5G Mobile: Impact on the Health Care Sector

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1 Executive Summary

1. The effect of 5G on the health care sector, its suppliers, and on sectors that use health care, will be substantial. IHS Markit calculates that the sales enabling effect of 5G will be over $1.1 trillion. 5G will have a large impact on the quality of health care received by hundreds of millions of patients and will fuel significant changes in the way in which health care is delivered. 5G will be an enabler of many new business models, but also a disrupter of old ones and will be a substantial enabler of a new era of "personalized health care."

2. The phrase that most pithily captures the impact of 5G within the health care sector is the "personalization of health care." The much greater ability to continuously gather patient-specific data and the ability to process, analyze and quickly return processed information and recommended courses of action to the patient will give patients greater ability to manage conditions on their own. The personalization of health care also means that physicians and other health care providers will—when they are required to administer care—be able to make 'first time right' diagnoses and tailor remedies more closely to a particular patient's personal needs. The economic consequences of the personalization of health care are substantial. Better monitoring means a greater ability to reward providers on the basis of outcomes not "volumes." Better monitoring also shifts the locus of care to the home and similar lower-cost settings, and away from the hospital. Both these effects of better monitoring will help contain costs.

3. Examples of the impact of 5G on health care include:

    - *Continuous monitoring: 5*G will support the continuous monitoring and processing of numerous sensory devices. This facilitates continuous monitoring of patients. Superior monitoring capability means that 5G can substantially increase the effectiveness of preventive care. By doing so, it can lower the burden of chronic disease that health care systems in the developed world.

    - *Predictive analytics*: 5G's enablement of continuous monitoring can be harnessed to its other attributes to even greater effect. While continuous monitoring will power the development of new data streams, the use of distributed computing—the processing of patient data nearer to the patient—will power predictive analytics and intelligent care based on those new data streams.

    - *Impact on business models:* 5G's enablement of superior health informatics has the potential to substantially facilitate a transition from volume-based fee-for-service models of medical delivery to outcome-based models.

    - *Remote Diagnosis and imaging:* 5G will also have benefits in areas such as remote diagnosis and imaging. For instance, 5G will support application of virtual reality, which can have important benefits in the delivery of medical care, e.g., in the diagnosis and treatment of critical medical episodes such as strokes.

    - *Improved state-of-the-art:* 5G will be an important element in the proliferation of data, and this proliferation combined with predictive analytics and machine learning will allow physicians and researchers to access aggregated information and accumulated knowledge on the latest evidence, diagnosis and treatment trends. This will not only

advance the state of medicine and health outcomes, but our understanding of the human condition itself.

4. Public policy decisions can help unlock the potential of 5G within the health care sector. Disruptive changes, such as the shift to outcome-based models of compensation, might encounter resistance from entrenched interests. Public policy measures such as changes in taxation and accounting policies can help change incentives of medical providers and thus facilitate the shift towards new provision and compensation models. Equally importantly, public policy towards innovation and intellectual property must ensure that those who are developing the essential 5G technology are appropriately compensated. This is critical to ensuring that the bedrock connectivity technology is developed at an optimal pace and to an optimal degree.

2 Introduction

5. A recent study by IHS Markit on the economic impact of 5G finds that between 2020 and 2035, 5G technology will have an impact on global GDP that is roughly equivalent to adding an economy the size of India to the present global economy. IHS finds that the "value chain" associated with 5G technology will amount to $3.5 trillion (in today's dollars) of output and 22 million jobs. They further find that another $12.3 trillion of output will be "5G-enabled"—i.e., this is the increase in output that 5G enables across a swathe of economic sectors.

6. This piece, and a companion piece on the automotive sector, sheds light on how 5G impacts and transmits through the economy. We use the example of health care as a sector that will be subject to significant transformation fuelled by the adoption of 5G. Our analysis is intended to be illustrative rather than comprehensive. What we want to illustrate is the "General Purpose Technology" or "GPT" nature of 5G. 5G will put mobile technology at the centre of a global economy characterized by the "Internet of Things." Mobile in the 5G era will transition from being an increasingly significant enabling technology into a true "General Purpose Technology"—that is, a technology that finds economy-wide use, drives complementary innovations in other sectors and becomes a driver of economy-wide innovation and productivity. 5G will make mobile technology a key medium through which devices are connected, information is transmitted, transactions are facilitated and new connected activities are enabled. The economic literature clearly indicates very sizeable impacts of GPTs on the aggregate economy in general. The impact of railroads in England and Wales in 1859 was estimated at 4% of national income but reached 10% of national income in 1890.[1] The ultimate economic impact of 5G and enabled technologies may be in this range.

7. *Why is 5G a catalyst for change in health care?* 5G technology has three technological characteristics that will enable it to have a significant impact on the health care field. These are (a) low latency, (b) high reliability, and (c) the ability to support a plurality of devices and sensors, and to translate information from these devices and sensors into critical and meaningful data points. The effects of these characteristics will be felt equally in both the delivery of mission-critical services and in the personalization of health care.

8. *5G and Mission-Critical Interventions:* Beyond enabling shifts in the point of care and in the quality and delivery of remote services, 5G has an important role to play in the delivery of mission-critical interventions. An example relating to the treatment of a stroke patient provided by Tas (2017) illustrates this. In this instance, ultra-reliable and low latency networks have a critical role to play—from the point where the patient's monitoring device sends a distress signal to the ambulance, to the ambulance situation itself where high-resolution images and data on vital signs can be streamed to the hospital ahead of arrival. [2] 5G

[1] The impact of Information and Communications Technology (ICTs) in the 1990s was actually even larger than the impact of previous GPTs and arguably occurred with less of a lag. One does not need to postulate that 5G will be as important as railroads in the 19th century or indeed ICTs in the 1990s to appreciate that it will have a very sizable economic impact—even a fraction of the impact of these past GPTs would still be enough to make 5G a significant enabler of growth in the coming two decades.

[2] Jeroen Tas, Philips Healthcare, comments at CES 2017.

can also make a critical difference in terms of its ability to expand the opportunities for remote diagnosis and remote treatment of strokes. 5G can support truly immersive virtual reality and augmented reality applications. Virtual and augmented reality can create an interactive experience in which stroke patients can be monitored by a physician or caretaker remotely. The ability to simulate a "live" experience and to ask the patient questions in real time not only provides for immediate treatment and diagnosis, but more effective treatment and diagnosis.

9. *5G, IOMT and the Personalization of Health care:* In the health care field, 5G is the underpinning of the Internet of Medical Things (IOMT). IOMT involves an ecosystem of connected devices that will particularly facilitate communications and feedback between patients on the one hand and medical devices and monitoring equipment on the other hand. Enhanced remote monitoring and enhanced possibilities for secure health surveillance at home are particularly powerful possibilities: some connected devices can provide continuous monitoring for patients with sensitive or critical conditions, but others can be used to provide a continuous loop of diagnosis and feedback that assists in the management of chronic conditions and medication management. Yet other devices can be used to monitor patient adherence to diet and healthy lifestyle regimes. These developments in enhanced remote monitoring, home care, highly personalized diagnosis and feedback based on the provision of a continuous stream of data from individual patients, and the ability to tailor and adapt health regimes to changing individual needs are the essence of "personalized health care." Although 5G's effects on both the delivery of mission-critical services (including its ability to support augmented and virtual reality in mission-critical services) and the personalization of health care are important, for present purposes we subsequently focus on the latter.

10. *Well-being, Cost Savings and Sales Enablement:* The personalization of health care offers improvements in well-being and quality of life. Conventional economic measures such as GDP do not always capture the value to society of such improvements. But the personalization of health care also offers cost savings and productivity improvements: this is conspicuously the case with the possibilities it offers for superior management of long-term and chronic conditions. Shifting the locus of care from hospitals to homes and other lower-cost settings offers another source of cost-savings. Such cost savings do indeed factor into conventional economic calculations. IHS have recently calculated the "sales enablement" effect of 5G on sectors related to the health care sector. They calculate that out of the aggregate "sales enablement" of $12.3 trillion (across the global economy, and attributable to 5G), some $1.11 trillion (or approximately 9 percent of the total) consists of sales enablement in health care.

11. 5G may also be a significant catalyst in fostering a trend that, by changing health care providers' incentives, offers the potential for significant cost savings: health care provision may change from a "volume-based" model in which providers of health care are compensated for quantity, not quality, to a "value-based" model in which compensation is linked to the value delivered. Information is the key to making this transition from the volume-based world— in which there are arguably incentives to health care providers to inflate rather than contain costs— to the value-based world. As 5G facilitates information collection,

information transmission and big data analytics, it will be a key ingredient of the transition to a "value-based" health care system.[3]

12. The remainder of this report elaborates on the themes discussed above:

    - It elaborates on the economic benefits unleashed by the "personalization of health care." At the heart of this "personalization of health care" is the "Internet of Medical Things"—an ecosystem of connected medical and health-monitoring devices. We discuss (a) 5G's role in enabling this ecosystem, (b) the ecosystem's role in enabling personalized and precise medicine, and (c) the economic benefits enabled by this shift to personalized and precise medicine, including the transition from volume-based to outcome-based models of compensation and care.
    - Using calculations carried out by IHS, a partial quantification of some of the economic benefits—in the form of the "sales enablement" effect of 5G is provided.
    - The public policy levers that can impact the benefits achievable from 5G are also discussed.

3 5G and IOMT

3.1 5G Enabling the "Internet of Medical Things (IoMT)"

13. 5G has several key properties that will enable a vast network of connected "things"—devices and machines that can speak to other devices and machines, with or without human intermediation. 5G facilitates this "Internet of Things" through:

    - Greatly enhanced mobile broadband data rates that enable ever faster flows of greater amounts of information.
    - Ultra-low latency and reliability—which is suitable for mission-critical services.
    - Ability to significantly and efficiently scale to connect a massive number of sensors.
    - Enhanced security, e.g., capabilities around biometric identification, which help safeguard the integrity of information.

14. The Internet of Medical Things (IoMT) "includes devices such as medical devices, wearables, remote sensors, and wireless patches that monitor and electronically transmit vital signs, physical activity, personal safety, and medication adherence."[4] 5G is a particularly effective catalyst for IoMT. 5G's ubiquity, ultra-reliability and ability to support higher-bandwidth

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[3] See World Economic Forum and Boston Consulting Group Insight Report, "Value in Healthcare: Laying the Foundation for Health System Transformation", April 2017, for a definition of "value-based" healthcare. The authors state that the fundamental characteristic of value-based healthcare is a focus on improving the quality of outcomes delivered for a given cost. They identify informatics and research and benchmarking—both of which are linked to the discussion in this short report—as two of the key enables of value-based healthcare.

[4] Darrell M. West (2016), "How 5G Technology Enables the Health Internet of Things", Brookings Center for Technology Innovation, Report. p.6.

transmission, at much lower latency than today's mobile networks will not just enable faster and greater flows of data, but will incorporate "back-end data centers, cloud services and remote file servers into a computational behemoth. There will be 'computing at the edge,' which means that computations can be performed near the source, on the device or sensor itself or in the cloud, depending on the immediate need. These 5G innovations will allow applications to quickly process content and provide an experience that is near real-time and very responsive."[5]

15. In short, the innovations associated with 5G do much more than just move bits of data at ever-higher rates. Instead, the "computational behemoth" described above enables the network to assimilate and process large amounts of data; and to do so intelligently so that it can be turned back into individualized recommendations and actions for patients and their caregivers. Further, these 5G innovations will facilitate (through cloud computing) the sharing of that information. The ubiquity of 5G enables the proliferation of connected "medical things". This property of "ubiquity" arises because 5G is not just an extension of existing 3G and 4G networks. It folds Wi-Fi and cellular mobile networks into a single seamless network. It is this ubiquity or seamlessness that supports the proliferation of connected devices and enables, for example, the continuous monitoring of patients. 5G's security properties are critical to safeguarding the security and integrity of the information, thus lowering a critical barrier to the dissemination and harnessing of information.

3.2 Impacts and Benefits of the Proliferation of Things

3.2.1 Connectedness and the Personalization of Health care

16. The benefits of this connected "ecosystem" are significant. As West (2016) puts it, "these devices will provide never before seen telemedicine diagnosis and treatment services." One observer points out that

> In this world, the point of care is now wherever you are, with sensors and devices that surround you every second of the day. Devices adapt to you, know about you and give you actionable insights. Every bit of information they gather will empower us to self-manage our health.[6] (Emphasis added).

17. As a tangible example, consider a glucometer. Today most diabetics do not use their glucometer to understand their blood sugar levels, and the device does not store data in a way that lends itself to being analyzed by the user. Even the act of keeping a systematic log of results is something that requires a significant amount of discipline on behalf of the patient. People with diabetes thus receive feedback on their progress and suggestions as to the future course of action typically through the medium of physician visits. In the connected world, not only can the glucometer continually transmit data to another device or a server that records it, but with the development of artificial intelligence and machine learning, the patient can

[5] Benjamin Sarda, "Vision from Orange Healthcare on 5G", undated.

[6] Jeroen Tas, Philips Healthcare, comments at CES 2017.

receive both feedback and guidance that is tailored to their current situation, lifestyle, and unique physiology. [7]

18. These possibilities for improved and personalized health care are amplified by the fact that in the IoMT environment, the information from the glucometer will not be processed in isolation. Rather, the IoMT world will feature the information from the glucometer combined with information from other sensors and intelligent devices. A much more complete view of the patient's health provides for much more powerful and potent actionable insights to be extracted from the data. For example, transient illnesses or infections may interact with an underlying long-term condition and create more complications for vulnerable patients than they do in the general population. A rich set of information will enable better monitoring and diagnosis of such interactions, and may be used to inform interventions or changes in the standard course of treatment.

19. This combination of superior possibilities for self-management and individualized actionable insights is the essence of "personalized health care." It represents a striking departure from today's world where so many things require the intervention of a practitioner, who himself or herself lacks the benefit of a continuous record of the patient's well-being and physical condition. Even for conditions that cannot be "managed" but require intervention, the intervention may be delivered remotely—e.g., caregivers at home or in the field can be in touch with specialists, both having access to the same, continuously-generated set of information. Or specialists could time interventions based on the flows of information that they receive from connected monitoring devices.[8] One might see, then, the advent of "bed less" hospitals or 'admit to home' care models, with lower costs but more personalized and timely care. This would represent a direct cost saving in terms of specialists' time and resources, and also a social gain in the form of better health and well-being.

3.2.2 Economic Benefits from Personalized Medicine and Better Health Outcomes

20. The developments discussed above have obvious societal benefits. For example:

    - *Management of long-term chronic conditions via superior monitoring.* A report for the British House of Commons states, "In the U.K., 15 million NHS patients in England with long-term conditions such as diabetes, arthritis and asthma account for 70% of the annual expenditure of the NHS in England." The increased prevalence of these long-term conditions was forecast to add £5 billion to annual system costs over the period 2011 to 2018. [9] In responding to questions posed by a committee, one medical practitioner noted that managing long-term conditions required continuity of care. He further noted that informational continuity was one of the important pillars

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[7] See, for example, NASA Tech Briefs, October 1st, 2016, "How IOT is Enabling the Next Generation of Medical Devices." This piece cites data from Freestyle, a medical device company. Freestyle claims that 36 percent of diabetic patients who had a glucometer did not log their results at all, leave alone analyze these results.

[8] Presumably the 5G-enabled ability to provide superior predictive analytics will benefit caregivers and specialists too—e.g., specialists can react to information without needing to continuously monitor it.

[9] See House of Commons Health Committee (2014), "Managing the Care of People with Long-Term Conditions", Second Report of Session 2014-15, Volume 1: Report and Minutes, Summary at page 3.

of continuity of care, pointing to the obvious potential for mobile devices to underpin lower-cost (and possibly home-based) continuity of care.[10] Kaiser Permanente found that patients who were self-monitoring their vitals were 50% more likely to have their blood pressure under control than those who were not.[11] The efficacy of "connected health" and most especially "mobile health" in boosting self-management of long-term conditions has been widely noted. Given the economic costs that these long-term conditions impose on health systems and on society, it is clear that the potential cost savings from superior management of long-term care by enhanced use of mobile health solutions is likely quite substantial. PWC (2013) estimated that for Europe, wider adoption of "M-Health" would save 99 billion Euros in health care costs between 2014 and 2017. The likely savings from an enhanced version of mobile health care—enhanced by 5G—are probably substantially greater.

- *Improved productivity, reduced health insurance risks.* In the U.K. alone, more than 130m work days were lost through sickness in 2013, at annual estimated cost of 32 billion Pounds.[12] Connected devices, ranging from wearables to more sophisticated monitoring devices aimed at patients with chronic and serious conditions, can also help to reduce this problem. This can happen through a mixture of continuous monitoring and an intelligent feedback loop, tailored guidance about how to manage conditions, and early interventions in mission-critical situations. Further, by bringing down the costs associated with managing (perhaps particularly) long-term or chronic conditions, connected health can play some role in reducing the probability of costly payouts for critical care and hospital stays, or (in the case of single-payer taxpayer-supported health systems) reduce the burden on taxpayers by containing costs associated with hospital stays or critical interventions.
- *Better health outcomes.* 5G-fueled "connected health" also obviously offers the prospect of improved health outcomes and the corollary benefits of more years of good health, reduced need to spend time in hospital, reduced need for costly treatments in the case of conditions like diabetes which respond to self-management, etc.

21. The personalization of health care that we described in the previous section goes hand-in-hand with a change in the business and delivery models within the health care sector. In the discussion that follows immediately below, we show how the 5G-fuelled development of health informatics will have a significant facilitating effect on the ability to monitor and improve patient outcomes. This will precipitate a move towards outcome-based models of health care, with significant implications for cost containment in health care systems. In

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[10] Oral Evidence of Martin McShane, November 12th, 2013, at Evidence Page 65, in House of Commons, supra.

[11] Accenture (2012) "Connected Health: The Drive to Integrated Healthcare Delivery", White Paper, https://www.accenture.com/us-en/insight-making-case-connected-health. To some degree, a finding such as this one may be biased in that it could reflect the fact that health-conscious patients were more likely to self-monitor, i.e., that even absent self-monitoring such patients would likely have taken better care of themselves. However, the virtue of "connected health" is that it makes it much easier for less motivated individuals to become health conscious via the interactivity, feedback and information availability that it provides.

[12] Andrew Ward, "Companies Wake Up to Cost of Ill Employees", Financial Times, October 14th, 2014.

addition to this, 5G will also provide new opportunities and new collaborative possibilities. These are also briefly discussed below.

4 5G's Impact on Health Care Services

22. The previous section focused on the impact of 5G on health care outcomes and health care experiences. This section focuses on the impact of 5G on the business of health care. The key lever through which 5G affects business models within the health care sector is through the potential that it (5G) creates for superior health informatics. Advances in health informatics, fuelled by 5G, will both facilitate a shift in the way health care is delivered and create new business opportunities.

4.1 Health Informatics and the Shift to Value-Based Health care

23. The previous discussion has highlighted the role of information (and "information continuity") in improving health care outcomes. Further improvements in informational content and informational continuity will lead to substantial savings to society as a whole. It will also lead to substantial savings and productivity increases for hospitals and for health care systems, which may result in greater profitability.[13] More fundamentally, however, information is absolutely central to a transformation that some observers have commented is a transformation from a "volume-based" to a "value-based" model of delivery in the health care sector.

24. The World Economic Forum and Boston Consulting Group have also made precisely this point in a recent piece.[14] Traditional delivery of health-care has rewarded vendors (e.g., physicians and specialists) based primarily on measures of volume. The authors argue that the traditional "fee-for-service" compensation model provides incentives for over-treatment and leads to the fragmentation of health care. What is required, they say, is to move to a world of "value-based health care" or (alternatively) "outcome-based health care." The essence of this new approach is to base the health care system on the delivery of the outcomes that matter the most to consumers, at the lowest possible cost. The authors argue that the divorce between outcomes on the one hand and costs and compensation on the other leads to economically inefficient incentives in health care—for instance, in a for-profit medical system, patients with complications are more profitable to treat than patients without complications.[15] What implication does this have for the incentives to reduce complications? They note that when cost containment measures are undertaken in health care, these are often measures that are based on micro-managing physician and specialist activities to make costs fit into budgetary parameters.

25. 5G can play a significant part in facilitating the transformation to an outcome-based model from the traditional model of health care delivery. The authors point out that one of the

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[13] If the healthcare industry were perfectly competitive, then all the reductions in its input costs get passed onto consumers. This textbook economics version of perfect competition does not apply to the healthcare sector, however.

[14] World Economic Forum, cited in note 3, *supra*.

[15] World Economic Forum, p. 21.

fundamental drivers of such a transformation would be the availability and quality of health informatics. More generally, three features of 5G are particularly critical to the goal of defining and monitoring the achievement of a desired set of outcomes and achieving those outcomes at lowest cost:

- *5G enables innovation at the "edge."* It involves a "distributed computing model that derives insights from the data generated by billions of devices."[16] Distributed computing implies that computational activity can occur near the source—e.g., the patient—thus speeding up the "loop" of collecting information from the patient, process the information, computing any possible courses of action or recommendations, and providing feedback to the patient. This aspect of 5G should be very germane to the emergence of the type of high-quality health informatics that are required to comprehensively measure outcomes.
- *5G will not just improve the tracking of outcomes, but will improve the outcomes themselves*. 5G's superior latency, reliability and transmission speed will help in fostering preventative care, and in improving outcomes where critical interventions are required. These facets of 5G will help with improving outcomes and reducing the costs associated with achieving a given level of outcome (i.e., 5G will improve productivity).
- *The superior security features* of the 5G ecosystem will facilitate the informatics revolution and allay concerns health systems and health authorities have now in managing sensitive patient data outside the walls of the hospital. Orange Health care notes "the high reliability and security of 5G infrastructures should help to alleviate the legitimate end user and health professionals concerns about privacy and hacking around health data and services."

26. Goldman Sachs estimates that the transition to value-based care could generate upwards of $650 billion in savings[17] by 2025 through shifting care to lower-cost settings, moderating price inflation and reducing the estimated $1.4T in annual health care waste in the US. Whether such large benefits can actually be achieved, however, will depend at least partly on effective public policies. We discuss this point in our concluding section on policy implications.

4.2 Health Informatics and New Business Opportunities

27. Health care is often described as data rich yet information poor. 5G offers the potential for new business models to emerge at the intersection of health care and data analytics. Health care is of course highly specialized, and it is essential to maintain confidentiality of patient records as well as security of information. However, the potential for "big data" in health care not only offers growth opportunities for data analytics vendors, but it also offers an opportunity for health care providers to monetise the information that they have, provided security and privacy concerns can be met. This information may be of interest to

[16] West (2016), p.2.

[17] Goldman Sachs Global Investment Research, "Healthcare's Holy Grail: Better Outcomes at Lower Costs", February 2017.

pharmaceutical companies and medical devices manufacturers who are pursuing embedded analytics within their devices and service enabled drug solutions.

28. The wider availability and accessibility of information fuelled by 5G could encourage the growth of collaborations that cut across silos in the health care industry—for example, information on patient outcomes in response to certain treatments or changes in the patient's environment may previously only have been available as part of a trial or experiment carried out within, say, a pharmaceutical company's laboratory. But in the future, with the developments in monitoring and informatics discussed above, such information may be more readily gathered by a wider range of industry participants, and it may be compiled and centralized more effectively (e.g., by specialized health informatics vendors). In this environment, at least from a technological perspective, collaboration across silos such as pharmaceutical developers, equipment manufacturers and health care systems should be appreciably easier to achieve.[18]

29. We next turn to a brief discussion of the broader economic gain enabled by 5G—these gains arise because 5G expands output and productivity in the health care sector.

5 5G Impact on Sales Enablement and the Using Sectors

30. A larger and more productive health care sector means enhanced sales and productivity for both the sectors that supply the health care sector and for sectors for which the health care sector is a supplier. These latter sectors are business-to-business buyers of health care services. Figure 1 offers a schematic diagram of the primary supplying and "using" sectors linked to the health care industry.

31. In their January 2017 study[19], IHS Markit calculate what they call "5G-enabled" global sales activity. This is the incremental sales activity across multiple industrial sectors that will be enabled by 5G—i.e., taking into account the sales activity that would already occur with pre-5G technology. After a ramp-up period in the late 2020s and early 2030s, they estimate the total global sales enablement potential of 5G to reach $12.3 billion in 2035, or 4.6% of real global output that year. Of this, some $3.4 billion of the impact will be felt in the

[18] Whether or not such collaboration arises will depend significantly, however, on economic incentives of the various actors. One possibility (discussed above) is that the "big data" developments discussed above lead to the emergence of stand-alone data vendors. In this case, relevant information could be more widely available than if data were harnessed and maintained within a vertically integrated environment, e.g., when an equipment maker or drug maker gathered the data and kept it to itself. Vertical integration could provide incentives to withhold the data from other market participants. But economic theory suggests caution in accepting either the thesis that stand-alone vendors will organically emerge (i.e., it may simply be more sensible to organize the data gathering and harnessing activities within the context of other operations such as drug-making or equipment-making), or that vertically integrated vendors will actually withhold the data from rivals. Analysis of such issues is beyond our present scope.

[19] IHS Economics/IHS Technology, "The 5G Economy: How 5G Technology Will Contribute to the Global Economy", January 2017, Appendix A. In the interests of precision, the sectors listed as "primary user sectors" are defined in terms of the ones that are most powerfully impacted by changes in the automotive sector resulting from implementation of 5G technology.

manufacturing sector.

32. IHS have more recently prepared estimates of the sales enablement effect in the global health care sector and its "using" and "supplying" sectors, totalling more than $1.1 trillion in year 2035.

Table 1: Sales Enablement in 2035

Sales Enablement due to use of 5G in the Health Care Industry, 2035 ($ billions)	
A. Sales Enablement in "Use" Sectors	**$253**
B. Final Vertical Sales Enablement	**$453**
% of health care industry sales	3.1%
C. Supply Chain Enablement	**$409**
D. Total Sales Enablement from "Health care" 5G	**$1,115**
% of $12.3 trillion 5G Sales Enablement	9.06%

Source: IHS Economics/IHS Technology

IHS calculates:

- The intersection of 5G and health care will lead to an expansion of $253 billion in global sales in 2035 (relative to the next-best non-5G scenario) for industries that process or add value to healthcare data. These industries include insurers; providers of data analytics; and providers of cloud-based data services.
- The intersection of 5G and health care will lead to an expansion of $453 billion in sales for what could be called the "health care vertical." This vertical includes not just what we normally think of as the health care profession—hospitals, doctors, etc.—but also medical equipment manufacturers such as those who supply IoMT devices, and (to a smaller extent) the pharmaceutical sector.
- The intersection of 5G and health care will lead to an expansion of $409 billion in sales for the "supply chain" to the sectors that are either part of the "health care vertical" or are in the "use" category. For example, increased sales of IoMT devices (part of the "vertical") also mean increased sales for semi-conductor firms who provide inputs into those medical devices.

33. These sales enablement calculations illustrate the significant economy-wide impact from the deployment of 5G in the health care setting. These sales enablement calculations are, however, a substantial understatement of the true economic impact of 5G. Some of the largest benefits of 5G likely defy precise quantification. One obvious example is the effect of 5G-fuelled health

care on the well-being and life satisfaction of patients. Another example is the impact of this increased well-being in reducing the burden and costs (on health care systems) on caring for patients with chronic diseases. A third example is the productivity gains to businesses and the wider economy from happier, healthier and more productive employees.

6 Policy Implications

6.1 Public Policy and its Effects on the Benefits from 5G Technology

34. The discussion above pertains to the benefits of 5G. These benefits are *potential benefits*. 5G technology is still, of course, a work in progress. Public policy measures can have an impact on the development of the technology itself. Public policy can also affect the realization of the potential benefits discussed above by affecting the incentives to deploy the technology. Public policy that allows or incentivizes existing actors within the health care sector to resist change will reduce the actual benefits that are realized from 5G. Conversely, public policy that encourages or incentivizes organizational changes that are responsive to technological changes will help in achieving the large potential benefits discussed above.

35. In this section, we discuss (a) policies that affect the development of 5G technology itself, and then (b) policies that can help to realize the full economic potential enabled by 5G technology.

6.2 Public Policy and Upstream Innovation: Intellectual Property and Standardization

6.2.1 5G as a Standards-Driven Technology

36. We start with a discussion of how public policy can significantly impact the development of 5G technology itself. A fundamental economic characteristic of 5G is that much of the technology will be embedded in standards, i.e., the industry will collaboratively develop a set of technologies and protocols that will then be implemented by every 5G-compliant device. There will not be competing and mutually incompatible versions of 5G. Standards-compliant devices and infrastructure allow for inter-operability and compatibility. Standards make products more valuable to consumers since compatible products can be interconnected to each other, enabling the emergence of large networks of users. These large networks also add value to manufacturers of standards-based products, because these manufacturers can benefit from economies of scale in development and production. Innovators and developers also benefit from reduced uncertainty—the standard allows for innovators and developers to invest with confidence that their products will be compatible with other communications products, and that they will have access to a broad marketplace enabled by the standard. The standard thus becomes a platform around which innovation conducted on a global basis and involving many firms coalesces.[20]

37. The economy-wide nature of 5G also provides a substantial and realistic potential for "spill-over" effects. For instance, there may be several mission-critical uses of 5G technology well outside the realm of health care. Improvements in reliability and latency developed in

[20] An overview of the economic benefits from standardization can be found in Grindley, Peter, "Standards, Strategy and Policy: Cases and Stories", Oxford: Oxford University Press (1995), pp.20-29.

response to demand from these use cases can also translate into improvements for health care. Indeed, to the extent that the breadth of the ecosystem around 5G-linked products incentivizes participation by technology firms (including Qualcomm and Ericsson, for example), this also improves the possibilities for collaboration in the form of joint development ventures or alliances between technology firms and firms (such as device makers) that are specialized in health care.

6.2.2 Risks of Retarding Innovation

38. Public policy towards intellectual property embedded in standards can affect the development of the technology. It can do so by impacting the incentives of technology developers to contribute their intellectual property to the standard. Recent public policy pronouncements in Europe, the United States and elsewhere have tended to focus on the market power that intellectual property owners allegedly derive from the inclusion of their intellectual property in a standard that all manufacturers of standards-compliant devices must use. This focus on market power has ignored critical variables such as the returns to the owners of intellectual property relative to the gains to society at large from the technology in the standard. Worse, the policy debate on market power has propagated (as remedies for controlling the alleged market power of intellectual property owners) theories of "fair and reasonable" compensation for standards-essential intellectual property that ignore the other side of the issue: the need to appropriately reward intellectual property owners for contributing their technology to the standard. This reward needs to take into account the highly uncertain returns associated with plowing money into research and development activities, as well as the value that the technology adds when embedded in the standard.[21]

6.3 Public Policy Measures in Health care: Complementing Technological Change

39. Even with appropriately calibrated IP policies that sustain rather than retard innovation, public policy in other areas can significantly affect the gains achievable from 5G technology in the health care sector. Three prominent examples are discussed below.

6.3.1 Addressing Privacy and Security Concerns

40. The revolution in health informatics depends on not just the availability of technology to gather, process and react to information, but on the guarantee of security and privacy. Privacy concerns are especially paramount in the European Union, e.g., there will be restrictions on where personal data can be stored (not outside the EU). Public policy can play a constructive role in setting standards for data quality, data protection, and protection of organizations that have access to and release information.

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[21] A full discussion of the many complex issues associated with standards-essential intellectual property can be found in (for example) "Standards Setting, Standards Development, and Division of the Gains from Standardization" (with E. Sherry), Competition Policy International (Sept. 2016); "A Public Policy Evaluation of RAND Decisions in the U.S. Courts" (with Ed Sherry), Criterion Journal on Innovation 1 (2016), 113–159; (115) "Patents and Patent Wars in Wireless Communications: An Economic Assessment," Digiworld Economic Journal 95 (3rd Q. 2014), 85.

6.3.2 Complementing the Informatics Revolution

41. Public initiatives can complement the "informatics-enabling" effect of 5G. The benefits of 5G-enabled informatics (e.g., in generating and processing data on a near-continuous basis from patients) can be complemented by systematic processes for providing access to the vast amount of information collected by public agencies. For example, agencies such as Center for Medicaid and Medicare Services (CMS), Center for Disease Control (CDC) and the FDA, all possess substantial amounts of data and information. So do similar agencies in other countries. Access to the vast amount of data (although again without compromising security and privacy) in the agency domain can be harnessed alongside patient data to yield better insights, better quality of care, and will perhaps even facilitate occasional substantial breakthroughs in treatment and prevention.[22] McKinsey (2013) points to initiatives undertaken by the CDC and the Department of Health and Human Services, in the U.S., to foster collaboration and information exchange across public and private sectors (e.g., through the development of data stores or portals for information exchange).

6.3.3 Policy that Enables the Transition to Value-Based Health care

42. *Complementing the transition to value-based health care:* What can public policy do to foster the transition from volume-based to value-based health care? 5G can undergird this transition. For the transition to actually work, it requires an alignment of incentives across different actors in the industry, on top of requiring the types of activities that promote the health care informatics revolution generally (e.g., the activities around data security, codes of conduct, standardization across different data formats etc.):

43. *Single-payer public health care systems*: As an example, consider a single-payer health care system of a type that is common in many developed countries. To the extent that hospitals and trusts are compensated on essentially a cost-of-service basis—e.g., if a hospital carries out several thousands of operations a year, the total cost is worked out on the basis of physicians and specialists' time, the cost of materials, and an allocation for hospital and system overheads—the government can legislate a change in the reimbursement model, and order the system to undertake steps that move reimbursement to an outcome-driven basis. Governments can also take steps to create the right incentives for cost reductions—e.g., cost reductions in the health care systems should be returned to the system, rather than being recognized as a benefit to the government bottom line more generally.

44. *Private health care systems*: In the context of a private health care system or a hybrid system (i.e., private health care but with a heavy dose of government intervention), the incentives for cost containment are harder to directly manage via public intervention. Some possibilities include use of the tax system to reward investments in "connected health care", and perhaps loans or even capital subsidies to finance "connected health care" initiatives. Of course, by setting standards around security and privacy, and by facilitating activities such as data release, access to data repositories etc., the government can anyway constructively reduce the costs and risks, and increase the benefits, associated with moving towards connected health

[22] See McKinsey (2013), "The Big Data Revolution in Healthcare: Accelerating Value and Innovation."

care. This alone should provide superior incentives to the private sector to embrace "connected health."

7 Concluding Remarks

45. The advent of 5G technology represents an important augmentation of the role of mobile technology in the wider economy. Mobile technology will go from a significant enabling technology to one that is pervasive and transformative in many uses across the economy, i.e., a "general purpose technology." The health care sector provides an excellent illustration of this transition. The reliability and ubiquity of 5G networks, combined with the role of such networks in facilitating "computing at the edge", will directly enable the personalization of health care. The personalization of health care means "more prevention" and "more precision", improving patients' quality of life, improving health outcomes and reducing costs to the health care system. 5G will enable substantial advances in health informatics and thus fuel both new business opportunities and significantly facilitate a perhaps-needed transition to "outcome-based" health care.

46. However, public policy has an important role to play in unleashing the full potential of 5G technology. With standardization, and the desire to make wireless technology widely available, licensing is the main mechanism, or business model, by which the developers of wireless technology can be rewarded, absent government subsidies. This puts an onus on policy makers and the courts to make sure licensing enables technology to be both developed and adopted. Public policy towards IP can impact—positively or negatively—the rate at, and extent to, which the 5G technology develops, by encouraging or retarding core innovation. Public policy in other areas—e.g., tax, regulation, privacy law—can also ensure that incentives to invest in technology development are robust and artificial barriers to effective adoption and use of 5G are minimized.