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Expansive mobile

Reaping the payoff from investment in mobile connected computing

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Communications Chambers

About the Author

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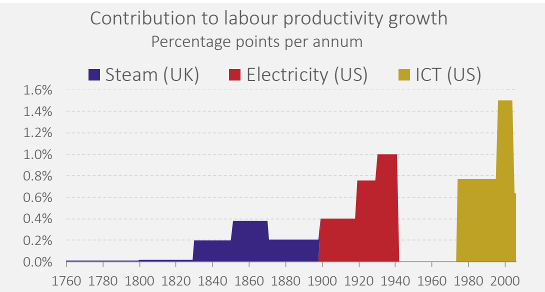
1. Executive summary

The pivot to multi-touch smartphones, apps and mobile data has been underway for just over a decade, with internet companies announcing 'mobile first' strategies from 2010 and with a growing number of applications now mobile only. Policy priorities need to shift too.

Mobile as a general-purpose technology

Mobile and wireless offer the promise of previous general-purpose technologies such as steam, electricity and computing; to boost productivity growth over a sustained period of time by supporting a broad-range of consumer, commercial and industrial applications.

Productivity growth contributions from steam, electricity and information and communications technology (ICT) are illustrated in the following figure.



Source: Communications Chambers, Crafts (2003, 2014), Bakker *et al* (2017) & Byrne *et al* (2013)

The impacts of general-purpose technologies tend to come in waves as new applications and business models are developed; mobile connected computing is a key building block for further ICT driven growth.

But to deliver on this promise mobile needs to be ubiquitous, capable and consistent; with declining unit costs and the capability and freedom to offer tailored mobile broadband, internet of things and low latency industrial connectivity. 5G will amplify this cluster of characteristics, which we refer to as 'expansive mobile'.

Only when expansive mobile is taken for granted as a building block will the full potential of mobile be realised, and that requires investment. Yet contemporary policy and regulation in Europe has seen network investment, adoption and use lag that in other developed regions; with an expectation that it will continue to do so.

Spillover benefits imply a need to foster investment in expansive mobile

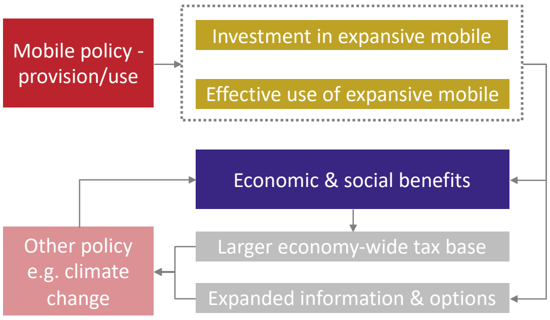
General-purpose technologies result in spillover benefits throughout the economy, complemented by network effects in the case of expansive mobile. Benefits are likely to significantly exceed private returns to investors in mobile networks (evidence suggests that more than half of the benefits of enhanced connectivity relate to spillover and network effects). Therefore, not only do barriers to private investment need to be removed, but investment needs to be actively fostered.

Pivoting to mobile first policy

To seize the potential of expansive mobile, to move beyond business as usual policy, regulation and investment, a shift in high-level policy focus is required with a pivot away from priorities identified in the pre-'mobile first' era which are reflected in current policy objectives, metrics and institutions.

Realigning policy around mobile first in Europe is overdue. In 2010 US National Broadband Plan stated that: *"the united states should lead the world in mobile innovation"*. China has targeted ubiquitous mobile and in December 2018 the Chinese Communist Party Central Committee and the State Council highlighted 5G commercialisation and the development of an industrial internet as priorities. Europe has been good at setting goals, but slow to update them to reflect the pivot to mobile.

Further, policy governing verticals throughout the economy needs to be revisited to ensure that it allows service innovation whilst continuing to protect the public interest. The old objectives may be fit for purpose, but the old rules may not be a good fit with new services and business models built on top of expansive mobile. The elements of a mobile first policy are illustrated in the following figure.



The following illustrates what focussing on mobile connected computing might mean in practice:

- European and member state policy would be refocussed to deliver expansive mobile.
- The European Digital Economy and Society Index (DESI) would be revised to include geographic mobile coverage and the unit price of mobile data (versus population coverage and bills respectively).
- A shift in emphasis to achieve more rapid and aligned spectrum release and greater assurance of spectrum rights over time.
- A refrain from extracting revenue from mobile network operators, instead promoting shared investment goals to drive expansive mobile.
- A timelier and more permissive framework for infrastructure deployment, including exemptions for low impact infrastructure (as in the US and Australia) and conditionality of coverage obligations on local agreement to a charter regarding permitting requirements and access to civic infrastructure.
- Review of regulation of verticals throughout the economy to ensure that policy goals are assured whilst permitting new applications and business models building on expansive mobile. For example, via flexible and timely approaches to medical device approval or regulatory approaches which work with rather than against data driven approaches to market governance utilised by platforms.

The prize

The prize from embracing expansive mobile includes not only sustaining the contribution of mobile to productivity, income and employment growth; but also deepening it. To illustrate the potential cumulative impact, the following table shows the impact of a 0.25% increase in the rate of growth over time.

Impact of 0.25% growth for EU-28 in first year and by 2030

	%	GDP (€15,300 billion base for EU-28)	Per capita (€30,000 base)
First year	0.25%	€38 bn	€75
By 2030 per annum	3%	€470 bn	€910
Net present value to 2030		€2200 bn	€4300

The prize goes beyond the productivity, income and employment growth to include a larger tax base, improved digital inclusion and gains across all areas of public policy driven by improved information to inform policy and an expanded and more effective set of policy options, for example in relation to health and the environment.

Europe should seize the opportunity presented by a policy pivot towards expansive mobile.

2. The pivot to mobile

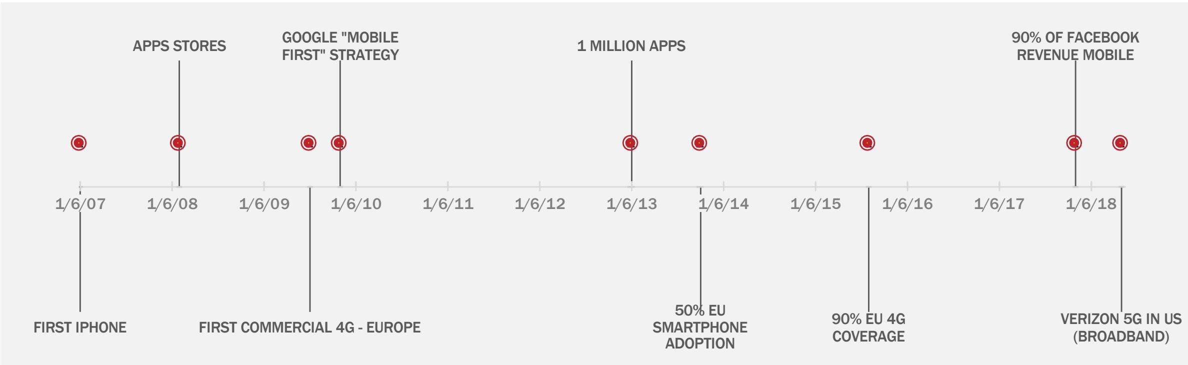
Overview

The pivot to mobile gained momentum from the synergy between multi-touch smartphones (2007), apps stores (2008) and LTE/4G data networks (from 2009).

In 2010 Eric Schmidt, the then Chief Executive of Google, called out a 'mobile-first' strategy at the Mobile World Congress[1] - realising that to survive and prosper they had to refocus on mobile. A growing number of start-ups adopted a mobile only, or primarily mobile, strategy.

Figure 1 shows milestones in terms of apps (upper half) and devices and networks (lower half) over the past decade.

Figure 1: Modern era mobile milestones



The pivot to mobile offered a richer user experience given the option of mobility coupled with location awareness and sensors including microphones, cameras and accelerometers.

However, some policy makers have adapted slowly, continuing to focus primarily on the PC and fixed broadband. Astonishingly - given the importance of mobile for development - the World Bank noted in 2016 that:[2]

> *"Available evidence suggests that access to the internet from big- screen devices (PCs), with always-on flat-rate access, provides a bigger boost to economic activities than access from small-screen devices (mobile phones), which generally have use-based pricing."*

The mistake here is two-fold:

- First, to miss the fact that mobile was improving rapidly, with capacity and capability growing in step with traffic growth of around 40% per annum whilst holding user costs roughly constant – an extraordinary rate of productivity growth contributing spill-over gains throughout the economy.[3]
- Second, to focus on applications that were better suited to a PC, such as long-form word processing, rather than the exploding

[1] PC Magazine, Google's New Rule: Mobile First, February 2010. https://www.pcmag.com/article2/0,2817,2359752,00.asp%3Cbr%20%3E%3C/a%3E

[2] World Bank, World Development Report 2016: Digital Dividends, May 2016. Page 208. http://www.worldbank.org/en/publication/wdr2016

[3] Corado and Jäger, Communication Networks, ICT and Productivity Growth in Europe, December 2014. https://pdfs.semanticscholar.org/6661/5aba77005a9bf411f5618c65d4e695b22d69.pdf

range of applications that are better suited to, or only feasible on mobile.

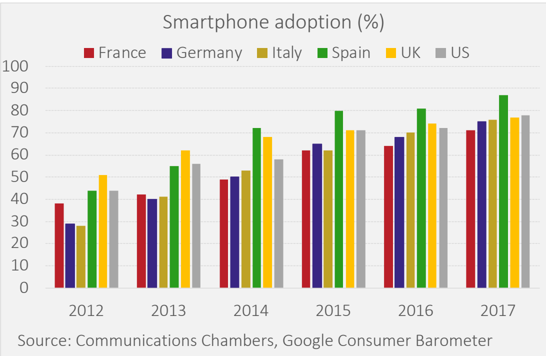
In contrast to the World Bank, The Economist noted in 2019:[4]

> *"They [smartphones] might be the most effective tool of development in existence."*

Smartphones

Smartphone adoption has been rapid, despite the premium price versus basic phones, and despite coinciding with the recession following the financial crisis (Figure 2).[5]

Figure 2: Smartphone adoption

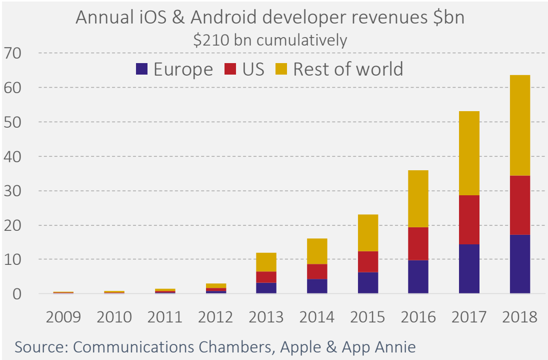


This indicates a high level of utility for smartphones, complemented by the growing variety of apps and improved mobile connectivity. Smartphone adoption in Europe is comparable to that in the US.

Apps

Figure 3 shows app store revenues paid to developers, another indication of the pace of the pivot to mobile (app developers also receive other revenues including advertising, commission fees and subscriptions outside of app stores).[6]

Figure 3: App store revenues paid to developers

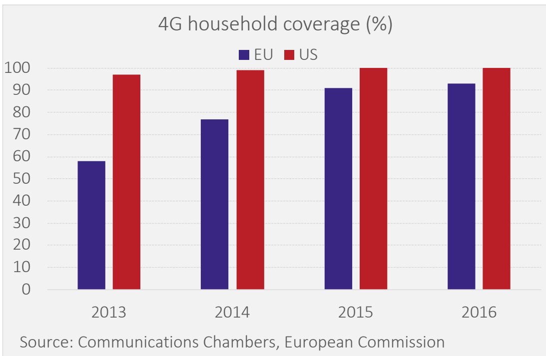


European app developers have kept pace with those in the US in terms of developer revenues.

Networks

The first commercial 4G deployment globally were in Stockholm and Oslo, and 4G household coverage in Europe grew from 8.3% in 2011 to over 90% by 2016[7], however Europe has lagged the US on 4G coverage (Figure 4).[8]

Figure 4: 4G coverage



The earlier deployment of 4G in the US spurred the development of categories of mobile-first

[4] The Economist, The maturing of the smartphone industry is cause for celebration, 10 January 2019. https://www.economist.com/leaders/2019/01/12/the-maturing-of-the-smartphone-industry-is-cause-for-celebration

[5] Google Consumer Barometer. Accessed 18 February 2018. https://www.consumerbarometer.com/en/

[6] Estimates based on Apple press releases and App Annie reports of the Android-iOS developer revenue ratio. Regional shares based on Apple Job Creation report for the US (December 2016) and UK (January 2016) which provided snapshots of regional revenue shares.

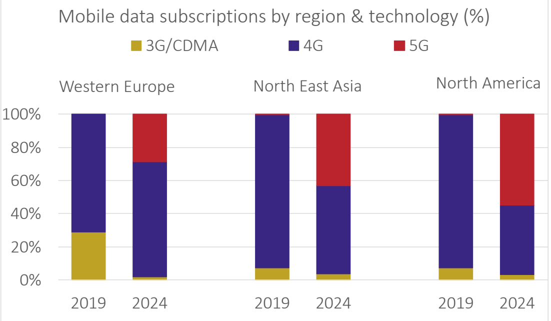
[7] EC, Digital Agenda key indicators, Accessed 15 February 2019. https://digital-agenda-data.eu/datasets/digital_agenda_scoreboard_key_indicators/visualizations

[8] EC, International Digital Economy and Society Index 2018, October 2018. Page 52. https://ec.europa.eu/digital-single-market/en/news/international-digital-economy-and-society-index-2018

and mobile-only apps that depended on mobile data connectivity, for example Uber which launched in 2010 in San Francisco.

Europe also lags North East Asia and North America in relation to 4G subscriptions in 2019 and is projected to do so for 4G and 5G out to 2024 (Figure 5[9]). The data shown is for all devices, subscriptions for smartphones alone by network technology show a similar lag.

Figure 5: Mobile network technology adoption



Source: Communications Chambers, Ericsson Mobility Report

Whilst Europe has broadly matched the US in terms of smartphone adoption and app development and monetisation via apps stores, it has lagged in relation to mobile network deployment and upgrades.

It is telling that Europe lags in the area where policy and regulation have had the greatest impact, namely networks. There is nothing inevitable about this.

It is crucial that policy makers recognise the importance of mobile and take the required actions to facilitate investment in expansive mobile.

[9] Ericsson Mobility Visualizer, Accessed February 2019. *https://www.ericsson.com/en/mobility-report*

3. Expansive mobile connectivity

Attributes of expansive mobile

Mobile connectivity has opened up a vast number of applications, but in practice falls short of the promise of connectivity anyplace anytime and does not meet the needs of some applications.

'Expansive mobile' refers to the possibility and potential of wireless that is more ubiquitous; more efficient in terms of the cost per unit of data traffic carried; more consistent and more capable, and which can be tailored to a range of specific and more demanding applications:

- Improved indoor and outdoor coverage, with an outdoor focus on economically relevant geographic coverage rather than coverage of premises *per se*[10].
- Improved productivity in carrying data, which will also be reflected in the unit cost of data for users.
- Enhanced capacity, improved service levels and greater consistency of service levels with increased emphasis on cell-edge performance.
- Tailored service levels for specific applications including, for example, millisecond latency required for real time control in manufacturing.[11]

Expansive mobile is not intended to be technology specific, but in the near to medium term will predominantly involve a mix of 4G and 5G technology (with Wi-Fi continuing to play an important role indoors). Network slicing, the ability for a single network to dynamically deliver a range of bespoke solutions, is however a characteristic associated with 5G.

Why expansive mobile matters

Expansive mobile is required to underpin the ongoing pivot to mobile applications and services, and the development of new internet of things and industrial wireless applications. Expansive mobile will also provide a layer of redundancy and resilience alongside fixed access.

Improved coverage, coupled with lower unit costs, will also contribute to digital inclusion which, whilst valuable in its own right, is also required to support mobile delivery of government services including health services. These shifts will benefit consumer and business users directly, but also contribute to productivity and income growth throughout the economy.

The requirement to unlock this potential is greater availability of spectrum and greater investment in existing and new wireless technologies. This in turn requires a different policy focus and a supportive regulatory environment. Other regions have adapted policy recognising the growing importance of mobile - to facilitate investment in mobile infrastructure.

The US, in its 2010 National Broadband Plan stated as part of one of its goals: *"the united states should lead the world in mobile*

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[10] Given improved fixed broadband availability in Europe, coupled with implementation of voice over Wi-Fi, the importance of in-premise mobile coverage may be reduced. However, mobile offers broadband access where fixed access is unavailable or of low quality, or where the option to join a Wi-Fi network is not readily available; offers an option for those who cannot afford both mobile and fixed access; and offers resilience via redundancy in case of a fixed broadband outage.

[11] Ericsson, Bringing 5G business value to industry - A case study uncovering 5G's potential for real-time control in manufacturing. *https://www.ericsson.com/en/trends-and-insights/consumerlab/consumer-insights/reports/5g-business-value-to-industry-blisk*

innovation".[12] China has targeted ubiquitous mobile and in December 2018 the Chinese Communist Party Central Committee and the State Council highlighted 5G commercialisation and the development of an industrial internet as priorities.[13] [14]

Europe has been good at setting goals, but slow to update them to reflect the pivot to mobile.

[12] FCC, Connecting America: The National Broadband Plan, March 2010. *https://transition.fcc.gov/national-broadband-plan/national-broadband-plan-executive-summary.pdf*
[13] HSBC, 5G in China - Upgrading the national infrastructure, February 2019.
[14] FT, 5G: Can Europe match the US and China on mobile networks?, January 2019. *https://www.ft.com/content/650d3bf8-1e32-11e9-b2f7-97e4dbd3580d*

4. Productivity growth and general-purpose technologies

Importance of productivity growth

> *"Productivity isn't everything, but in the long run it is almost everything. A country's ability to improve its standard of living over time depends on its ability to raise its output per worker."* Paul Krugman, 1994[15]

The reason productivity growth is almost everything in terms of the standard of living is that only two things can increase real income per capita – working more productively and working longer hours; and there is a limit to how many hours one can, or would wish, to work.

In practice productivity growth has not only increased real incomes in Europe, it has also supported a long-term increase in leisure, whilst having no discernible impact on the long-term level of employment (whilst in the short-term growth helps reduce unemployment). Real income growth also supports increased expenditure by the state on services such as education and health.

It is also clear that measured productivity growth does not capture everything. Time savings and lives saved via public sector use of mobile will not necessarily be captured in productivity statistics; nor will the consumer benefits in terms of consumer surplus (the difference between willingness to pay and what is actually paid) and leisure based use of mobile necessarily be fully reflected in productivity and GDP measures. For example, the estimated consumer surplus for services such as Uber[16] and social media[17] are considerable.

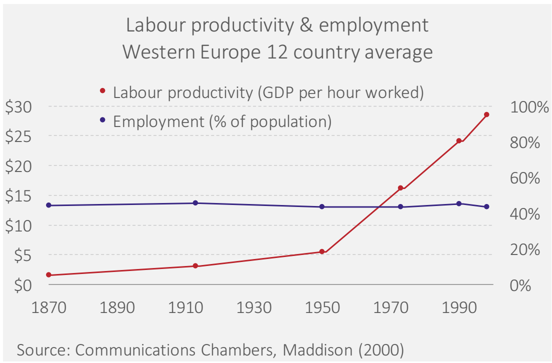
However, unmeasured consumer gains from internet-linked technologies, whilst material, may be comparatively small relative to the impact of variations in productivity growth.[18]

Other policy objectives including employment, equality and the environment are touched on in subsequent sections.

Long-run historical perspective

Between 1870 and 2000 in Europe productivity increased 10-fold, split between 5-fold real income growth and increased leisure, whilst employment per capita remained almost constant (Figure 6).[19]

Figure 6: Productivity growth and employment



Sectors which see rapid growth in productivity, such as agriculture, contributed to overall

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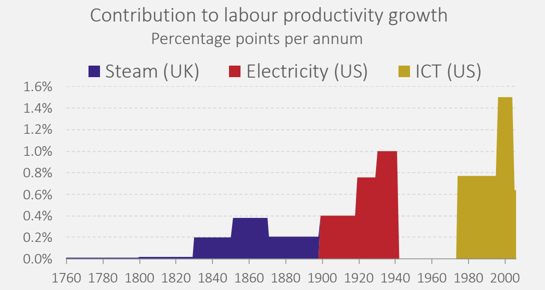
[15] Krugman, The age of diminished expectations, 1994. Cambridge: MIT Press.
[16] Cohen, Hahn, Hall, Levitt and Metcalfe, Using Big Data to Estimate Consumer Surplus: The Case of Uber, September 2016. https://www.nber.org/papers/w22627
[17] Corrigan, Alhabash, Rousu and Cash, How much is social media worth? Estimating the value of Facebook by paying users to stop using it, December 2018, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0207101
[18] Syverson, Challenges to mismeasurement explanations for the U.S. productivity slowdown, February 2016. https://www.nber.org/papers/w21974
Crafts, Is slow economic growth the 'new normal' for Europe? 2017. http://wrap.warwick.ac.uk/97402/1/WRAP-is-slow-economic-growth-normal-Europe-Crafts-2017.pdf
[19] Maddison, *The World Economy – A Millennial Perspective*, OECD Development Centre Studies, 2000.

productivity growth, but saw their share of GDP decline dramatically. This illustrates one reason why focussing on the share of an activity in GDP is not informative, namely activities experiencing high productivity growth and making an outsize contribution to overall growth may be small and/or contract, as their relative price declines.

General-purpose technologies

General purpose technologies (GPTs) including steam[20], electricity[21] and ICT[22] have had a material impact on productivity growth, as shown in Figure 7[23], though GPTs are themselves typically a small share of GDP.

Figure 7: Productivity growth contributions



Source: Communications Chambers, Crafts (2003, 2014), Bakker *et al* (2017) & Byrne *et al* (2013)

Material productivity impacts came with a lag: James Watt's stream engine was invented in 1769, but stream only had a material impact once high-pressure stream engines came into general use; electricity only had a material impact once factories were reorganised around decentralised motors and computing had a material impact once computers were networked and economic activity reorganised around connected computing.

A new technology has to itself have attained high-productivity to be cheap enough, widespread enough and complemented by innovations in the organisation of economic activity to have a material impact on aggregate productivity growth.

The way in which complementary innovation unfolds also means that productivity growth associated with a given GPT may come in multiple waves:[24]

> *"History shows that productivity growth driven by general purpose technologies can arrive in multiple waves; it need not simply arrive, give what it has, and fade away forever thereafter."*

Rumours of the death of productivity growth (in tech) are greatly exaggerated

The share of ICT in GDP in Europe has been relatively constant at around 5%[25], yet ICT capital contributed around one-third of GDP growth in the three decades to 2016.[26] Further, the European Commission estimate that 75% of the value added by the Digital Economy comes

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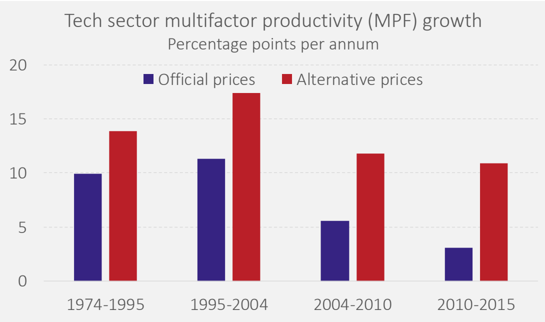
[20] Crafts, Quantifying the contribution of technological change to economic growth in different eras: A review of the evidence, September 2003. Table 5. http://eprints.lse.ac.uk/22350/1/wp79.pdf
[21] Crafts, Productivity Growth during the British Industrial Revolution: Revisionism Revisited, September 2014. Table 7. https://warwick.ac.uk/fac/soc/economics/research/centres/cage/manage/publications/204-2014_crafts.pdf
Bakker, Crafts and Woltjer, The Sources of Growth in a Technologically Progressive Economy: the United States, 1899-1941, October 2017. http://eprints.lse.ac.uk/85081/1/WP269.pdf
[22] Byrne, Oliner and Sichel, Is the information technology revolution over? March 2013. Table 1. https://www.federalreserve.gov/pubs/feds/2013/201336/201336pap.pdf
[23] The gap in the chart does not necessarily indicate no ongoing growth contribution but reflects the period over which estimates are available for electricity. Note also that stream overlapped with electricity, continuing to contribute to growth beyond 1900.
[24] Syverson, Will history repeat itself? 2013. https://ideas.repec.org/a/sls/ipmsls/v25y20134.html
[25] OECD, Value added by activity, accessed 10 January 2019. https://data.oecd.org/natincome/value-added-by-activity.htm
[26] ITIF, How ICT Can Restore Lagging European Productivity Growth, October 2018. Figure 7. http://www2.itif.org/2018-ict-eu-productivity-growth.pdf?_ga=2.205706384.227114790.1547140924-1327040919.1544518581

from traditional industries, rather than ICT producers.[27]

Post the 2007 financial crisis, however, overall productivity growth has slowed globally and in Europe.[28] Further, Robert Gordon (2016) argued that the contribution of information technology to productivity growth does not measure up to the 'great inventions' of early 20th century.[29]

However, whilst the broader productivity slowdown appears real (it is not explained away by measurement issues), the picture is clouded by the impact of the financial crisis.[30] Further, the 'great inventions' of the 20th century made a strong but not dominant contribution to productivity growth, and their impact was similar to that of IT over the past several decades.[31] Finally, and crucially, when tech sector input price declines are appropriately measured a strong ongoing contribution to productivity growth is indicated (Figure 8).[32]

Figure 8: Tech sector productivity growth



Source: Communications Chambers, Byrne *et al* (2017)

This makes the overall productivity slowdown more puzzling, though it is not unreasonable to expect the current wave of innovation in tech to pay off - but with a lag:

> *"If the tech sector continues to innovate so rapidly, why has overall productivity growth been exceptionally sluggish? …we suspect that the answer depends importantly on the long lags necessary for innovations to diffuse through the economy and move the needle on overall productivity. This pattern of slow diffusion has been seen in the past both with electrification in the late 19th and early 20th centuries, as well as for semiconductors in the second half of the 20th century. We believe that the faster rates of innovation in high tech that are evident, once measurement biases have been corrected, could be the fuel for a future pickup in productivity growth."*

Connected computing

Nobel Economist Robert Solow quipped in 1987 that:[33]

> *"You can see the computer age everywhere but in the productivity statistics."*

The answer to the paradox was that connected computing was required to move the dial on productivity, as Alan Greenspan, then Chairman of the Federal Reserve Board noted in 2000:[34]

> *"The full value of computing power could be realised only after ways had been devised to link computers into large scale networks…"*

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[27] European Commission, *A digital Single Market Strategy for Europe - Communication from the Commission*, May 2015.
[28] European Central Bank, The slowdown in euro area productivity in a global context, 2017. Economic Bulletin. *https://www.ecb.europa.eu/pub/economic-bulletin/articles/2017/html/index.en.html*
[29] Gordon, The Rise and Fall of American Growth, 2016. Princeton University Press.
[30] Crafts, Is slow growth the 'new normal' for Europe? April 2017.
[31] Bakker, Crafts and Woltjer, The sources of growth in a technologically progressive economy: the United States, 1899-1941, September 2017. *https://warwick.ac.uk/fac/soc/economics/research/centres/cage/manage/publications/341-2017_crafts.pdf*
[32] Byrne and Sichel, The productivity slowdown is even more puzzling than you think, August 2017. *https://voxeu.org/article/productivity-slowdown-even-more-puzzling-you-think*
[33] Robert Solow, New York Times Book Review, July 12 1987.
[34] Alan Greenspan, The revolution in information technology, March 2000. *https://www.federalreserve.gov/boarddocs/speeches/2000/20000306.htm*

Wireless connectivity and devices, coupled with the cloud, are now at the forefront of connected computing. The evolution of mobile networks from voice and SMS networks to data networks coupled with the parallel development of smartphones and the internet of things (IoT), cloud computing, machine learning and new business models including platforms (some of which are only feasible with mobile), constitutes a further wave of connected computing.

However, at scale this is a comparatively recent phenomenon, and one might expect the full payoff with a lag:[35]

> *"Just as a long lag transpired from the development of the PC in the early 1980s to the subsequent pickup in labor productivity growth, there could be a lagged payoff from the development and diffusion of extensive connectivity, handheld devices, and ever-greater and cheaper computing power."*

An illustration of the way in which this is playing out is the plan by IBM to offer detailed and timely weather forecasts drawing on a range of data sources, including the barometric sensors in smartphones.[36] This illustrates how mobile connectivity allows data to be crowd-sourced, and predications based on such data to be shared in real time. It also illustrates how the benefits of connectivity, for example by allowing crowd sourced data to improve forecasts for all users, can exceed the private benefits of connectivity for individual users.

[35] Byrne, Sichel and Oliner, Is the Information Technology Revolution Over? March 2013. *https://www.federalreserve.gov/pubs/feds/2013/201336/201336pap.pdf*

[36] IBM, New IBM Weather System to Provide Vastly Improved Forecasting Around the World, January 2019. *https://newsroom.ibm.com/2019-01-08-New-IBM-Weather-System-to-Provide-Vastly-Improved-Forecasting-Around-the-World*

5. Benefits of expansive mobile

Mobile broadband already supports a diverse and growing set of applications – it is a general-purpose technology.

Expansive mobile, including 5G deployment, would deepen and broaden the role of mobile as a general-purpose technology, thereby underpinning transformation throughout the economy and the realization of associated benefits.

Expansive mobile would improve the availability and affordability of mobile connected computing; and, via flexibility to offer bespoke service levels, extend wireless to areas ranging from ubiquitous support for low-power low-data rate internet of things applications to ultra-low latency applications in industry. This would not only help sustain the contribution of mobile to productivity, income and employment growth; but deepen it.

In terms of specific applications, as with existing mobile, much of what emerges and is valued may not be clear, absent hindsight. The way in which mobile connected computing resulted in widespread use of mapping and navigation, rich communications and online platform-based services including transportation was not fully and widely anticipated in advance. However, as William Gibson said in 1993:

> *"The future is already here — it's just not very evenly distributed"*

As a way of anticipating the longer-term future this adage isn't complete, but it is helpful, and points to the following possibilities extrapolating from what we can see now.

Expansive mobile versus a business as usual counterfactual

Mobile will continue to evolve, so the counterfactual to expansive mobile is not no change, but business as usual in terms of policy, regulation and investment. However, there are reasons for believing that pursuit of expansive mobile would represent a step change for Europe:

- First, the deployment and use of mobile data networks in Europe has lagged that in North East Asia and the United States and is expected to continue to do so under a business as usual scenario. There is scope to do much better in terms of an enabling policy environment.
- Second, evidence suggests that the spill-over benefits from expansive mobile are likely to significantly exceed private benefits; so the payoff from initiatives to promote investment - beyond the increase from removing barriers to investment alone – would be large.

Both of these considerations imply that whilst it is not possible to be precise about the benefits of expansive mobile versus business as usual, the incremental benefits are likely to be large.

More people connected more of the time

Whilst single network outdoor 4G population coverage in Europe was 98% in 2017, coverage is 91% measured as the average of each operator's coverage within each country.[37] Indoor and geographic coverage are significantly lower but are not reported at the EU level. There is a coverage and measurement gap.

[37] https://ec.europa.eu/digital-single-market/en/connectivity

In 2017 69% of Europeans had a smartphone, and 18% of households had no broadband access via smartphone or fixed broadband at home.[38] 20% of European adults have never used the internet or use it less than once a week.[39] There are significant adoption and usage gaps.

Whilst mobile has lowered barriers to digital inclusion,[40] inclusion remains a challenge. Improved incentives for investment in extending mobile coverage and upgrading networks to improve service quality and lower unit data costs would help, as would reframing digital inclusion initiatives around mobile.

Digital exclusion is also a barrier to online only or by default provision of government services, whilst gaps in mobile coverage and smartphone adoption limit the potential for app-based services which could have particular benefits, for example, in preventative health and health care.[41]

Whilst it might be argued that mobile coverage expansion or device adoption and use is subject to diminishing returns, there are several forces that work in the other direction:

- Incremental coverage and adoption become more important as services shift to online and app-based provision.
- New applications may only be feasible or enable old ways of doing things to be dropped, when coverage is near ubiquitous.
- The benefits of a shift to online and app-based provision of government services, including innovative health and preventative health care services, is dependent on near universal availability and use to ensure comprehensive provision and use.
- Better utilization of assets, both as connectivity allows computing to shift to the cloud allowing more efficient utilization of computing resources and as peer-to-peer services allow better utilization of a range of assets. This shift from assets to services also lowers barriers for start-ups; whilst the decoupling of the benefits of ICT for tradeable cloud services from local investment in computing makes investment in non-tradeable connectivity more important.
- Network effects for peer-to-peer services (Metcalfe's law) since benefits grow more than proportionately with additional users. Coverage, as well as the number of potential users, matters for network effects since for a growing number of applications geographic coverage determines the likelihood that a real time interaction is feasible, for example, to order an Uber or send a rich message.

Connecting more people more of the time will prove transformational. It is a critical element of expansive mobile.

Multi-network resilience

As society and the economy come to depend on connected computing, we will increasingly value resilience. One way in which mobile connectivity can contribute to resilience is through its flexibility to adapt to demand (for example, the rapid deployment of capacity related to planned or unplanned events) and as a backup when fixed connectivity is lost (by reverting to mobile

[38] European Commission, E-Communications and Digital Single Market, Eurobarometer 462, Published July 2018, fieldwork April 2017. https://ec.europa.eu/digital-single-market/en/news/e-communications-and-telecom-single-market-special-eurobarometer-report

[39] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Digital_economy_and_society_statistics_-_households_and_individuals#Internet_usage

[40] Williamson and Wood, Mobile inclusion - a digital future for all, March 2015. http://www.plumconsulting.co.uk/pdfs/Plum_March_2015_Mobile_inclusion_-_a_digital_future_for_all.pdf

[41] For example, as highlighted in the UK National Health Service long-term plan, January 2019. https://www.longtermplan.nhs.uk/publication/nhs-long-term-plan/

or via routers that incorporate fixed and mobile access). The resilience gains from availability of multiple networks are likely to be greater than those from improvements in reliability of a single network.[42]

Network security

We have also become more aware of the range of threats to security. 5G will require, and help enable, new levels of network security, for example via the operation of virtual independent network slices.[43]

New applications

New applications will flow from ubiquity, but they will also flow from more capable and flexible bespoke wireless connectivity. Examples include:

- More connected things, including sensors embedded in smartphones and dedicated internet of things sensors. Mobile examples include the use of anonymised user location data to assist in disaster relief[44]; and scope to offer detailed and timely weather forecasts drawing on data sources including the barometric sensors in smartphones.[45] These applications benefit from ubiquity, whilst internet of things applications require bespoke low-power connectivity so that devices can operate for long periods of time without needing an external power source or recharging.
- More consistent availability of higher bandwidth to support, for example, remote general practitioner consultations via video. The UK National Health Service long-term plan notes that[46]: *"Over the next five years, every patient will have the right to online 'digital' GP consultations, and redesigned hospital support will be able to avoid up to a third of outpatient appointments - saving patients 30 million trips to hospital, and saving the NHS over £1 billion a year in new expenditure averted."*

Enterprise & industrial use

Unlike the first phase of computing (mainframes), mobile computing was primarily consumer driven at first.

That has shifted, with growing adoption of enterprise apps and dedicated enterprise app developers[47], collaborative efforts to promote development and adoption of mobile and mobile applications by enterprise[48], and the exploration and implementation of wireless applications in industry – referred to as Industry 4.0.[49]

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[42] Assuming network failures are independent, if the likelihood of a day long network failure were 10% per annum, the likelihood of both networks failing together on the same day is less than 0.001%, or one 9's single-network resilience is transformed into better than four 9's dual-network resilience, a level of resilience that would be -essentially impossible and certainly prohibitively costly - to engineer for a single network.

[43] Ericsson, A guide to 5G network security. *https://www.ericsson.com/en/security*

[44] UN and GSMA, The State of Mobile Data for Social Good Report, June 2017. *http://unglobalpulse.org/sites/default/files/MobileDataforSocialGoodReport_29June.pdf*

[45] IBM, New IBM Weather System to Provide Vastly Improved Forecasting Around the World, January 2019. *https://newsroom.ibm.com/2019-01-08-New-IBM-Weather-System-to-Provide-Vastly-Improved-Forecasting-Around-the-World*

[46] National Health Service (NHS), Long-term plan, January 2019. *https://www.longtermplan.nhs.uk/publication/nhs-long-term-plan/* "…total
See also regarding the potential health benefits from the use of connected computing: Branstetter and Sichel, The Case for an American Productivity Revival, June 2017. *https://piie.com/system/files/documents/pb17-26.pdf*

[47] For example, Mubaloo. *https://mubaloo.com*

[48] For example, between Apple and partner companies providing services to enterprise.
https://www.apple.com/uk/business/partners/
https://www.apple.com/uk/business/success-stories/

[49] *https://www.ericsson.com/en/cases/2017/smartfactory* and *https://www.ericsson.com/en/networks/trending/insights-and-reports/5g-for-manufacturing*

Case study examples of industry 4.0 include use of wireless monitoring of tools to optimise maintenance[50], automation in the mining industry[51] and the use of millisecond latency 5G for real time control in the manufacture of components of turbines such as aircraft jet engines, an application that could create annual savings of approximately EUR 27 million for one single factory, and up to EUR 360 million globally.[52]

This shift will be accelerated by expansive mobile including ubiquitous coverage, enhanced capacity and capability and service levels tailored for specific enterprise and industrial applications. A growing range of applications will also depend on investment in 5G.

[50] Ericsson, The world's first cellular IoT-based smart factory, September 2018. *https://www.ericsson.com/en/networks/cases/cellular-iot/cellular-iot-enables-smart-factories/industry-4-0*

[51] Ericsson, A case study on automation in mining, June 2018. *https://www.ericsson.com/en/trends-and-insights/consumerlab/consumer-insights/reports/a-case-study-on-automation-in-mining*

[52] Ericsson, Bringing 5G business value to industry - A case study uncovering 5G's potential for real-time control in manufacturing. *https://www.ericsson.com/en/trends-and-insights/consumerlab/consumer-insights/reports/5g-business-value-to-industry-blisk*

6. The value of expansive mobile

A number of studies have considered the benefits of connectivity and associated applications. There are two general points to note regarding such assessments:

- First, that connectivity and applications are complements, and that benefits are a joint product of the two.
- Second, that a level of fixed and mobile connectivity exists already, and the benefits of enhanced connectivity are relative to this counterfactual.

Existing studies are not always clear on these points, with a number of studies of fixed broadband in particular attributing benefits to enhanced broadband that may already be delivered – at least for many households - by existing broadband.[53] Disentangling what is genuinely incremental is not straightforward, but it is nevertheless important to be clear regarding the question under consideration.

Existing studies

There are a range of existing studies, though many focus on fixed rather than mobile connectivity. However, two published in 2018 are mentioned because they focus on the benefits of 5G and improved mobile coverage respectively and include reviews of existing literature.

The first, by Australian Department of Communications and the Arts in relation to 5G, focusses on scenarios of potential long-run growth impacts from enhanced mobile.[54] The study also highlights the role of mobile connectivity as a general-purpose technology which enables a wide range of applications throughout the economy.

The second, by UK regulator Ofcom, considers the benefits of increased mobile coverage, and concludes that there are positive spillovers and externalities which mean that privately profitable investment in relation to coverage can be expected to fall short of what is socially optimal.[55]

Focus of this study

The focus of this study is on expansive mobile - more capable and ubiquitous mobile and wireless networks capable of supporting a wider range of consumer, commercial and industrial applications - of fulfilling the promise of wireless as a general-purpose technology enabling benefits and spillovers throughout the economy.

The character of potential benefits was considered in the previous section. However, given their range and the fact that not all applications can be anticipated (just as the full range of present-day applications of electricity were not anticipated), the approach to quantification is necessarily broad brush.

The primary focus is on the 'growth accounting' literature which seeks to decompose and understand the impacts of information and communications technology on productivity growth. This provides a dynamic basis for assessing the impact of expansive mobile as a general-purpose technology. Other policy objectives in relation to employment, inequality and the environment are also touched on.

In addition to considering the potential dynamic benefits of expansive mobile for future

[53] NESTA, Exploring the costs and benefits of fibre to the home (FTTH) in the UK, March 2015. https://www.nesta.org.uk/report/exploring-the-costs-and-benefits-of-fibre-to-the-home-ftth-in-the-uk/
[54] Department of Communications and the Arts, Impacts of 5G on productivity and economic growth, April 2018. https://www.communications.gov.au/departmental-news/impacts-5g-productivity-and-economic-growth
[55] Ofcom, Consultation: Award of the 700 MHz and 3.6-3.8 GHz spectrum bands – Appendix A.11, December 2018. https://www.ofcom.org.uk/__data/assets/pdf_file/0021/130737/Annexes-5-18-supporting-information.pdf

productivity growth, estimates of the existing private consumer surplus (the difference between what consumers pay and what they would be willing to pay) from existing smartphone adoption and future data growth are considered. These provide a contrast to, and foundation for, considering dynamic benefits including spill-overs.

Consumer surplus associated with smartphones and data growth

Rennhoff and Routon (2016) estimate the consumer surplus from smartphones for the US using data for 2006-2013 and conclude that:[56]

> *"The aggregate monthly wireless consumer surplus from smartphones is approximately $7.03 billion (an $84.36 billion annual surplus) in the U.S. Hausman (2002) estimates cell phone introduction increased consumer surplus by $52.8-$111 billion annually, implying smartphones have had a comparable, and perhaps even a larger effect than its predecessor."*

Given that apps stores were launched in 2008, and the proliferation and evolution of applications with increasing dependence on connectivity since 2013, consumer surplus can be expected to have grown.

A forward-looking approach, which aims to estimate the increase in consumer surplus associated with the growing capacity, efficiency and utilisation of mobile data networks, is to value the increased area between the demand curve (willingness to pay) and supply curve (cost) over time based on assumptions regarding network evolution and consumer demand.

Williamson and Wood (2017) estimate the net present value of additional consumer surplus to 2030 (using a 4% social discount rate) due to additional spectrum availability and corresponding unit price declines and traffic stimulation:[57]

> *"We focus not on the overall benefits of smartphone and app use but on the incremental benefits of additional data capacity. We assume the downlink spectrum grows from 130 to 430 MHz by 2030 and that this drives both productive and dynamic gains as unit costs decline and output grows… Assuming isoelastic demand… the increase in data traffic) from 19-fold by 2030 to 64-fold by 2030 with additional spectrum) results in additional consumer surplus of 72 per cent over productivity gains alone. The overall benefit is approximately €140 billion in present value terms for Europe"*

The two estimates reported above differ. The first is the annual consumer surplus associated with smartphones in the US; whilst the second is the net present value to 2030 of incremental consumer surplus associated with the increase in data use from additional spectrum availability in Europe. The GDP of the US and EU-28 are broadly comparable at around $20 trillion and $17 trillion respectively (the US consumer surplus from smartphones is therefore equivalent to about 0.4% of GDP).

Dynamic growth impacts including spillovers

The estimates of consumer surplus discussed above are useful, but do not tell us what impact expansive mobile might have on productivity and income growth when account is taken of spill-overs throughout the economy.

To get a feel for the possible magnitude of such spill-overs we consider the growth accounting literature which utilises specifically constructed

[56] Rennoff and Routon, Can you hear me now? The rise of smartphones and their welfare effects, *Telecommunications Policy*, Volume 40, 2016.

[57] Williamson and Wood, Mobile value, spectrum and data demand – a bootstrap approach to estimation, *Info*, Volume 19(1), 2017.

price deflators for the components of ICT (rather than official deflators given their shortcomings).

As discussed in Section 4, with adjusted deflators, the estimated contribution of ICT to growth is significant and ongoing.[58] Other studies utilise growth accounting and econometrics to tease out the contribution of connectivity and cloud including spillover and network effects.

These include studies on the US by Corrado (2011)[59], eight European countries (Austria, Finland, France, Germany, Italy, the Netherlands, Spain and the United Kingdom by Corrado and Jäger (2014)[60], the UK by Goodridge *et al* (2014) [61] and a study focussed on cloud services – which are intimately linked to connectivity – by Byrne and Corado (2017)[62].

Whilst the precise findings of the studies differ, they are broadly aligned. The findings are as follows:

- Whilst the ICT share of GDP is around 5%, the contribution to growth is around one-third to one-half of pre-financial crisis growth, or around one percentage point per annum.
- Connectivity/cloud contributes around half of the growth contribution of ICT, roughly 0.5 percentage points per annum.
- The majority of benefits flow from network effects and spill-overs rather than from the productivity growth of the connectivity sector *per se* (though properly measured the direct/private benefits are material given the rapid rate of productivity growth for the communications sector).

These contributions appear ongoing post the 2007 financial crisis, though masked by a slowdown in productivity growth in the rest of the economy.

Whilst the overall slowdown is not fully understood, there are sound grounds (due to lagged effects in terms of payoffs and due to the shift from ICT capital to ICT services which temporarily depresses IT investment as IT capital utilization improves) for expecting a re-bound in overall productivity growth if the contribution from ICT and connectivity is ongoing.

Further, whilst it is not possible to be precise about the mobile contribution within connectivity, wireless connectivity is key to the ongoing pivot to mobile applications and services, and the development of new enterprise and industry applications.

EU-wide impact

Expansive mobile would not only help sustain the contribution of mobile to productivity, income and employment growth; but deepen it.

Assuming the impact on growth is 0.25% per annum (half of that for connectivity overall historically), the net present value of the impact out to 2030 would be equivalent to 14% of GDP. The impact on GDP and income per capita is shown for the EU in Figure 9.

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[58] Byrne, Oliner and Sichel, Prices of high-tech products, mismeasurement, and pace of innovation, April 2017. https://www.nber.org/papers/w23369
[59] Corrado, Communication Capital, Metcalfe's Law, and U.S. Productivity Growth, 2011. https://ideas.repec.org/p/cnf/wpaper/1101.html
[60] Corrado and Jäger, Communication Networks, ICT and Productivity Growth in Europe, December 2014. https://pdfs.semanticscholar.org/6661/5aba77005a9bf411f5618c65d4e695b22d69.pdf
[61] Goodridge, Haskel and Wallis, The "C" in ICT: communications capital, spillovers and UK growth, November 2014. https://spiral.imperial.ac.uk/bitstream/10044/1/18382/2/Goodridge%202014-10.pdf
[62] Byrne and Corrado, ICT Services and their Prices: What do they tell us about Productivity and Technology? September 2017 https://www.federalreserve.gov/econres/feds/files/2017015r1pap.pdf

Figure 9: Impact of additional growth of 0.25% per annum for the EU

	Base year EU-28	Increase in first year	Increase by 2030	Net present value
GDP	€15,300 bn	€38 bn	€470 bn	€2200 bn
Income per capita	€30,000	€75	€910	€4300

Member state impact

Figure 10 shows the member state impacts of a 0.25% per annum increase in growth, assuming all are able to benefit equally from expansive mobile (Appendix A includes the income effect of additional growth for all member states).

However, the extent and nature of the contribution would likely differ in practice, not because the underlying technology is only available to some (it is universally available); but because some member states are likely to prove better able to foster investment in expansive mobile and reap the rewards throughout the economy.

The past contribution of ICT to productivity growth is included in the table, since it provides one indicator of member state capacity for benefiting from ICT. The contribution of ICT capital to growth is based on OECD estimates from 1985-2017 and does not include spillovers, which may more than double the overall contribution[63], but for which consistent estimates are not available for the countries shown. However, history is not destiny, and the potential of expansive mobile should, one hopes, motivate policy change.

Further, whether productivity and income growth manifests as employment growth, or income growth for existing employees, will depend on the existing level of employment and labour market policy. Whilst in the long-run productivity growth has proved neutral for employment, in the short-run growth can be expected to improve employment outcomes, particularly in countries with high existing unemployment (also shown in figure).[64]

Figure 10: Historical data alongside the impact of 0.25% growth by 2030 on income per capita

	ICT capital contribution 1985-2017[65]	Unemployment[66] December 2018	Income per capita 2017	Increase by 2030	Net present value
France	0.32%	9.1%	€32013	974	€4572
Germany	0.31%	3.3%	€37808	1150	€5400
Italy	0.27%	10.3%	€29035	883	€4147
Portugal	0.36%	6.7%	€22742	692	€3248
Spain	0.28%	14.3%	€27745	844	€3963
UK	0.36%	4.0%	€31120	947	€4445
Denmark	0.47%	5.1%	€38865	1182	€5551
Finland	0.21%	6.8%	€33146	1008	€4734
Sweden	0.61%	6.4%	€36975	1125	€5281

[63] Oulton, Long Term Implications of the ICT Revolution: Applying the Lessons of Growth Theory and Growth Accounting, November 2010. http://cep.lse.ac.uk/pubs/download/dp1027.pdf

[64] An estimate by the European Central Bank suggest a positive employment-GDP relationship with an elasticity of 0.55 for the Euro area. European Central Bank, The employment-GDP relationship since the crisis, ECB Economic Bulletin, Issue 6, 2016. https://www.ecb.europa.eu/pub/pdf/other/eb201606_article01.en.pdf

[65] OECD, Contributions to GDP growth, accessed 6 February 2019. https://stats.oecd.org/index.aspx?queryid=66347

[66] Eurostat. http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=une_rt_m&lang=en

Other non-income growth impacts

Whilst the focus above is on the impact on productivity, income growth and employment growth, the welfare effects of expansive mobile will be wider than these impacts.

In relation to leisure, the benefits of productivity growth can translate into increased income or leisure, and historically have resulted in gains in both leisure and income.

In terms of distributional impacts, expansive mobile should help reduce the digital divide, reduce work and income inequality by promoting growth and reducing unemployment, and increase the tax base thereby increasing scope for redistribution.

In terms of the environment, expansive mobile would open up options for substitution which could be environmentally beneficial, in particular if supported by other policy initiatives.

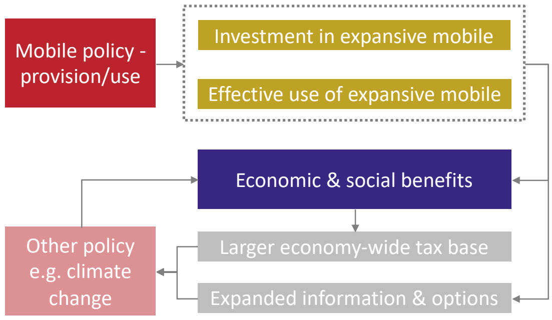
Therefore, in addition to productivity and income growth, it is reasonable to expect leisure, employment, equality and the environment to be enhanced by expansive mobile – provided in relation to inequality and the environment that other complementary policy measures are adopted which leverage productivity growth and the flexibility offered by expansive mobile to support innovative new approaches to policy challenges.

7. Policy linkages

It is important to focus on achieving a policy shift which not only removes barriers to mobile investment, but also supports utilisation of expansive mobile to transform activity throughout the economy.

Not only would this increase productivity and income growth, it also increases the economy-wide tax base, thereby increasing the scope to pursue other priorities. Expansive mobile and the applications flowing from it would also support improve evidence-based policy and an expanded set of policy options. Figure 11 provides a high-level view of the linkages.

Figure 11: Overview of policy linkages



Refreshing policy goals

The European Commission and member states have policy goals including fostering growth and jobs and completing the single market. There are also specific goals in terms of connectivity. In contract, independent national regulators have responsibility for regulation of the telecoms sector, and some have responsibility for spectrum policy. Their primary duty is to consumers.

Given that mobile connected computing is a general-purpose technology with spillover benefits throughout the economy, the remit of regulators is narrow in comparison with the broader interests at stake. A 'bias' in favor of investment is required, and this may require governments to offer strategic guidance to regulators and other policy makers who impact on the mobile sector.

Further, it is perverse that government policy in some jurisdictions is in part motivated by a desire to extract value from the mobile sector, rather than fostering investment beyond what the market alone would deliver given the positive spillover expansive mobile would deliver.

Aligning metrics with expansive mobile

The European Digital Economy and Society Index (DESI), which summarises relevant indicators on Europe's digital performance, includes metrics related to mobile but is weighted towards fixed connectivity and does not capture key attributes of expansive mobile. The DESI should be refreshed to reflect the pivot to mobile and the potential which expansive mobile would bring.

To illustrate, elements of the DESI that should be reviewed are the metric for mobile coverage (which focusses on outdoor coverage of premises) and price (which reflect bills rather unit prices). The review of metrics should go beyond these two aspects, though they are priorities where clear alternatives can be identified.

Coverage

The priority in terms of coverage is shifting from population (proxied by outdoor coverage of premises) to geographic coverage and indoor coverage. There is also interest, reflected in a number of member state proposals in relation to coverage, in covering specific infrastructure including road, rail and other transport corridors.

In considering obligations, attention needs to be given to their cost, the impact on the finances of investors and the impact in terms of capex priorities (given constraints not just on finance but availability of skilled staff etc.) – which could result in delay of other valued investment in order to meet obligations.

There is, arguably, growing recognition of the need to not only improve investment incentives but to encourage investment beyond what a consumer driven market alone would deliver. France[67] and Germany[68] have both taken steps in the direction of fostering expansive mobile, though questions have been raised regarding the commercial feasibility of the obligations related to the 5G auction in Germany.[69]

Performance

Coverage depends on quality of service, with higher data rates corresponding to lower coverage, *ceteris paribus*. The same network will deliver higher levels of coverage for low data rate internet of things (IoT), followed by voice and then data, with data coverage depending on the performance threshold specified.

One approach is to consider application requirements. For example, Ofcom adopted a stricter application-based basis for determining coverage in 2017, specified as the ability to complete a 90-second call without interruption and a speed of at least 2 Mbps to support mobile video.[70]

Ericsson have also considered user centric performance metrics including 'time to content' which depends not only on download speeds but also upload speeds:[71]

> *"Benchmarking some of the most popular global and local websites – including e-commerce, e-banking, news and entertainment – it was found that many pages require an uplink speed of at least 300 kbps to meet a target time-to-content of 4 seconds or less. Ultimately, it is up to each mobile operator to define app coverage targets depending on subscriber expectations."*

The above highlights the fact that network performance is not adequality reflected in a single measure, and measures may differ. There may also be some tension between the need for policy purposes to define network performance, and an operator specific approach depending on subscriber behaviour and expectations. However, an agreed definition is required for reporting purposes and benchmarking.

Price

The current measure of price utilised for the DESI is not actually a price but aims to measure bills (which reflect prices and consumption of services).[72] This is not the way we measure prices elsewhere, where prices are expressed per unit of consumption, for example, Euros per kWh of electricity. We would not say the 'price' of electricity had gone up if bills rose with consumption, even as the price per kWh fell. But that is precisely what we do in telecoms.

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[67] ARCEP, New deal for mobile, November 2018. *https://www.arcep.fr/en/news/press-releases/detail/n/new-deal-for-mobile-2.html*

[68] Federal Ministry of Transport and Digital Infrastructure, 5G Strategy for Germany, July 2017. *https://www.bmvi.de/SharedDocs/EN/publications/5g-strategy-for-germany.pdf?__blob=publicationFile*
Reuters, German 5G auction roaming proposal keeps barriers high for new entrants, August 2018. *https://uk.reuters.com/article/uk-germany-telecoms/german-5g-auction-roaming-proposal-keeps-barriers-high-for-new-entrants-idUKKCN1LF26T*

[69] Reuters, German 5G auction roaming proposal keeps barriers high for new entrants, August 2018. *https://uk.reuters.com/article/uk-germany-telecoms/german-5g-auction-roaming-proposal-keeps-barriers-high-for-new-entrants-idUKKCN1LF26T*

[70] Ofcom, Connected Nations 2017, December 2017. Paragraph 3.3. *https://www.ofcom.org.uk/__data/assets/pdf_file/0024/108843/summary-report-connected-nations-2017.pdf*

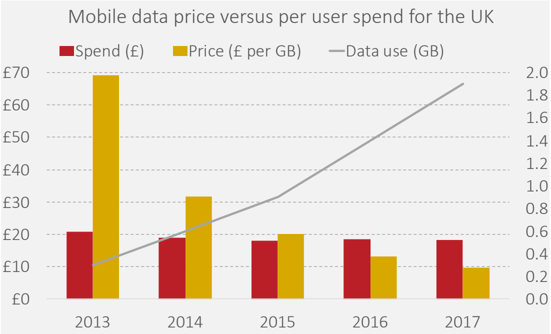
[71] Ericsson, uplink and slow time-to-content, November 2016. *https://www.ericsson.com/assets/local/mobility-report/documents/2016/emr-november-2016-uplink-and-slow-time-to-content.pdf*

[72] European Commission, Mobile Broadband Prices in Europe 2017. *https://ec.europa.eu/digital-single-market/en/connectivity*

Further, given the shift in emphasis to data and the growing shift to uncapped voice and SMS, (the elimination of roaming charges in the EU reinforces this shift), the approach to price metrics needs to change.

The focus, perhaps the sole focus, of a revised price measure should be the cost per unit of data rather than expenditure on mobile.[73] The difference between spend and price per GB is shown in Figure 12 for the UK, alongside data use per handset (right hand scale).[74]

Figure 12: The rapidly declining unit cost of mobile



Source: Communications Chambers, Ofcom

Whilst spend has remained roughly constant, the price of mobile data (per GB) fell 7-fold from 2013 to 2017.

A focus on the unit cost of data would also better align with underlying productivity growth[75], and would help promote a pro-investment stance, since investment in more efficient technology is the key way in which mobile unit costs and prices are reduced over time.

Aligning incentives with expansive mobile investment

The FCC published a '5G FAST Plan' in September which is notable for its brevity, it fits on a single page.[76] It includes three calls to action: (1) pushing more spectrum into the marketplace; (2) updating infrastructure policy; and (3) modernizing outdated regulations. As a broad outline, it's all there. China too has highlighted 5G commercialisation and the development of an industrial internet as national priorities.[77] [78]

Spectrum

More spectrum. There are, however, challenges in Europe that the US does not face. First, ensuring that spectrum planning and release is coordinated across member states. Second, whilst in the US spectrum is unencumbered by recurring fees and periodic renewal of rights; Europe is plagued by uncertainty and regulatory opportunism regarding continuity of spectrum rights and fees[79], discouraging investment and spectrum trading. Third, mid-band spectrum is fragmented in many member states and there is insufficient cross border coordination in relation to spectrum assignment, which acts as an impediment to 5G deployment.

Europe has attempted to address these issues with limited success in the past, given member

[73] Williamson, The price of telecoms – getting it right – why it matters, 2018. http://www.commcham.com/pubs/2018/2/8/the-price-of-telecoms-getting-it-right-why-it-matters.html
[74] Ofcom, Pricing trends for communications services in the UK, May 2018. Based on Ofcom Figure 4 data. https://www.ofcom.org.uk/__data/assets/pdf_file/0030/113898/pricing-report-2018.pdf
[75] Heys (Office of National Statistics), Measuring the digital economy: Is history about to be rewritten? January 2018. https://blog.ons.gov.uk/2018/01/19/measuring-the-digital-economy-is-history-about-to-be-rewritten/
[76] The FCC's 5G FAST Plan, September 2018. https://www.fcc.gov/document/fccs-5g-fast-plan
[77] HSBC, 5G in China - Upgrading the national infrastructure, February 2019.
[78] FT, 5G: Can Europe match the US and China on mobile networks?, January 2019. https://www.ft.com/content/650d3bf8-1e32-11e9-b2f7-97e4dbd3580d
[79] It has been argued that fees are necessary to ensure that operators face the opportunity cost of spectrum use. This is not necessarily the case since operators face ongoing trade-offs in meeting demand growth i.e., they face an opportunity cost for spectrum. However, government users of spectrum may not be constrained and may be unresponsive to opportunity cost – in which case recurring fees and/or compensation for the costs of vacating spectrum may be justified. Williamson, Keeping an eye on the prize – investment in mobile networks to deliver coverage, capacity & the 5G strategy: A reappraisal of recurring spectrum fees, May 2018. http://www.commcham.com/pubs/2018/5/3/recurring-spectrum-fees.html

state resistance. Nevertheless, the costs of the *status quo* approach need to be recognised, and creative ways forward explored.

These might include: narrowing the focus to those elements that matter most in terms of coordination whilst leaving discretion at the member state level in other areas; exploring ways of increasing confidence in continuity of spectrum rights beyond extending minimum license duration, for example, moving to rolling renewal by default with clear conditions and notice for any change; and exploring incentive based mechanisms along the lines of the US two-sided incentive auction as opposed to utilising mandate alone.

Infrastructure policy and regulation

Means for reducing planning delays and excess fees for infrastructure deployment should be an ongoing focus,[80] and where constraints or fees are imposed by local or regional government, consideration should be given to making coverage obligations conditional on local agreement to a code of conduct which would keep the costs of meeting national obligations in check. Otherwise local authorities can impose unreasonable costs on operators who are nevertheless obliged to provide deep coverage locally.

This suggested policy approach mirrors that adopted commercially by Verizon in relation to 5G in the US[81], where local agreement to certain terms is a pre-requisite to deployment.

Finally, whilst Europe has taken steps in relation to infrastructure costs, regulated access to mobile operators' own infrastructure may prove self-defeating to the extent that it blunts incentives for building, expanding and upgrading such infrastructure.

Increasing the payoff from expansive mobile

To benefit from expansive mobile, it needs to be utilised and the rest of the economy needs to be able to adjust to capitalise on its general-purpose nature.

In relation to digital inclusion, efforts should be re-targeted towards mobile devices and connectivity, which offer an easier route to adoption and applications use.

In relation to increasing the scope to benefit from expansive mobile throughout the economy, the outlines of what should be done are clear:

- First, the tendency to seek to ensure existing rules apply to new technology and business models should be abandoned in favour of a principle and problem-based approach which seeks to ensure that the objectives of regulation are achieved, but in ways that are permissive of new approaches.
- Second, the approach to regulation in key verticals should be proactively reviewed to ensure it is compatible with digital transformation - including via mobile connectivity and applications. An example is medical device approval, which may currently be incompatible with achieving the full potential from rapid innovation of mobile device and software-based approaches to care.[82]

[80] There may be lessons from reforms to address this issue in the US and Australia:
FCC, Accelerating Wireless Broadband Deployment by Removing Barriers to Infrastructure Investment - Declaratory Ruling and Third Report and Order, September 2018. *https://docs.fcc.gov/public/attachments/DOC-353962A1.pdf*
ACMA, Industry Code C564:2018 - Mobile Phone Base Station Deployment, December 2018. *https://acma.gov.au/-/media/Networks/Information/pdf/Mobile-Phone-Base-Station-Deployment-Code-C564_2018-pdf.PDF?la=en*
[81] Verizon, The forthcoming competition between cities over wireless technology, December 2018. *https://www.verizon.com/about/our-company/fourth-industrial-revolution/forthcoming-competition-between-cities-over-wireless-technology*
[82] U.S. Food and Drug Administration (FDA) Breakthrough Device Programme – Final Guidance, December 2018. *https://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/HowtoMarketYourDevice/ucm441467.htm*

- Third, in deciding what rules are required, regard should be had to the role of mobile operators and online service providers in introducing competition into previously uncompetitive areas, and the use data by multi-sided platforms to support market governance which addresses (some) market failures previously addressed via law and regulation.[83]

Utilising expansive mobile to inform policy

Not only could a shift in policy stance support investment in, and use of, expansive mobile; expansive mobile would in turn support better policy by allowing better informed policy.

Mobile applications can provide (appropriately anonymised) data to support improved evidence-based policy development. Examples include the use of data from Strava[84] and Uber[85] to improve city and transport planning; and use of data from mobile to support medical research, for example, via the Apple software framework 'ResearchKit'.[86]

The policy 'option value' of expansive mobile

Finally, a general-purpose technology such as expansive mobile opens up 'policy option values' for government. There are three elements that result in additional policy option values:

- First, to the extent that productivity and national income growth are increased, there will be additional government revenue. This can be used to fund expenditure priorities and/or reduce taxes.
- Second, new means of government service delivery, for example in relation to health or job search, may become feasible if expansive mobile is available.
- Third, expansive mobile will open up additional substitution possibilities within the economy, thereby making other policy initiatives more effective and/or less economically costs.

The third point above deserves elaboration. Improved mobile communications may help substitute for travel and open up other possibilities, thereby helping mitigate greenhouse gas emissions.[87] However, the impact of improved communications *per se* on transport is ambiguous since communications and transport are both substitutes and complements.[88]

Yet, whilst the impact of enhanced communications on travel may be ambiguous or positive, enhanced communications introduces options that would increase the effectiveness and/or lower the economic cost of other policies designed to reduce congestion or mitigate emissions i.e. it is complementary. For example, the response to a carbon tax would be greater if video communications, app-based transport, smart app/thermostats and other internet-of-

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83 Williamson and Bunting, Reconciling private market governance and law: A policy primer for digital platforms, January 2018. https://www.researchgate.net/publication/325618289_Reconciling_Private_Market_Governance_and_Law_A_Policy_Primer_for_Digital_Platforms

84 https://metro.strava.com

85 https://movement.uber.com/?lang=en-GB

86 https://www.apple.com/uk/researchkit/

87 World Economic Forum, Digital technology can cut global emissions by 15%. Here's how, January 2019. https://www.weforum.org/agenda/2019/01/why-digitalization-is-the-key-to-exponential-climate-action/

88 Mokhtarian, Telecommunications and Travel - The Case for Complementarity, Journal of Industrial Ecology, Volume 6(2), April 2002. https://onlinelibrary.wiley.com/doi/10.1162/108819802763471771

things based solutions[89] were widely supported by expansive mobile.

Conclusion

As discussed in Section 4 there is a large potential economic and social payoff from expansive mobile. Further, the social payoff from investment in expansive mobile exceeds the private payoff due to network effects and spillover benefits throughout the economy.

This points to the need for a supportive policy approach, and better alignment of regulatory decisions with broader public policy goals including productivity and income growth, which go beyond the remit of sector regulators.

Both supply-side constraints in relation to the mobile sector covering spectrum, infrastructure and regulation; and demand side constraints on adjustment throughout the economy to capitalise on the general-purpose nature of expansive mobile should be addressed.

However, in view of the spillover benefits of expansive mobile, the reorientation of policy should go beyond removal of constraints and include incentives to go beyond what the market would deliver. These could include funded obligations in relation to coverage extension and financial support for densification, potentially via neutral hosts.

The removal of value from the sector via fees and regulation should be replaced by a focus on growing the contribution throughout the economy, which will in turn enhance the tax base.

By undertaking this reorientation of policy, a virtuous circle will be created between investment in expansive mobile, its utilisation in a diverse range of applications and growth which will contribute both directly to societal welfare and to government finances.

Finally, the availability of expansive mobile would increase the effectiveness and/or lower the cost of policies focused on other objectives. For example, expansive mobile would expand the set of feasible policies and the range of possible responses to policies designed to reduce greenhouse gas emissions.

89 "ICT solutions such Internet of Things (IoT) can help reduce greenhouse gas emissions by up to 15% by 2030." Ericsson, Internet of things. *https://www.ericsson.com/en/about-us/sustainability-and-corporate-responsibility/environment/climate-action/sustainable-cities*

Appendix A: Calculated impact of a growth increment due to expansive mobile

Calculations assume an increment to growth from expansive mobile of 0.25% per annum. The net present values (NPVs) are calculated to 2030 assuming a 4% discount rate.

Historical data alongside the impact of 0.25% growth by 2030

	Whole economy (€)				Per capita (€)			
	GDP 2016 bn	Increase 2019 million	Increase 2030 million	NPV bn	Income per capita	Increase 2019	Increase 2030	NPV
EU	14958	38,458	467,891	2,197	29,983	75	912	4,282
Belgium	425	1,098	13,354	63	35,503	89	1,080	5,071
Bulgaria	48	129	1,571	7	15,376	38	468	2,196
Czechia	176	479	5,831	27	24,861	62	756	3,551
Denmark	282	732	8,906	42	38,865	97	1,182	5,551
Germany	3160	8,193	99,683	468	37,808	95	1,150	5,400
Estonia	22	59	718	3	23,275	58	708	3,324
Ireland	273	735	8,946	42	43,701	109	1,329	6,242
Greece	176	451	5,481	26	20,420	51	621	2,917
Spain	1119	2,916	35,475	167	27,745	69	844	3,963
France	2229	5,729	69,704	327	32,013	80	974	4,572
Croatia	47	122	1,490	7	18,187	45	553	2,598
Italy	1690	4,312	52,466	246	29,035	73	883	4,147
Cyprus	18	49	595	3	24,869	62	756	3,552
Latvia	25	68	822	4	20,128	50	612	2,875
Lithuania	39	105	1,283	6	22,672	57	690	3,238
Luxembourg	53	138	1,682	8	53,735	134	1,634	7,675
Hungary	114	310	3,773	18	19,739	49	600	2,819
Malta	10	28	344	2	26,666	67	811	3,809
Netherlands	708	1,843	22,418	105	38,633	97	1,175	5,518
Austria	356	925	11,251	53	38,165	95	1,161	5,451
Poland	427	1,168	14,209	67	20,107	50	612	2,872
Portugal	186	487	5,919	28	22,742	57	692	3,248
Romania	170	469	5,704	27	18,355	46	558	2,622
Slovenia	40	107	1,308	6	24,800	62	754	3,542
Slovakia	81	212	2,581	12	22,552	56	686	3,221
Finland	216	560	6,808	32	33,146	83	1,008	4,734
Sweden	463	1,188	14,454	68	36,975	92	1,125	5,281
UK	2403	5,845	71,112	334	31,120	78	947	4,445