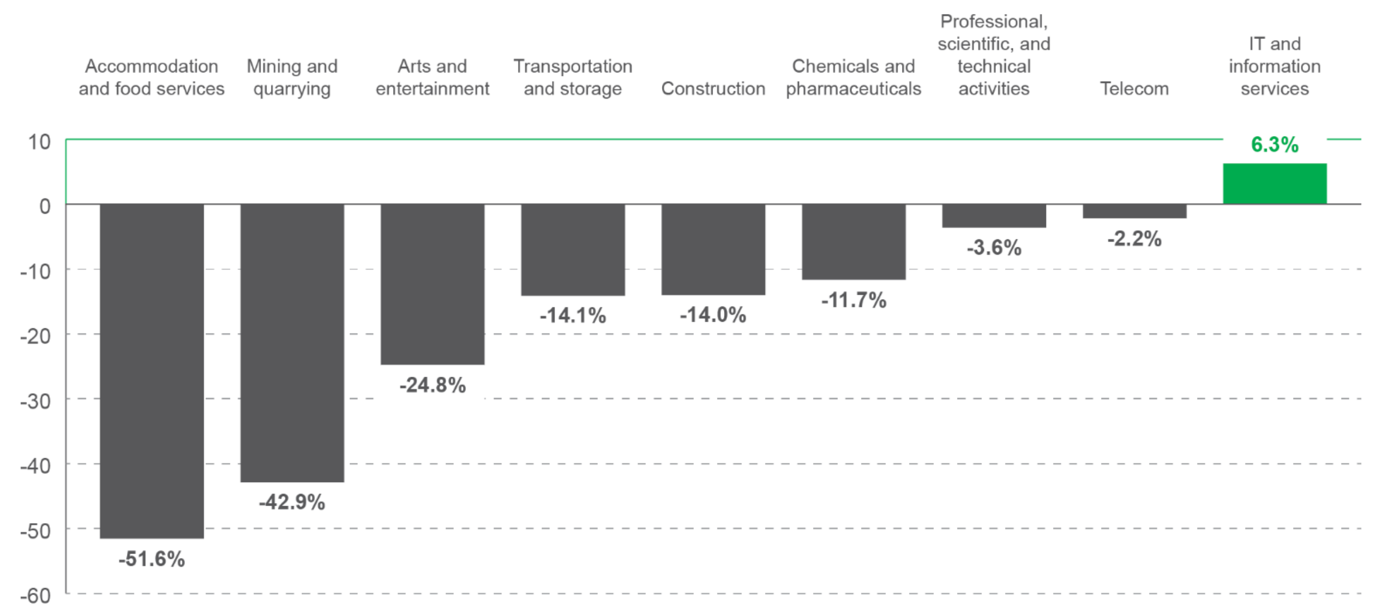
COVID-19 has put the existing operational processes and business models of enterprises across all countries and verticals under unprecedented strain. It has forced organizations to make rapid tactical changes to how they operate and serve their customers. COVID-19 has also, if anything, added urgency to existing digital transformation efforts and forced organizations that lack such strategic efforts to initiate them.

A recent Omdia study notes that “the shift to digital applications has accelerated, and companies will expect projects to be delivered in weeks (vs. years previously).”[12] Another survey (from Informa Tech and Omdia) 5G World 2020 Global Insights Survey (August 2020) found that 17% of enterprises thought that COVID-19 would trigger new 5G investment cases and revenue opportunities. Another 14% believed that COVID-19 would accelerate 5G investment and launch plans.

The operational imperatives, as well as the growing awareness of the contribution of connectivity for enterprise resilience, are shifting the economic value of the use cases in a post-pandemic world. This is one reason why investment in 5G technology did not fall off the cliff during the economic downturn that followed the onset of COVID-19, even as many other investment activities saw sharp declines.

In fact, IHS Markit’s new forecast shows a 10.8% net increase in global 5G investment and R&D during 2020-35 compared to the 2019 forecast (see the section below on Economic Impacts of 5G). In 2020, investment by sectors in the 5G ecosystem is expected to increase or only slightly decrease. Meanwhile, several other major industries are expected to experience severe investment declines. The pressing need for expanded connectivity in the COVID-19 era is sustaining 5G investment growth.

Percent change in global investment in 2020 by industry



Source: IHS Markit analysis based on data provided by Omdia

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Rising 5G investments will drive a first wave of economic benefits in terms of new jobs and added value. A second wave of benefits will arise as the investments begin to pay off in terms of greater productivity. But 5G will not only enable higher productivity for those that utilize it, it will also enhance the productivity of wireless connectivity itself. 5G will help to optimize spectrum use as well as increase the bytes per second pushed through the spectrum. Both will mean a lower cost per byte that can unleash the innovation needed to create new and affordable applications.

It is widely understood that COVID-19 has influenced—even changed—the way human beings live. The immediate needs that have been surfaced by the pandemic, as well as shifting trends in e-commerce and work location choice, may have changed the course of industry investment and adoption. Recent remarks by European digital chief Margrethe Vestager underscore the urgency of that change.

> “The coronavirus outbreak showed how important internet services and 5G are … We have seen the current crisis highlight the importance of access to very high-speed internet for businesses, public services and citizens, but also to accelerate the pace towards 5G. We must therefore work together towards fast network rollout without any further delays.”[13]

Vestager could have been speaking of how the cadence of human activity that was typical of pre-COVID-19 times no longer applies for many, and that 5G must be able to step in to address that change. Some manifestations of these changes that are helping to accelerate the imperative of 5G are as follows.

Work from home

Work from home (WFH) has replaced the office or workplace for untold millions of professional workers. As a result, offices and workplaces are empty or sparsely occupied and only usable under several restrictions, e.g., limited admission, social distancing, mask wearing, regular sanitization of frequently used surfaces or equipment, etc. Many peripheral sectors supporting the workplace—transportation systems, cafeterias and restaurants, cleaning services, office supplies, to name a few—have experienced falling demands as well.

Workers have found alternative ways to continue office operations from elsewhere, most often their homes, and to maintain or even enhance their productivity. A Gartner survey of over 300 US companies in the early stages of the COVID-19 pandemic found that 74% of companies expected at least 5% of the office workforce to work permanently from home in the post-COVID-19 era. Apart from employee health and safety, cost savings were a major driver for allowing and accepting WFH arrangements (Kovar, 2020). A similar survey by Global Workplace Analytics (2020) revealed that 88% of workers globally are in WFH arrangements during the COVID-19 pandemic, up from 31% before the pandemic's onset. Also, once the COVID-19 pandemic is over, 82% of US office workers (about 75 million employees) and 76% of office workers globally would prefer WFH over a return to the office.

Those who work from home still collaborate with colleagues or liaise with clients or suppliers as needed, except they do so by substituting the virtual for the physical workplace. Knowledge workers and management professionals are least likely to be furloughed or laid off under COVID-19 conditions and are most likely to work from home in the post-COVID-19 era. Thus, it is not just employee health and safety, but also the nature of the occupations themselves that will shape WFH trends, both during and after the COVID-19 period (Press, 2020).

WFH involves the use of modern ICT, including fixed and mobile broadband services that enable real-time communication through email, voice telephony, and videoconferencing. 5G can help in several ways. By reducing latency and increasing speed, it can make videoconferencing more secure and reliable and enable better interactivity among participants. As AR/VR devices and experiences develop and run on 5G they can become a viable substitute for business travel. The WFH setting is already prepared for the additional technological benefits of 5G: in the Global Workplace Analytics (2020) survey, over 80% of respondents stated that they had the technology knowledge and skills needed for WFH, as well as easy and reliable access to company networks (presumably by both fixed-line and mobile means). This augurs well for the adoption of 5G's eMBB services for WFH purposes.

In the United States, the major MNOs are also the major providers of fixed-line communication services, and they have tried hard in difficult circumstances to maintain the volume and quality of connectivity desired by their customers. Broadband connections for home use now double up for work purposes as well. This calls for an extraordinary surge in bandwidth availability, particularly during the busy daylight and early evening hours. Broadband service providers like Verizon and AT&T appear to have met this challenge reasonably well. Having done so, they have not shied away from the deployment of 5G to upgrade their respective MNO networks. Reardon (2020) quotes AT&T's former CEO on an earnings call shortly before he left that post in June 2020 as saying that AT&T's 5G deployment continues even while having "to navigate workforce and permitting delays." Also, in mid-June 2020, Verizon (2020) made a similar claim. The workplace of the future for untold numbers of professional white-collar workers may well be the home, and services like fiber-based fixed line broadband or high-bandwidth mobile services from 4G/LTE to 5G's eMBB will be supporting that need.

For the other 20% of respondents, 5G can help bridge the gap in a couple of critical ways that 4G and fiber cannot currently provide. Due to the popularity of video, audio streaming, adoption of smart home devices, the ability of home fixed broadband networks to provide sufficient quality of service for professional applications is questionable. At times when children are home schooling and adults home working, there's even more competition for bandwidth. There are also concerns with home router security, which increases the risk to enterprises when employees are utilizing their home routers. 5G can play several roles to address these and related challenges with WFH trends: 1) deployments in areas where fixed broadband is absent or is poor quality; 2) integration into hybrid routers; and 3) deployment as secondary connection via dedicated enterprise-grade 5G router. There is already some anecdotal evidence of demand for MiFi and 4G increasing in past few months. Vendors such as, Inseego, Digi International, and Cradlepoint have targeted this opportunity.

Distance learning

COVID-19 has also forced a major rethink on how schools and colleges should operate. Unlike traditional face-to-face instruction in designated classrooms or lecture halls, alternative models of instruction are being trialed and used, including those variously described as “virtual education” or “distance learning.” In all these models, some measure of broadband use (whether fixed-line or mobile) is called for. Instructional content is delivered online to students at home, either in real time or on-demand.

From a technological perspective, there are several ways for 5G to boost distance learning. These include (1) cloud-based storage of information that allows students and teachers to connect and interact from anywhere; (2) smart classrooms that rely on 5G’s MIoT functions to track attendance and monitor student attention and engagement levels; (3) faster, lower latency and more accessible online video-based learning; and (4) flexible and more personalized learning by students with varying learning capacities (Singh, 2020; Etherington, 2016; Harman, 2019).

Issues of social equity are, however, front and center in such models. The availability of broadband for the requisite performance for online instruction varies widely among households, mainly by socio-economic status. The devices needed to receive instruction, such as computers or mobile phones, are not available to all students, or their working quality may vary. Some students may have to depend on Wi-Fi hotspots at locations away from their homes. Thus, uneven access to high-bandwidth broadband is a serious impediment to ensuring equity in the manner in which online learning occurs. This is also true for the manner in which online instruction occurs. Teachers themselves may not have access to the required broadband or equipment necessary to effectively teach students remotely. This problem can be particularly acute in areas that are not reliably served or remain unserved by broadband service providers, such as in rural areas or inner cities.

5G has the potential to level the playing field in those areas. While that may be true in theory, the actual rate of 5G penetration will remain crucial to distance learning outcomes. World Economic Forum analysts note that, by mid-April 2020, COVID-19 had forced 191 countries to close schools and universities, affecting 1.57 billion students. Some tech-heavy distance learning measures put in place (including AR/VR, 3D printing, and AI-based robotics) can help to facilitate online learning, but these technologies are not currently available to the vast majority of affected students (Xiao and Fan, 2020). Until such time as 5G’s more impactful applications have been diffused widely, its eMBB applications will be on the front lines for enabling video-based distance learning, especially in areas where high-speed broadband is not available reliably from fixed-line sources.

Tele-health/medicine

COVID-19 is much larger than just a health crisis. People’s health, whether or not they survive the deadly virus, is at the center of that crisis. Even then, health issues arise in all forms and at all times, regardless of any role that COVID-19 may play in them. As a result, healthcare is one of the largest industries even without COVID-19. In the United States, for example, healthcare spending is expected to be 18.9% of GDP in 2020 (IHS Markit Connect, 2020). In addition, such spending as a percentage of GDP in several developed countries is expected to range from around 10% to just under 14%.

Technology, particularly for wireless communication, is already embedded in the operations of the healthcare industry. COVID-19 has provided both the opportunity and urgency to go farther. Lockdowns and social distancing requirements in the COVID-19 era have meant that even routine doctor’s office visits or other medical consultations (whether or not because of COVID-19) are now fewer or even impossible. To the extent feasible, telephone or video consultations have replaced in-person visits, and these are increasingly relying on broadband connections. COVID-19’s boost to tele-health/medicine is manifest in two noteworthy sets of statistics.

First, following President Trump's declaration of a COVID-19-related national health emergency in the United States in March 2020, Forrester Research forecast that virtual healthcare interactions would top one billion by the end of 2020 (representing a huge expansion of the use of tele-health services) and Frost and Sullivan estimated that tele-health visits with doctors surged by 50% in March 2020 alone (Coombs, 2020).

Second, data from FAIR Health's Monthly Telehealth Regional Tracker show that, between March 2019 and March 2020, the number of telehealth claim lines rose an impressive 4,347% (from 0.7% of all medical claim lines to 7.52%).[14] In contrast, the growth in telehealth claim lines over the year February 2019 to February 2020 (the pre-pandemic period in the US) was markedly lower, and that growth rate in the early days of the pandemic was nearly four times higher in the US Northeast (which suffered the initial surge of COVID-19) than nationwide (Gelburd, 2020).

A survey of 117 executives conducted at the beginning of 2020 by the Center for Connected Medicine (CCM) found that "about a quarter of healthcare executives (26%) said the shift to telehealth and virtual care was a top innovation priority at their organizations." After the pandemic hit, a follow up survey in the summer by CCM found "that has now jumped to 49% of executives who say virtual care is a top innovation priority."[15]

For the most part, current 4G/LTE or fixed-line/Wi-Fi connections suffice for tele-health visits but, for bandwidth-heavy data transmissions or in broadband-underserved areas, a 5G solution is the emerging answer. Those tele-health consultations may become popular for another reason: saving time to travel to doctor's offices and wait in them for scheduled appointments. Other applications of high-bandwidth and low-latency wireless connections, such as for remote surgery using medical robotics and multimedia image communication (Wells, 2020) or more advanced remote monitoring of patient health (Xinhua, 2020), are also likely to be more reliably implemented by 5G than pre-5G technology. For example, China has pioneered the use of 5G-aided robotics for remotely monitoring and serving the needs of suspected COVID-19 patients (such as in Wuhan in the Hubei province of China), thus protecting health and hospital workers. It is feasible that 5G technology will enable much wider use of robotics in healthcare that can help alleviate much of the strain on our current healthcare workers. In addition to robotics, the technology could be used to provide visits to homes virtually. Cellular plays an important role in remotely monitoring things like CPAP, blood glucose, ECG. Mobile Personal Emergency Response Device (mPERS) are already important for monitoring the elderly who live alone. The need for remote monitoring has only increased with the onset of COVID-19. 5G will provide much more effective monitoring as it is set to provide, inter alia, deeper coverage, higher availability, and lower latency than LTE.

Online retail and e-Commerce

Perhaps the most familiar of all human activities is shopping, whether to buy necessities like food or clothing, durables like appliances or automobiles, or luxuries like yachts or diamond jewelry. What many of these have in common, regardless of price, is that customers usually make their purchases at retail establishments. The retail sector depends on advertisements, attractive stores, signage, and showrooms (as needed) to attract and serve customers. Almost invariably, transactions in this setting occur face-to-face between buyers and sellers, with larger stores and shopping malls attracting large numbers of buyers at any given time. COVID-19 and subsequent public health lockdowns have fundamentally disrupted this retail marketplace.

In its place, the shopping experience has shifted dramatically to online retail and e-commerce. While COVID-19 proved to be a catalyst for this, the move to online shopping had started even before the pandemic. In March 2020, when a pandemic was declared in the United States, online sales accelerated rapidly while in-store sales declined. Kantar predicts that e-commerce will account for two-thirds of retail sales growth during the 2020-25 period.

Even though brick-and-mortar stores have not disappeared, online shopping and e-commerce outlets (like Amazon, Wayfair, Etsy, etc.) have captured much of the selling opportunities diverted from traditional retail establishments in the aftermath of COVID-19. Other retailers (like Walmart, Macy's, Home Depot, etc.) have adopted a more flexible multi-channel strategy. Using various sales, advertising, and stocking strategies, multi-channel firms now offer robust electronic options as well to customers reluctant to shop in stores. Transactions conducted that way are almost always facilitated by credit/debit cards, direct bank withdrawals, and delivery to designated premises. In other words, online retail has become a sophisticated multi-faceted operation that requires collaboration with, or self-provision of, various ancillary financial and logistics services.

The contribution of 5G in this new world of shopping is primarily to enhance the customer experience, especially in the aftermath of COVID-19. Much of the new online retail experience can be delivered by existing mobile broadband services. However, 5G can make that experience better and more versatile (Di Pietrantonio, 2019).

1. Faster speeds and lower latency can enable long-form video advertisements to deliver more features and product information.

2. AR/VR can become the perfect conduit for an immersive in-store experience by giving the customer a full view of all products on display.

3. When combined with AI, chatbots can provide an interactive experience that is better than having a personal shopper.

4. 5G-enabled wearables may provide fast access to information about a multitude of products and create greater customer engagement.

5. While still only in its nascent stage, safe and contactless delivery to the customer's premises can be made using drones.[16]

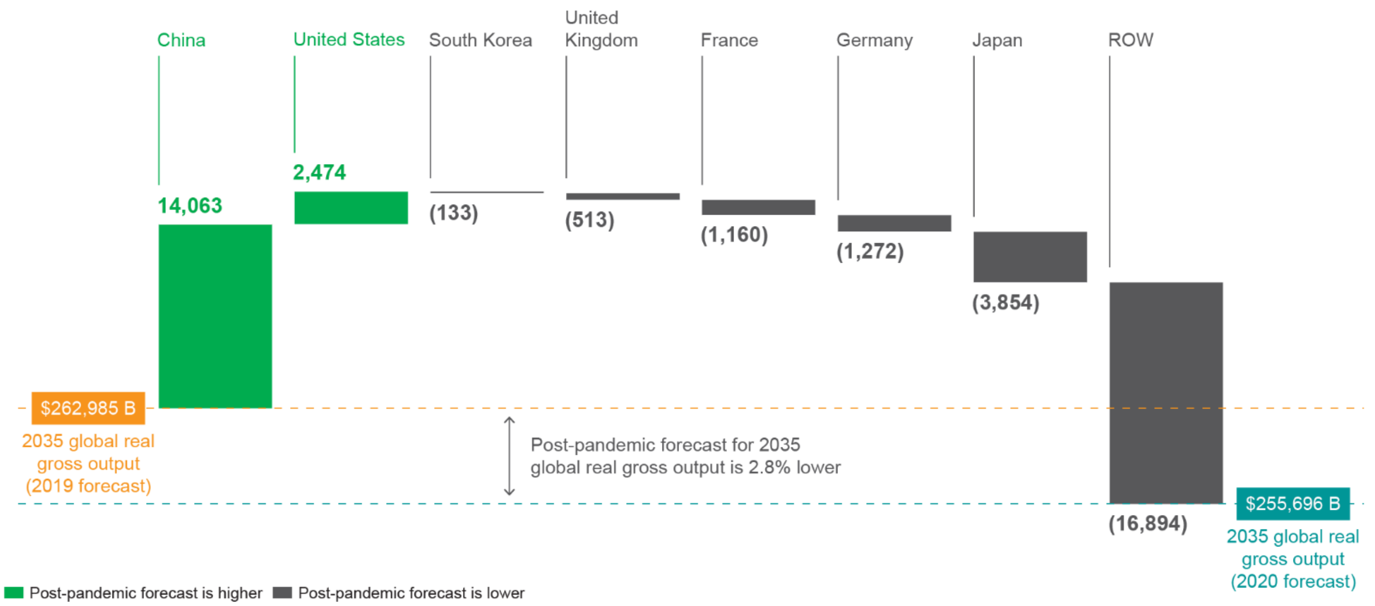
Additionally, a big part of the ability to deliver on ecommerce is tied to the logistics and supply chain's ability to respond quickly to consumer needs. As mentioned, 5G technology can help automate factory floors in ways that greatly achieve efficiency improvements. From real time monitoring of machines to real time tracking of inventory. On the shipping front, the ability to have fully autonomous vehicles can be achieved with the power of 5G. The technology will not only allow for more driving time and hence faster shipping, it will also provide a safer driving experience both for the shipping companies and other cars. That is because 5G technology will allow for cars to communicate with one another and therefore better avoid collisions (this is not just through current sensor technologies where cars can sense other objects, 5G enables the communication between cars such that they can more intelligently and collectively optimize their routing). This not only lowers the risk to lives and property and thus liability for logistics companies, it also reduces product loss, thereby increasing supply and the delivery speed of that supply.

Economic impacts of 5G in a post-COVID-19 world

Economic contribution of 5G

IHS Markit anticipates economic growth rates in the post-COVID-19 world will be lower and, by 2035, global gross output (sales) levels will be about 2.8% lower than the pre-pandemic forecasts from 2019. World real GDP levels will be down by 3.1%.

Shift in forecast 2035 real gross output by country/region ($B)



Source: IHS Markit analysis based on data provided by Omdia

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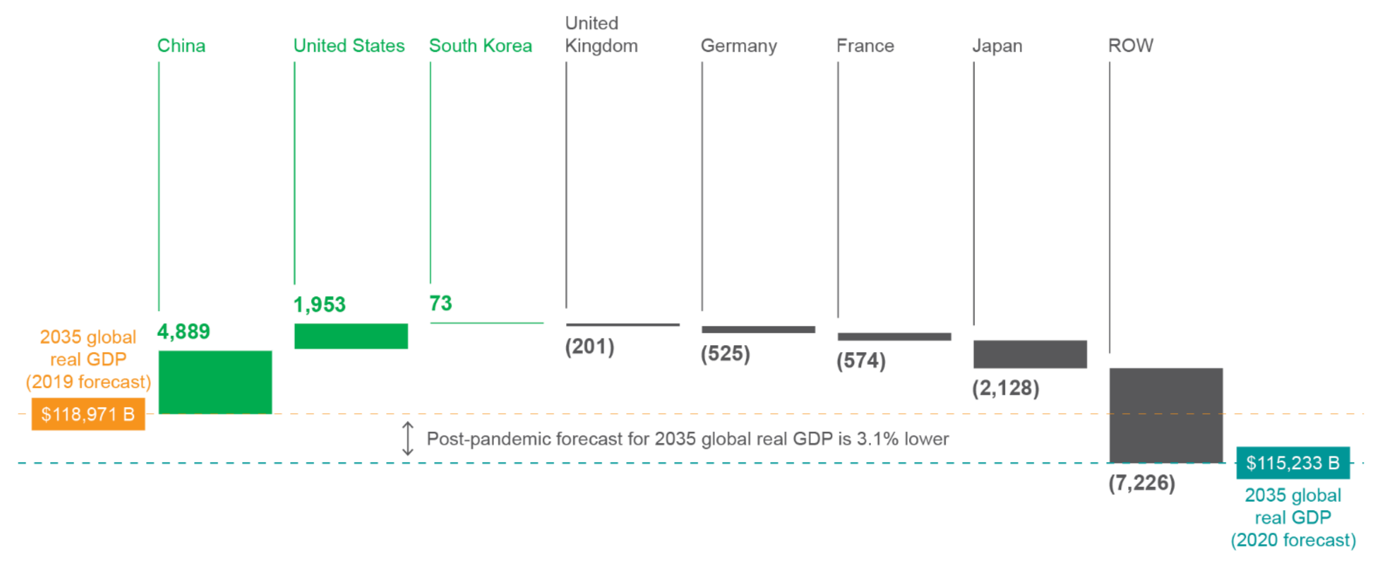
Shift in forecast 2035 GDP (value added) by country/region ($B)



Source: IHS Markit analysis based on data provided by Omdia

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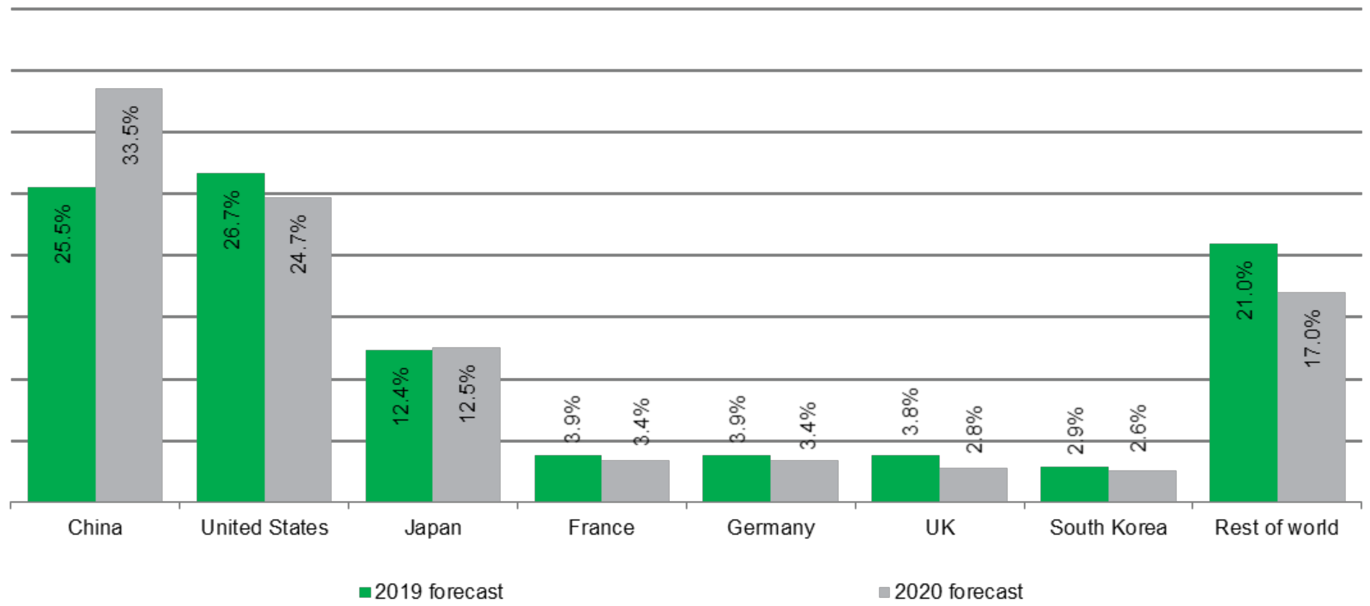
Whether measured by output or GDP, a comparison of the forecasts for the seven leading countries and a Rest of the World composite reveals some notable share shifts among the countries. China will gain nearly 5.0 percentage points of global GDP, while the United States will gain close to 2.5 percentage points. The other countries assessed, with the exception of South Korea, are now expected to capture shares of global GDP that are smaller than forecast in 2019. China's increase in investment is driven by factors including rapid deployment of 5G; the ability of the government to mandate the usage of 5G by specific verticals; and the "Made in China" program, whereby China is planning to design its own differentiated products. Also noteworthy, though, is the Rest of the

World, which is now forecast to capture almost 5.0 percentage points less of global GDP in 2035. This underscores the importance of initiatives such as the UN Social Development Goals (SDGs). The potential role that 5G can play in support of the SDGs are explored later in this document. That is, there is a potential upside for many countries that accelerate their 5G deployment and digital transformation initiatives. This is not a zero sum gain. As China's advances show, those that accelerate their deployment can reap greater benefits and help grow the proverbial pie.

Establishing the 5G value chain

A key to sustainable GDP growth is continual investment in infrastructure plus R&D. Indeed, IHS Markit estimates that country-level investment in 5G CAPEX plus R&D will demonstrate a pattern similar to GDP. China and the United States are expected to dominate 5G CAPEX and R&D, investing a total of $1.7 trillion and $1.3 trillion, respectively, over the 16-year time horizon of this study. It is also worth noting that China's share of 5G investment is now expected to surpass that of the United States.

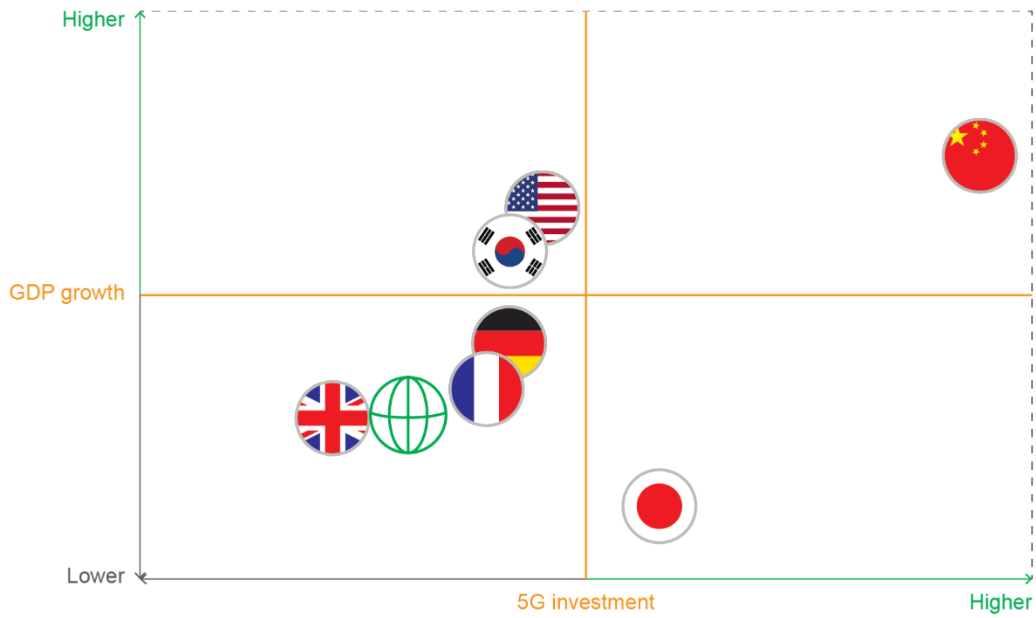
Average annual share of value chain R&D and capex by country, 2020–35



Source: IHS Markit © 2020 IHS Markit

Overall, the IHS Markit revised 2020 forecast of the global average of 5G-related investments from 2020 through 2035 is 10.8% higher than the forecast from 2019. While, on the surface, this represents a significant ramp-up in investment, a closer examination of the seven countries and the Rest of the World reveals a more complex dynamic. The graphic below plots the relative changes in GDP growth and 5G investment, which may provide some insights regarding economic and policy dynamics on 5G investment.

Relative shifts in pre- vs. post-pandemic forecasts of average 5G investment and GDP growth, 2020–35



Source: IHS Markit analysis based on data provided by Omdia

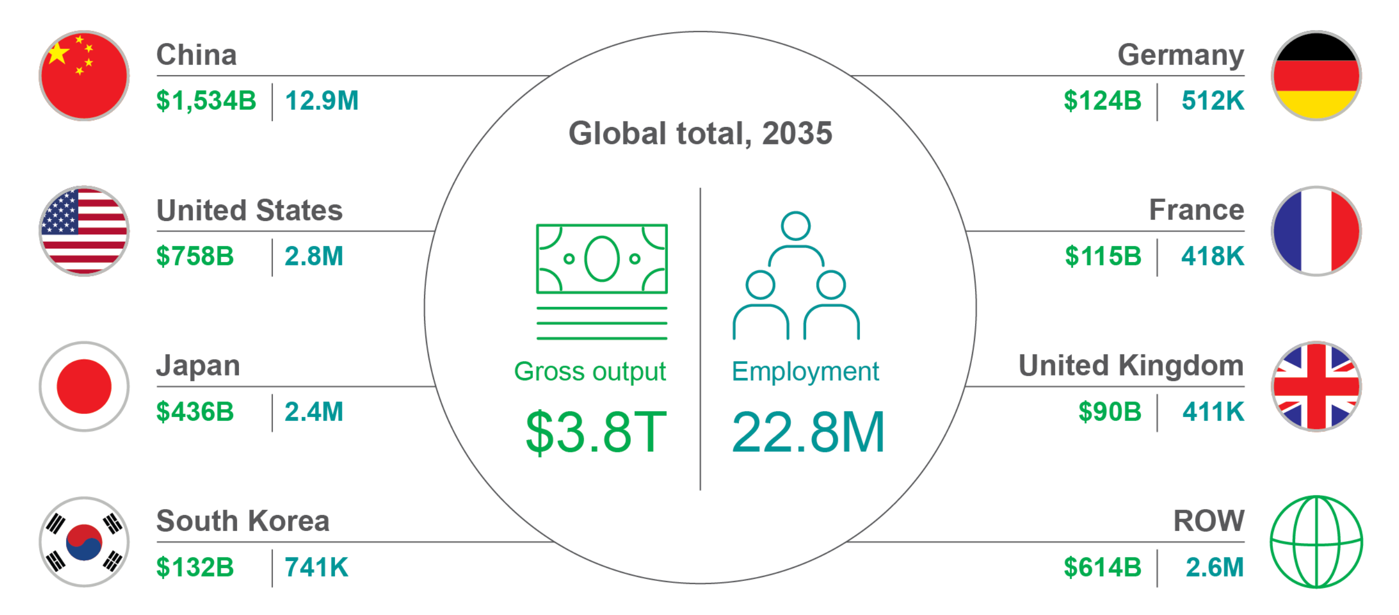
Countries that engage in continual and aggressive investment, especially in R&D, will increase the likelihood of establishing robust 5G value chains capable of serving both domestic and global markets. They will be well positioned to continually improve and strengthen the foundational technology base across a broad spectrum of technology firms, including but not limited to:

1. Network operators
2. Providers of core technologies and components
3. OEM device manufacturers
4. Infrastructure equipment manufacturers
5. Content and application developers

From 2020 to 2035, IHS Markit anticipates that the collective investment in R&D and CAPEX by firms that are part of the 5G value chain within the seven countries will average over $260 billion annually. In the early years, foundational R&D and network infrastructure deployments will dominate 5G investment activities. Subsequently, IHS Markit expects the overall investment in foundational R&D and CAPEX to taper slowly. A second wave of investment will shift the focus towards development of applications and services that exploit the unique capabilities of 5G. The sustained investment cycle is another indicator that 5G is a “long game” that will see investment priorities shift as infrastructure is deployed, the underlying technology base is continually strengthened and new business models come online.

IHS Markit estimates that, by 2035, the 5G value chain alone will drive $3.8 trillion of economic output and support 22.8 million jobs. Not surprisingly given the relative size of the population and the investments made, 5G will support the highest number of jobs in China. Slower economic growth in the post COVID-19 economy will dampen investments by developing and emerging economies in 5G infrastructure, thereby limiting their ability to establish thriving local 5G value chains. Indeed, the Rest of the World share of the 5G value chain in the 2020 study is expected to be $143 billion lower than forecast by the 2019 study (from $757 billion to $614 billion). In contrast, the 2020 study forecasts that China's investment will be 38% higher than that forecast in 2019. The 2020 study also forecasts that China's share of the 5G value chain in 2035 will be about $400 billion higher at $1.5 trillion than the $1.1 trillion that was forecast in 2019.

The economic contribution of the 5G value chain, 2035



Source: IHS Markit analysis based on data provided by Omdia

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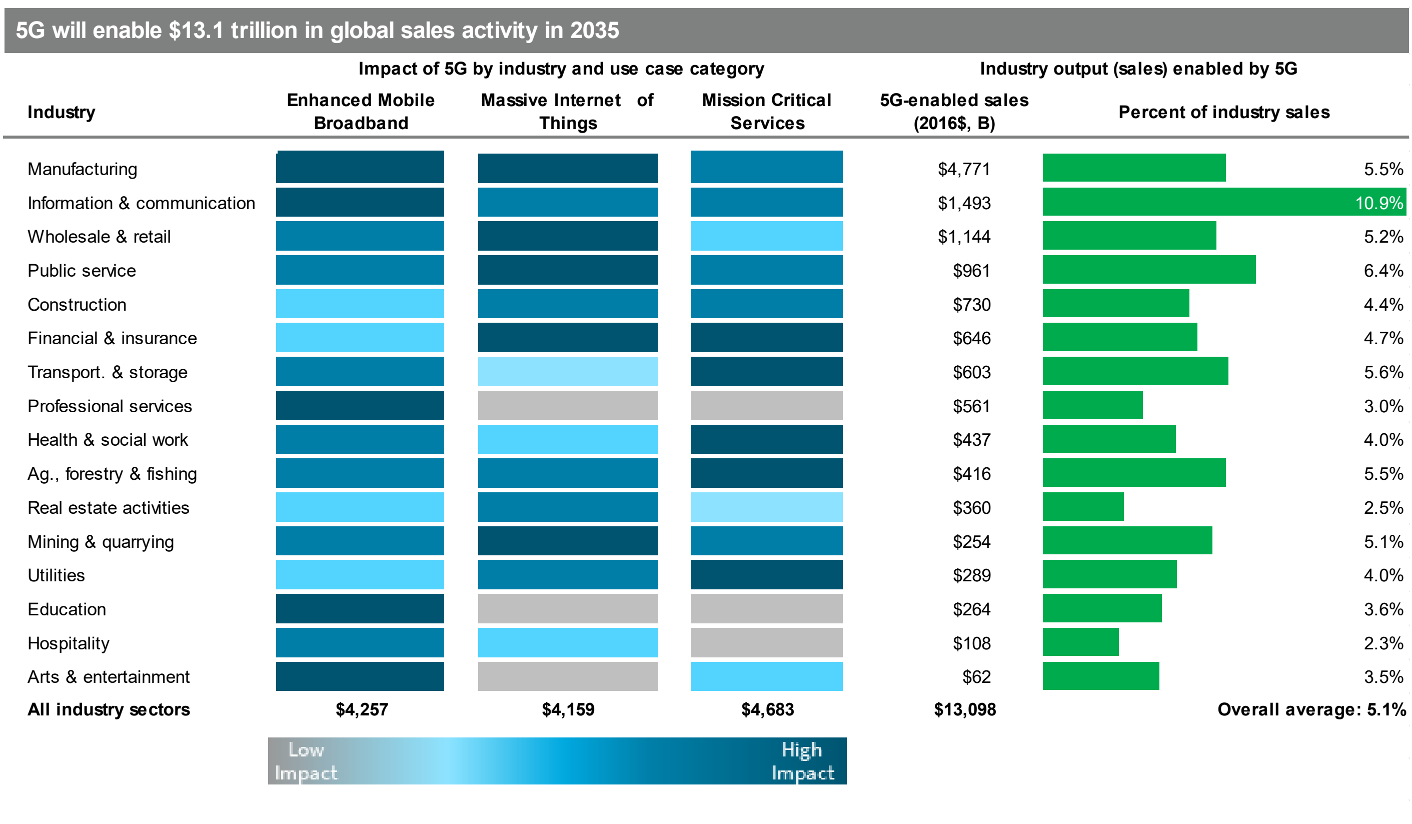
5G sales enablement

Ultimately, CAPEX investments and R&D will enable the 5G use cases to come online. By 2035, the entire range of 5G use cases will be fully ramped up and organizations will have evolved their business models to take full advantage of 5G. Looking ahead to 2035, IHS Markit projected how much 5G could boost industry sales, over and beyond what would be possible with the current trajectory of 4G. IHS Markit examined how 5G would enhance sales activity in 16 major industry sectors, based on the International Standard Industrial Classification of All Economic Activities, Revision 4 system (ISIC). Developed by the United Nations, ISIC provides standardized reporting of economic indicators regardless of country. The Comparative Industry Service, a proprietary product of IHS Markit, which is consistent with ISIC, was leveraged to integrate additional economic information, as needed, to enhance the analysis.

IHS Markit concluded that 5G deployments will positively affect virtually every industry sector. The economic and regulatory structures of the various industries will affect the timing and adoption of the new business models that 5G will enable, which is why IHS Markit focused on a longer time horizon and chose 2035 as the analysis year. Under reasonable assumptions about the 5G standards process, regulatory environment, and industry adoption patterns, IHS Markit forecasts that potential global sales activity across multiple industry sectors enabled by 5G could reach $13.1 trillion in 2035. This represents about 5.1% of all global real output in 2035.

A word of caution is warranted concerning the sales enablement metric. Specifically, the sales enablement metric is not a direct measure of contribution to global GDP and should not be interpreted as such. Rather, sales enablement is a measure of global sales activity that 5G will enable across the 16 ISIC industry sectors. This includes both intermediate purchases required to make and deliver goods and services plus sales to end-users (i.e., final demand). Intermediate purchases occur, for example, when a car manufacturer buys components (tires, batteries, etc.) needed to build a vehicle from a network of suppliers. The car is assembled, sold to a dealership (another intermediate purchase) and eventually sold to a consumer (final demand). The sales enablement metric captures the sales transactions that occur at every point of the journey from initial assembly to the customer driving off with the car. GDP, on the other hand, only measures the value of final demand for goods and services within an economy. In this example, only the final purchase by the customer would be included in a GDP calculation. Thus, relative to GDP, the sales enablement metric will be significantly larger. However, sales enablement provides insights regarding the amount of business activity that ripples across an entire economy.

The following infographic presents the consolidated sales enablement findings by industry, ranked from highest impact (manufacturing) to lowest impact (arts & entertainment). Manufacturing will garner almost $4.8 trillion or 36% of the $13.1 trillion in sales enablement. At first, this may appear high until one considers that implementing any of the 5G use cases will stimulate, at a minimum, complementary spending on equipment, all of which will be produced by the manufacturing sector. For example, drones will enable sales within the transportation sector, which will require the transportation sector to buy the drones from the manufacturing sector. Medical use cases will require complementary spending on 5G-ready equipment from the manufacturing sector. The same line of reasoning applies to the information and communications sector, which will see the second largest share of 5G-enabled economic activity at almost $1.5 trillion. Implementing any of the 5G use cases will require spending on communication and content services.



Source: IHS Markit

While 5G could enable about 5.1% of global real output in 2035, the 5G-enabled sales percentage by industry will vary from a high of 10.9% in the information and communications sector to a low of 2.3% in the hospitality sector. The sheer size of the manufacturing sector, which will account for over 33% of global real output in 2035, along with the fact that much of the 5G-enabled manufacturing sales will be secondary (i.e., equipment sales in support of use cases) will lead to a percentage (5.9%) that is slightly higher than the overall average. Perhaps more notable is the fact that 5G could enable 6.4% of public service (government) and 5.9% of agricultural output in 2035, driven by smart cities and smart agriculture deployments, respectively.

To put these findings in a broader context, it is essential to consider the secondary linkages across multiple industries for a given use case. For example, the availability of autonomous vehicles and drones will do more than stimulate sales of driverless cars and unmanned aerial vehicles to consumers. They will also be deployed in agricultural and mining applications ranging from surveillance of remote natural resources to autonomous transport of ores to self-driving tractors. They will be widely used in the transportation sector for driverless transport and delivery of commercial and consumer goods. Municipalities will integrate autonomous vehicles into their transit systems while using drones for monitoring functions. In manufacturing, autonomous vehicles will also be used in intra-plant stocking and retrieval systems. Finally, autonomous vehicles will also positively affect the insurance industry as vehicle accident rates decrease.

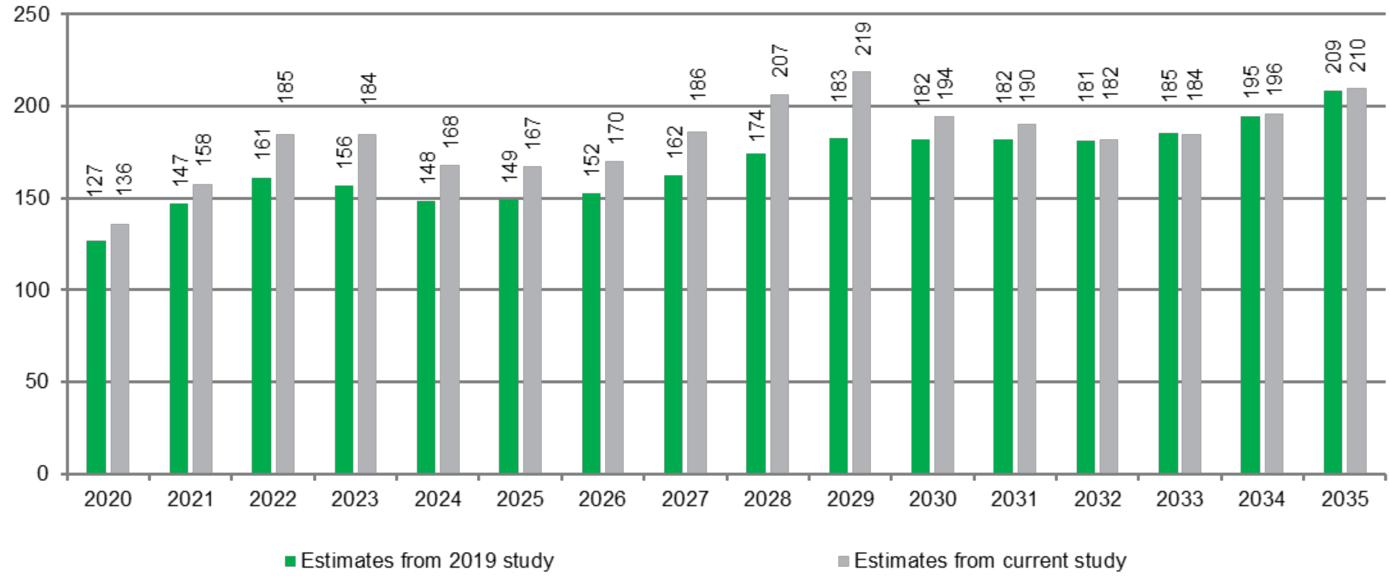
Sustainable global economic growth

Another measure of the economic contribution 5G will make to the global economy is an assessment of its net effect on global GDP. The sales enablement and value chain activity, while extremely large and positive, may have offsetting effects. For example, investments and spending that otherwise might have occurred in other sectors of the global economy, which could have stimulated growth and positive productivity effects, may be foregone in favor of 5G-related investments. If a net positive contribution is made to global GDP, then 5G can legitimately be considered a source of global expansion and growth.

IHS Markit used its proprietary Global Link Model (GLM), a system that captures the inter-connected nature of the global economy. IHS Markit exercised the GLM with two primary sets of inputs. The first was the annual investments (CAPEX and R&D) made by the 5G value chain within each of the seven countries that were the primary focus of the study for the 2020–35 period. This captures the effects of strengthening the country-level economy by making investments that deepen each country's respective capital stock. The second set was the use case productivity improvements (determined as part of the sales enablement analysis). This captures the economic knock-on effects attributable to companies increasing their efficiency and launching new business models enabled by 5G technology.

For the 2020–35 period, IHS Markit forecasts global real GDP will grow at an average annual rate of 2.7%, of which 5G will contribute almost 0.2%. From 2020 to 2035, the annual GDP contributions of 5G will total almost $2.9 trillion. While this figure is in real (inflation-adjusted) dollars, a simple sum does not factor in potential global risk. Therefore, IHS Markit takes the net present value of the GDP contributions, discounted at a modest 3% rate, to derive a risk-adjusted value of $2.3 trillion. To put that into perspective, from 2020 to 2035, the total contribution of 5G to real global GDP growth will be equivalent to the current GDP of France—the seventh largest economy in the world. Based on this assessment, IHS Markit concludes 5G will be a source of positive global economic expansion and growth.

Annual net contribution of 5G to global growth (billions of 2016 US$)



Source: IHS Markit © 2020 IHS Markit

Sustainability and societal impacts of 5G

In addition to the substantial economic benefits, the ability to create sustainable solutions using the 5G platform can impact important social goals. Using the lens of the 17 UN Sustainable Development Goals (SDG),[17] the social impacts of 5G can be revealed. For instance, if businesses and entrepreneurs effectively leverage 5G technology for public safety (e.g., rapid deployment of emergency personnel when a serious accident is detected), or remote health monitoring and medical diagnostic capabilities that reduce testing needs and times and speed up treatment, or helping underserved communities leapfrog existing technologies to gain affordable access to reliable high-speed internet service, or greater use of robotics for dangerous or repetitive jobs, then they can impact UN SDG goals for Sustainable Communities, such as Quality Education, No Poverty, Decent Work and Economic Growth, and Good Health and Well-Being.

More specifically, many research articles have discussed the environmental benefits of 5G: lowering greenhouse gas emissions, better managing electricity use, and better monitoring and mitigation of air and water pollution. The potential environmental benefits of 5G are substantial (Deloitte, 2019; Cho, 2020). For example, international standards require 5G to use much less energy than 4G, e.g., use less power to transmit the same (or greater) amount of data.[18]

A recent Centers for Disease Control and Prevention study estimated that each chronic disease "was associated with annual absenteeism costs greater than $2 billion" in the US alone.[19] Real-time monitoring of health conditions, such as for blood pressure and blood glucose levels, accompanied by medication management, can improve the quality of life of those living with chronic diseases by quickly controlling the onset of their symptoms instead of forcing them to wait to see their doctors. This is 5G's favorable impact on SDG's Goal 3, ***good health and wellbeing***.

SDG's Goal 4, ***quality education***, has been at the forefront of many conversations during the ongoing COVID-19 pandemic. How can students and teachers adapt quickly to remote learning and still achieve the desired learning outcomes? Do students need to be in a classroom to learn? Perhaps some do and others do not. Having 5G fixed wireless broadband access in currently underserved communities could substantially mitigate education gaps during a pandemic. It may also enable new innovations in education delivery that schools do not provide currently.

5G can also help to achieve SDG's Goal 6, ***clean water and sanitation***, principally through connected water supplies that enable real-time, remote monitoring of water conditions. It can also monitor the sanitation equipment to quickly identify and locate degraded equipment and make repairs.

5G's beneficial impacts on productivity are key to SDG's Goal 8, ***decent work and economic growth***. That productivity gain leads to economic growth is well understood. A recent research study concluded that a 10% increase in mobile broadband adoption is associated with a 0.6-2.8% increase in a nation's GDP (Edquist et al., 2017). The other side of the coin from productivity-led economic growth is rising wages, which is a cornerstone for achieving "decent work." The debate over whether technology destroys decent work has been ongoing for a long time, but long-term results point to overall increases in jobs. [20]Just as 4G technology helped to usher in a new category of occupations called "app developers," 5G is bound to create a number of yet-to-be-defined occupations. This is not to minimize the disruption that technology will bring to some jobs, especially those that tend to be more repetitive or tedious in nature. A cohesive policy framework that includes upskilling of the workforce is critical to help minimize such disruptions.

5G offers several opportunities for entrepreneurs and businesses to innovate, thus contributing to SDG Goal 9, ***industry, innovation, and infrastructure***. Which industry or vertical will do so most will depend on the extent to which 5G use cases can be exploited, private or shared networks can be built, and new and innovative products can be created. Undoubtedly, indirect effects of these developments will touch other goals including poverty and hunger alleviation and responsible production and consumption.

In the 5G context, SDG's Goal 10, ***reduced inequalities***, is related to the goal of quality education (Goal 4). 5G's ability to close gaps in education can help to reduce inequalities of opportunity and, in turn, mitigate income inequalities. This follows from the literature that exists on how education impacts income.[21] 5G's signature offering of superior connectivity creates the potential to overcome all forms of inequality (of opportunity, more generally) than of income alone.

Finally, SDG's Goal 11, ***sustainable cities and communities***, can be advanced by leveraging 5G to optimize resource use, including energy, water, and people's time. Knowing where traffic is congested or needs to be managed in real time, where the nearest parking space or building access point is located, or where an accident has occurred and medical emergency personnel needs to be directed to the scene, are all examples of how 5G can save time or lives and build more resilient communities in the process. In fact, many governments are looking at the potential of 5G, particularly in the transportation and logistics industries, to lower greenhouse gas emissions through less idled traffic, better route management, optimization for more-efficient deliveries, as well as the ability to have vehicles (including autonomous vehicles) communicate with their surroundings—improving safety for both drivers, cyclists, and pedestrians—and better optimize public transportation to minimize unnecessary stops. The low-latency and high data capacity of 5G will make all these innovations possible, which will help advance the objectives of SDG 11, therein supporting more sustainable communities.[22]

Does 5G face any headwinds?

For all its promise, 5G does face potential headwinds beyond the recent pandemic both from the supply side and the demand side of the market.

On the supply side, the news is mostly good. The earlier-than-expected arrival of the 5G standard's Release 15 in 2018 fueled optimism about a quick launch of 5G service. That early release meant, however, that only eMBB applications could be pursued for now, while most ramp-up of MIoT and MCS applications was pushed off to

Releases 16 and 17. By mid-September 2020, 397 MNOs in 129 countries/territories had invested in 5G, 124 MNOs had deployed 3GPP-compliant technology in their networks, and 101 of them in 44 countries (about 15% of MNOs in existence[23]) had launched one or more 3GPP-compliant 5G services (GSA, 2020a).

Despite this promising start, can the almost ubiquitous presence of 4G networks hold up—at least to some degree— plans of speedy and widespread 5G deployment? Where various versions of 4G, namely, LTE, LTE-Advanced, and LTE-Advanced Pro are deeply entrenched in mobile communications, a phased, rather than a quick, transition to 5G is the more likely scenario. The considerable sunk investments in those 4G standards can be hard to abandon. The infrastructure upgrades that need to be made for 5G—such as rapidly densifying cellular networks by adding large numbers of small cells—and the spectrum (in various bands) that has to be acquired can be prohibitively costly and time-consuming for already leveraged MNOs (O'Donnell, 2018).

On the demand side, as noted in an earlier section, COVID-19 has also caused shifts in human behavior that are actually stoking the demand for high-speed broadband such as can be provided by 5G's eMBB applications. Other demand-side headwinds may be systemic (hence, more predictable), such as those originating from end-users (whether households or businesses).

One of the big challenges for adoption of 5G across verticals industry is skills and business model flexibility. Many companies lack expertise in cellular, data analytics, etc. Historically, manufacturers have typically had capital expenditure (capex)-centric budgets for the acquisition of operational technology (OT) like capital equipment. with private wired connectivity. They are far less used to operating expenditures (opex) - paying recurring fees, the typical way cellular is charged. Even if industrial companies deploy their own private LTE/5G networks, they are unlikely to avoid the need for opex fees to third-party specialists such as system integrators. This means that both suppliers and industrial companies need to develop flexible budgeting and business models. One way is monetization of outcomes (e.g., telecoms operators and industrial companies are considering 5G network slicing to provide guaranteed levels of service in terms of availability, bandwidth and latency). This would be monetized by hitting performance service-level-agreements (SLAs), rather than through charging for data volumes.

Other challenges on the demand side for implementing private networks include the fact that enterprises building their own dedicated private networks for the first time may face several technological or financial hurdles, including the high costs of acquiring their own spectrum, building out the small-cells architecture needed for a private network, or accelerating obsolescence of their existing network equipment.

Similar on the consumer demand side, there may be resistance to replace existing purchases, end-user confusion about available choices, lack of product awareness, etc. that all shape the demand side of modern-day markets. Also, consumer concerns about coverage and reliability of cellular networks can act as inhibitors of demand.

These are still early days for drawing firm conclusions about the effects of these factors on 5G demand. According to Omdia, global 5G subscriptions reached just over 15 million at the end of 2019, representing just about .2% of the worldwide mobile subscriber base. However, that proportion is expected to increase significantly in upcoming years, reaching over 29% by 2025. These projections suggest that any transition to 5G services is more likely to be gradual than abrupt, and that demand for 4G/LTE services is likely to endure in the foreseeable future.

Some researchers (e.g., Rendon Schneir et al., 2019), have examined the role of the demand side in a prototype market that would likely be targeted for early 5G services: dense urban area, spectrum use in the low to mid-bands, only eMBB services offered, and broadband consumption only occurring outdoors (indoor traffic assumed to be offloaded to Wi-Fi). The study concluded that any revenue consequences in this scenario depends critically on the rate of traffic growth—a demand-side factor. Given the importance of the demand side of the 5G market, two specific sources of headwinds—one directly on the demand side and the other indirectly affecting it—are discussed below.

Affordability

For the demand side of 5G to keep up with the much-vaunted supply side, end-users (particularly, commercial customers) will need to invest in devices and IT infrastructure that can leverage the 5G technology. For this to happen, there must be both a willingness and, more importantly, ability to pay for the devices as well as the 5G service platform. With a new technology or product, the capabilities and value of which are not fully understood in advance, the end-user's willingness to pay for it evolves as a learning process.

Another major affordability concern is that, similar to every new mobile standard generation, phone handsets optimized for use with various versions of 4G/LTE and backward-compatible with 3G or prior standards will not be forward-compatible with 5G service, particularly 5G that operates in mmWave frequencies (but 5G will be backward compatible with previous cellular generations). Consumers that have recently purchased 4G/LTE phones may be reluctant to upgrade to 5G phones if they are priced high. 4G/LTE phones can conceivably be used with current non-standalone 5G service under DSS. When standalone 5G service appears in a few years, dedicated 5G phone handsets will be needed to take full advantage of 5G. For now, low-end 4G/LTE phones will be unable to work with 5G at all.[24]

Finally, a major driver of consumer acceptance is a less well-known factor called "network externalities."[25] These externalities can be thought of as demand-side economies of scale and have a pronounced reinforcing or feedback loop effect in some networks (e.g., the original public switched telephone network which, in the US, at one point swelled to include over 95% of households). Network externalities also create "installed bases" (such as with operating systems) that encourage individuals to build "communities of interest" that share the same (or similar) networks and the services available through them.

Digital divide

How quickly and pervasively will the 5G network and the services it engenders become accessible to end-users in different geographies/locations, both within a country and globally? Without actual access to 5G service, there can be no demand side. The transition to fully deployed 5G will take several years, particularly if MNOs transition through their current 4G/LTE networks in a phased manner. IHS Markit expects that to happen gradually through the middle and out years of the 2020-35 period.[26]

It is not merely 5G reaching its full potential that will determine accessibility for all end-users. How end-users are distributed spatially will also matter. The specter of the "digital divide"—when end-users in different geographic locations have varying degrees of access to service (including none at all) regardless of their personal circumstances—is a constant concern for policymakers around the world.

Policy initiatives to mitigate the digital divide are in place, or are being designed and implemented, in the United States, European Union, India, Australia, and many other countries. 5G is expected to play a significant role in these initiatives.

The experience with a similar initiative for the digital divide in the European Union (EU) has been more mixed. While it has been understood for several years that the introduction of 5G (alongside fixed broadband networks) in EU member countries is critical to the future of a digitalized Europe, the EU has been forced to acknowledge that progress has been slow and uneven. Recently, Ursula von der Leyen, President of the European Commission, admitted that it is "unacceptable [that] 40% of people in rural areas still do not have access to fast broadband connections" (Stolton, 2020). This statement has been accompanied by the announcement of a common EU “toolbox” plan that exhorts member states to allocate, without further delay, spectrum in the three “pioneer” bands (700MHz, 3.4-3.8GHz, and some part of 24.25-27.5GHz) to kick-start the “5G for Europe” action plan adopted by the EU in 2016 (European Commission, 2020). Although this toolbox is aimed primarily at alleviating the pressures on existing networks from how EU citizens have adapted to COVID-19, it is also designed to push up the penetration of 5G in the EU.

In the United States, beginning with the Connect America Fund and the Rural Digital Opportunity Fund, the FCC has now begun rulemaking for the proposed 5G Fund for Rural America that aims to provide up to $9 billion to bring 5G mobile broadband to parts of the country that would otherwise remain underserved or unserved (FCC, 2020). The FCC has authorized auctions of 280MHz of C-band spectrum (3.7-3.98GHz) that have been transferred from satellite service providers to 5G use. This range of frequencies, as well as those in the low-band range (around 700MHz) can be used for 5G service in most areas including rural communities (Mann, 2020).[27]

These initiatives are just the beginning. As the 5G network continues to be rolled out and proof of concept trials being completed, it is expected that there will be more innovations both in the private and public sectors to help bridge the digital divide.

Conclusion: 5G in a post-COVID-19 world

The world has been preparing for quite some time for the arrival of 5G and its promise to change human lives for the better. Despite its adverse economic impacts, COVID-19 has, somewhat unexpectedly, given this development more urgency. Because of this, the economic impacts of 5G in a post-COVID-19 world are higher. While 13.1 trillion dollars of global sales enablement is slightly lower than the previous estimate (pre-COVID-19), which is only because the economy in 2035 is now expected to be smaller due to this setback in 2020, the percentage of sales enabled in 2035 is now higher than in our previous estimate (enabling 5.1% compared to 5% of industry gross output).

In order to fully realize these economic benefits, the various players in the 5G ecosystem will need to work together to advance this technology and fully deploy the potential use cases. Fortunately, a phased transition from 4G to 5G is possible, particularly given the long deployment cycle envisioned for 5G. Two important developments in network configuration can facilitate such a transition.

1. **Network sharing**. In the early stages of 5G deployment, MNOs daunted by the considerable costs of building out a densified network can consider participating in a “multi-tenant network” instead (Rendon Schneir et al., 2017). This has happened in China already. In 2019, China Telecom and China Unicom announced plans to realize cost savings of $28-38 billion by jointly building a 5G network, while China Mobile expressed an interest in joining that arrangement (Sbeglia, 2019). The sharing of network resources, radio access networks, and backhaul can generate important cost savings and improve business viability under different revenue (demand) growth scenarios, particularly in dense urban areas (Rendon Schneir et al., 2019). It should be noted that network sharing is not a new concept and aided the expansion of legacy 3G and 4G networks. To reap the benefits of network sharing, operators will need to navigate some regulatory restrictions and work together and with governments to bring connectivity to hard-to-reach areas such as along major transport routes.

2. **Dynamic spectrum sharing (DSS)**. DSS is a relatively new capability that enables an operator to use the same spectrum (e.g., 700MHz or 2.1GHz) for different radio access technologies, such as 4G LTE and 5G. Informa Tech and Omdia’s 5G World 2020 Global Insights Survey (2020) indicated around a half of operators planned to deploy DSS. Operators cite efficient usage of spectrum and an acceleration of 5G availability as key benefits of DSS; however, some operators argue that DSS could potentially cause network congestion and may not deliver the same performance as 5G deployed on dedicated spectrum.

5G is facing some headwinds as well; some familiar and others unexpected. COVID-19 is a potentially history-altering phenomenon and will probably remain so until a cure (in the form of vaccines) and widespread immunity have become prevalent. Geopolitical events, such as US sanctions against Huawei (according to Omdia, Huawei was the second largest smartphone vendor by unit shipment in 2019.), trade conflicts that disrupt supply chains, or regulatory disparities across countries, are also potential disruptors for 5G. All of these can alter the growth trajectory that was originally envisioned for 5G.

With any new or disruptive technology, once the early euphoria associated with it has passed, questions always arise about whether, or how long, the technology will resonate with those who use it. Will the end-user class (consumers, businesses, governments, etc.) arise almost spontaneously—almost in the spirit of "if you build it, they will come"—or will it emerge more gradually? This is an important question for 5G because its promises may only be fully realized over the course of a lengthy and phased rollout cycle. Furthermore, different end-user segments may only become actively engaged as the 5G use cases that interest them most become available at different phases of that life cycle.

For such a phased rollout to succeed, reassuring signals must be received from the various end-user segments of their acceptance of 5G throughout the rollout period. There are a number of proof of concept trials underway from industrial use case to manufacturing use cases to smart city use cases. Some promising models using PPP (public-private partnerships) can help overcome some of the financing and policy constraints such as those underway in the United States (e.g., with Department of Transportations in Virginia, Georgia and Florida) and the 5GCAR project in Europe in order to pilot C-2VX (cellular-vehicle to everything) technology.[28]

What sets 5G apart from previous mobile standards is that it is not merely a product (or service) but also a platform; one upon which many use cases and new products will be built. As discussed in this report, this enriched structure is the basis for expecting that, in time, 5G will not only improve connectivity, which will enable much more efficient use of our time, talents and resources, it will also address several pressing needs including better management of natural resources, increased energy efficiency, increased delivery of education and healthcare, better monitoring of supply chains, and allowance for people and businesses to be more resilient during times of disruption.

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End notes

[1] These include Agriculture, Forestry, and Fishing, Arts and Entertainment, Construction, Education, Financial and Insurance, Health and Social Work, Hospitality, Information and Communication, Manufacturing, Mining and Quarrying, Professional Services, Public Service, Real Estate Activities, Transport and Storage, Utilities, and Wholesale and Retail Trade.

[2] IHS Markit (2019) describes the procedure.

[3] MIoT and MCS are alternately referred to as Massive Machine-type Communications (mMTC) and ultra-reliable low-latency communications (URLLC), respectively.

[4] Release 16 was announced on July 3, 2020. Release 17's announcement date remains uncertain, at least in part because of the ongoing COVID-19 pandemic. See Koziol (2020). It typically takes a year for a new release of a standard to be manifest in new products and services. See O'Donnell (2019).

[5] See, e.g., IHS Markit (2019), Forge and Vu (2020, Table 4), or World Economic Forum (2020).

[6] There will always be the overhanging question about whether data generated within private networks will remain contained within them for maximum security and control. If some of the data need to go to the cloud or to edge servers on an MNO's network, then the desired level of control may not be available. See Badman (2020).

[7] COVID-19 is, so far, the deadliest viral disease of modern times when both the infection count and the mortality rate are considered. Major outbreaks of viral disease in the past 100 years or so include the 1918 Spanish Flu, which eventually infected and killed many more people than COVID-19 has to date, but the mortality rate was lower at 2%; the relatively short-lived SARS outbreak in 2002 that had a mortality rate of 15% but relatively few infections (just over 8,000 worldwide); and the 2009 H1N1 Flu that had a high infection count but only a 0.02% mortality rate. See Ries, J. (2020).

[8] There are major geopolitical and national security issues at play here. None is more impactful than the move by the US to severely restrict the ability of Huawei (a leading maker of telecom equipment and smartphones with alleged links to the Chinese government) to sell its products in the US and several European and APAC countries. The international response to US sanctions against Huawei has been varied. It has created a particularly confusing picture in Europe: the Czech Republic and Poland have fully complied with the US sanctions, but UK and France have been ambivalent, and Germany has gone so far as to require Huawei to stockpile components and provide privileged access to them. This has affected both existing 4G contracts and the rollout of 5G. See Cerulus (2020).

[9] https://www.3gpp.org/release-17

[10] Samsung, Huawei, LG, and Xiaomi have already rolled out their 5G smartphones and Apple is expected to do so in October 2020.

[11] "Connecting the Dots", Omdia, Ask Omdia series, (June 2020)

[12] Omdia's Digital Enterprise Services Insights: Shifting Europe IT Priorities and Spending Post-COVID-19 (September 2020).

[13] See Chee (2020).

[14] A claim line refers to a service or procedure listed on an insurance claim.

[15] Heather Landi, "How COVID-19 shifted healthcare executives' technology priorities and what to expect in 2021." Fierce Healthcare (Oct 21, 2020) at https://www.fiercehealthcare.com/tech/these-are-technology-innovations-health-systems-fast-tracked-during-covid-19-pandemic

[16] In the US, Amazon Prime Air, UPS, and Wing (from Alphabet) have received regulatory approval for drone-delivery operations from the Federal Aviation Administration. See Palmer (2020).

[17] See United Nations (2020).

[18] One way to measure this is to note that one kilowatt-hour (kWh) of electricity is needed to download 300 high-definition movies in 4G while, with 5G, one kWh can download 5,000 ultra-high-definition movies. See Cho (2020).

[19] See Centers for Disease Control and Prevention (2016).

[20] Acemoglu and Restrepo (2019) conduct a detailed empirical investigation of this issue and conclude: "Our evidence and conceptual approach support neither the claims that the end of human work is imminent nor the presumption that technological

change will always and everywhere be favorable to labor." The McKinsey Global Institute expresses optimism about automation and robots favoring job growth on balance. See Ellingrud (2018).

[21] Wolla and Sullivan (2017) make the case that education (or investment in human capital) leads to higher income. Jamison et al. (2006) demonstrate that education quality and years of schooling increase per capita income even more in open economies than in closed economies.

[22] See "Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe." A study conducted for the European Commission by: Tech4i2 Real Wireless CONNECT, Trinity College Dublin InterDigital (Sept 2016) at https://ec.europa.eu/digital-single-market/en/news/5g-deployment-could-bring-millions-jobs-and-billions-euros-benefits-study-finds

[23] See Research and Markets (2020).

[24] DSS and dual connectivity for both 4G and 5G may alleviate some of the concerns about the sub-optimal performance of 4G/LTE phones with 5G service. See Tibken (2019).

[25] As the term itself suggests, network externalities arise when consumption occurs within a network, like 5G. Those externalities are positive when the value of the network to each existing user goes up as new users join the network. If significant new value or positive network externalities are created by expanding the 5G network, the question of affordability can become more nuanced as "value" supersedes "price" as the determinant of the use of the service and the purchase of devices that run on that service.

[26] IHS Markit (2019) shows the annual net contribution to global growth slowly ramping up between 2020 and 2027, plateauing between 2028 and 2033 and then rising impressively in the out-years 2034 and 2035, almost certainly the result of all the MCS services becoming available once truly low latency is achieved.

[27] Also see Reardon (2019).

[28] See https://www.autoconnectedcar.com/2020/09/audi-usa-american-tower-qualcomm-vdot-deploy-c-v2x-to-protect-work-zones/, https://aashtojournal.org/2020/10/30/audi-launches-c-v2x-school-zone-test-in-georgia/, https://www.ericsson.com/en/news/2019/9/5g-and-v2x

Research team

Aniruddha Banerjee
IHS Markit
Director, Economics & Country Risk Consulting

Karen A. Campbell
IHS Markit
Associate Director, Economics & Country Risk Consulting

Bob Flanagan
IHS Markit
Director, Economics & Country Risk Consulting

Brendan O'Neil
IHS Markit
Executive Director, Economics & Country Risk Consulting

Bill Morelli
Omdia
Senior Research Director

Julian Watson
Omdia
Principal Analyst, Internet of Things

Josh Builta
Omdia
Research Director, Internet of Things

Daryl Schoolar
Omdia
Practice Leader, Fixed & Mobile Networks

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