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THE FUTURE OF BROADBAND POLICY, PART 2: TECHNOLOGICAL NEUTRALITY, PATH DEPENDENCY AND PUBLIC FINANCING

A REPORT BY THE FLORENCE SCHOOL OF REGULATION, COMMUNICATIONS & MEDIA AREA

This report has been prepared by the Florence School of Regulation, Communications and Media, at the Robert Schuman Centre for Advanced Studies, European University Institute.

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The Future of Broadband Policy, Part 2: Technological Neutrality, Path Dependency and Public Financing

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EXECUTIVE SUMMARY

In September, 2016, the European Commission published its plan to renew the regulatory framework for electronic communication services in the European Union. In addition to providing an answer to the need to modify rules in order to take due account of the massive technological and market developments of the last decade, this series of the Commission's initiatives (the Connectivity Package) appears to be driven by at least two major policy objectives. First, to create a regulatory environment that is able to boost the realisation of an effective and economically flourishing Digital Single Market in the EU. Second, to achieve ambitious connectivity targets by 2025.

The reform raises various challenges, and it can be discussed and analysed from different perspectives. This Report focuses on a specific issue only, that is, the approach contained in different parts of the Package, of departing from and bending technological neutrality to push investments and markets in the direction that policymakers consider desirable.

Technological neutrality is a widely accepted principle, which the European Commission has, until now, used to guide developments in the electronic communications services. However, the Package contains numerous references to fibre as a technology that offers better quality parameters than, for instance, copper or cable, and that is theoretically best placed to realise the very high capacity (VHC) networks for which the Commission is calling. This explicit preference for fixed, and fibre only, networks raises various questions, which this Report examines with the aim of contributing to the debate and helping to minimize the risks that are implied by the Commission's choice.

The Report starts with an analysis of the technological solutions that are presently most exploited in the Member States, in order to expand ultra-fast broadband coverage and to increase the speed available. It discusses the state of the art decisions in terms of investment, and considers the main implications for competition, market structures and policy possibilities.

It then explores the role of technological neutrality, as a policy instrument, in its interaction with different dimensions of the industry. In doing so, it recalls the relationship between the support of a specific technology and market structures, also in terms of the foreseeable effect on regulation, competition and private investments.

The Report continues by spelling out the risks and trade-offs of the Commission's choice to support the deployment of an all fibre network. It is undeniable that investments in FTTH are 'future-proof', in the sense that they represent a technological solution for fixed connectivity that is unlikely to be rendered obsolete by other solutions for fixed connectivity at any time soon. Yet, the fact that the objectives set by the Connectivity Package are very likely to entail greater public involvement in network financing suggests that a more refined notion of 'future-proof' technology should be applied. In particular, whenever public investments are involved, "future-proof" choices should be taken to refer to investments that maximize the overall benefits for society for the long-term foreseeable timespan. A policy that disproportionately focuses on the promotion of an all fibre fixed network, risks nudging the evolution of the market in a single direction, which may result in the creation of new market bottlenecks and forestall innovation in other technologies.

Moreover, the Report argues that if one broadens the view in relation to the range of technologies whose diffusion may be welfare-enhancing, it is all but clear that a strong preference for FTTH only should emerge. Fixed connectivity technologies are only one of the set of relevant technologies, but surprising changes have been brought about and are about to intensify ,due to the increased performance of wireless technologies, both mobile (LTE and 5th generation – 5G) and fixed (Fixed Wireless Access networks that connect fixed points with a wireless link). A mix between wired and wireless technologies may constitute a cheaper and safer option that will enable Member States to reach the most difficult targets, especially in terms of covering the areas of persistent digital divide quickly.

Furthermore, wireless solutions may turn out to be 'future-proof' from a more classical and dynamic perspective: whenever uncertainty about the real extent of the demand for VHC is binding for operators' investment policies, meaning that investment will only be undertaken in potentially profitable areas if demand reaches a given threshold, wireless technologies may be a solution that allows dynamic discovery of the real extent of the demand at significantly lower cost than fixed connectivity solutions.

The Report also points out that the Commission's strategy may fail to take into due account the diversities of the technologies that are already available at national level, and could thus contribute, in the end, to accentuating the differences among the Member States, to the detriment of the Digital Single Market objective and, in the final analysis, to the achievement of EU-wide connectivity targets. In doing so, the Report looks at the situations in various Member States, at their disparities, in terms of infrastructure, and at the need to cope with the issue of path dependency in order to understand how this may affect the evolution of network investments.

Finally, the impact on private and public investments of a non-technologically neutral regulation is analysed. Artificially picking a winning solution, or aiming at connectivity targets that the demand cannot sustain, risks diverting or delaying private investments and creating a need for greater public intervention. In fact, investors would be deprived of the necessity to continuously analyse which type of technology best fits the current estimates of the demand for connectivity and, in turn, deciding which technology to use and where to invest, because it appears to be the best option for each business case. Considering that the Package seems to favour fixed solutions, this reaction could be amplified with regard to wireless technologies, and thus negatively affect the development of 5G, which, however, is also expected to contribute to the achievement of the connectivity targets.

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CHAPTER I. Introduction

> *When these difficult Cases occur, they are difficult chiefly because while we have them under Consideration all the Reasons, pro and con, are not present to the Mind at the same time; but sometimes one Set present themselves, and at other times another… Then during three or four Days Consideration I put down under the different Heads short Hints of the different Motives that at different Times occur to me for or against the Measure. When I have thus got them all together in one View, I endeavour to estimate their respective Weights…and thus proceeding I find at length where the Ballance lies.*
>
> *Benjamin Franklin (1772), Letter to Joseph Priestley.*

On 14 September, 2016, the European Commission adopted a set of initiatives and legislative proposals that aimed to place the EU at the forefront of Internet connectivity, a pre-condition for the Digital Single Market to thrive. This "Connectivity Package" is composed of: a new European Electronic Communications Code (EECC), which merges four existing telecoms Directives (Framework, Authorisation, Access and Universal Service Directive)[1]; an updated Regulation on the Body of European Regulators of Electronic Communications (BEREC)[2]; and a Regulation to support local communities in providing free public Wi-Fi to their citizens[3]. Together with these legislative proposals, the European Commission has issued two additional policy papers: the "Communication aiming to build a European Gigabit Society" (COM (2016)587)[4], and the "5G Action Plan" (COM(2016)588)[5]. These documents establish a set of new, non-binding connectivity targets for a competitive Digital Single Market (DSM) that is to be reached by 2025, which are, mainly: (i) the availability of Gigabit connectivity for all key social institutions, like schools, transport hubs, universities, hospitals, as well as "digitally intensive enterprises"; (ii) a download speed of at least 100Mbps for all European households; and (iii) the availability of 5G connectivity in all urban centers and major terrestrial transport paths.

The package has been issued following, amongst others, the results of a public consultation that the European Commission launched last year in order to understand and assess the needs in relation to Internet speed and quality beyond 2020, by taking into account all of the stakeholders' views: households, businesses, public institutions, in order to develop adequate *future-proof* public policies.

So far, to promote the development of the digital economy and society, the European Commission has intervened by using several different policy approaches, from setting targets for coverage, the adoption and speed of Internet connections, to adopting regulatory

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[1] The proposal, together with its accompanying documents, is available at: https://ec.europa.eu/digital-single-market/en/news/proposed-directive-establishing-european-electronic-communications-code

[2] Available at: https://ec.europa.eu/digital-single-market/en/news/proposed-regulation-establishing-body-european-regulators-electronic-communications-berec

[3] Available at: https://ec.europa.eu/digital-single-market/en/news/proposed-regulation-promotion-internet-connectivity-local-communities-and-public-spaces-wifi4eu

[4] The text is available at: https://ec.europa.eu/transparency/regdoc/rep/1/2016/EN/1-2016-587-EN-F1-1.PDF

[5] The text of the Communication, together with that of the related Staff Working Document is available at: https://ec.europa.eu/digital-single-market/en/news/communication-5g-europe-action-plan-and-accompanying-staff-working-document

provisions with which to foster first the development of service-based competition and then having competitors climbing some sort of ladder of investment in the electronic communications market. As is known, forms of intervention have been both on the supply and demand-sides, and are generally technologically neutral.

Technological neutrality is a widely accepted principle which underpins the European 2002 Regulatory Framework. In accordance with Recital 18 of the Framework Directive 2002/21, EU Member States have to ensure that "*national regulatory authorities take the utmost account of the desirability of making regulation technologically neutral, that is to say that it neither imposes nor discriminates in favour of the use of a particular type of technology* […]".

In its actions, the European Commission has, until now, used technical neutrality as an instrumental principle through which to guide developments in the electronic communications sector. However, with the adoption of the Connectivity Package, the Commission appears to depart, at least partially, from this consolidated approach. In fact, the Package contains numerous references to fibre as being a technology that offers better quality parameters than, for instance, copper or cable, and that is theoretically best placed to realise the very high capacity (VHC) networks for which the Commission is calling.

This explicit preference for fibre only, and fixed, networks raises various questions. However,, first and foremost, it is important to adequately assess the risks and trade-offs of abandoning technological neutrality, in terms of market developments, competition and investments. This will be the leading thread of our study. In some ways, the present work is connected to, and represents, the continuation of the study prepared in 2016 by the Florence School of Regulation Communications & Media, to contribute to the public consultation on the needs for Internet speed and quality beyond 2020.[6] In that previous study, the focus was mainly on the effect on market dynamics and competition of very high "public" targets for broadband coverage and speed, a theme related to the respect for, or the abandoning of, the technological neutrality that is investigated here.

After this Introduction, Chapter II of the Report will set the stage for the analysis by presenting the technological solutions that are presently most exploited in Member States in order to expand ultra-fast broadband coverage and speed. The chapter will discuss the state of the art decisions in terms of investment, and will consider the main implications for competition, market structures and policy possibilities.

In Chapter III, the Authors will focus on the risks and trade-offs of the Commission's choice to support the deployment of an all fibre network, while bearing in mind that there is no consensus in the specialised economic literature regarding the incremental benefits of rolling-out such a network, at least on a predictable time horizon, in comparison with the option of staying with the legacy network, or supporting gradual improvements on the same network (e.g., G.Fast). To be specific, the Report will analyse the value of technological neutrality from a broad theoretical perspective and will, specifically, look at the potential impact of the abandoning of technological neutrality on the development of wireless technologies and on the deployment of 5G and fixed wireless solutions.

Chapter IV will focus on a different angle on the problem that may be caused by picking a specific technology. In fact, this strategy may fail to take into due account diversities in the technologies that are already available at the national level, and could thus contribute, in the end, to accentuating the differences among Member States, to the detriment of the Digital Single Market objective and, in turn, to the achievement of the EU-wide connectivity targets. The Report will refer to the present situation various Member States, to the disparities in terms of infrastructure and the need to cope with the issue of path dependency. The theoretical focus of this part of the Report will be to specifically discuss the different

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[6] See: Florence School of Regulation, Communications & Media Area (2016), The future of broadband policy: public targets and private investment, available at: http://cadmus.eui.eu/handle/1814/38884.

dimensions of path dependency in order to understand how they may affect the evolution of network investments.

In Chapter V, the issue of shaping a regulatory environment that is not technologically neutral, and its impact on private and public investments will be faced. For example, artificially picking a winning solution, or aiming at connectivity targets that demand cannot sustain, risks diverting or delaying private investments and create the need for greater public intervention. In fact, investors would be deprived of the necessity to continuously analyse what type of technology best fits the current estimates of demand for connectivity and, in turn, to decide which technology to use and where to invest since it appears to be the best option for each business case. This reaction could be amplified with regard to wireless technologies. In fact, a regulatory environment that openly supports only fixed fibre solutions would probably discourage investment in the development of wireless solutions, and have an impact on the deployment of 5G, which, on the other hand, is also expected to contribute to connectivity targets.

In conclusion, building on previous research by the Florence School of Regulation, Communications & Media Area, the present Report will identify and assess the different areas of risk that are implied by departing from the principle of technological neutrality in order to stimulate further thought so as to address the concerns described above.

The Authors will conclude by making some policy recommendations to contribute to the debate that has been opened by the, at least partial, departure from the principle of technological neutrality that is presently enshrined in the Commission’s Connectivity Package, in an effort to clarify the issues and minimize the risks.

CHAPTER II. Technological solutions for ultra-fast broadband in Europe: state of the art, policy and market consequences

From a technological perspective, we know that the main factors that influence the deployment of broadband and ultra-broadband networks, irrespective of the speed and the different technological solutions, are the following:

a) the population density and dispersion as well as the country's topography;

b) the sub-loop length, influencing the potential capacity over the existing network;

c) the presence of alternative infrastructures.

In particular, the last 15 years have seen a steady increase in the capacity deliverable over the copper legacy network. Technologies like ADSL and, more recently, VDSL2 and Vplus, have obtained speeds on the old copper network capacities that were inconceivable at the end of the last century. A further upgrade, G.fast, will boost bandwidths to around 0.5Gbps, while being cost-effective and rapid to deploy. Already, today's technology is able to deliver 500 Mbit/s on copper over distances of 50/100 meters and 100 Mbit/s at 200/250 meters. As the numbers given clearly indicate, the legacy copper network can sustain high capacities, but only on relatively short distances. Hence, the use of the legacy networks as a "last mile" delivery medium requires the use of coding/decoding (active) devices in locations that are "not too far" from the user's premises (Cambini et al., 2016). Figure 1 reports the speeds that different copper-fibre hybrid technologies could presently offer, depending on the line length.

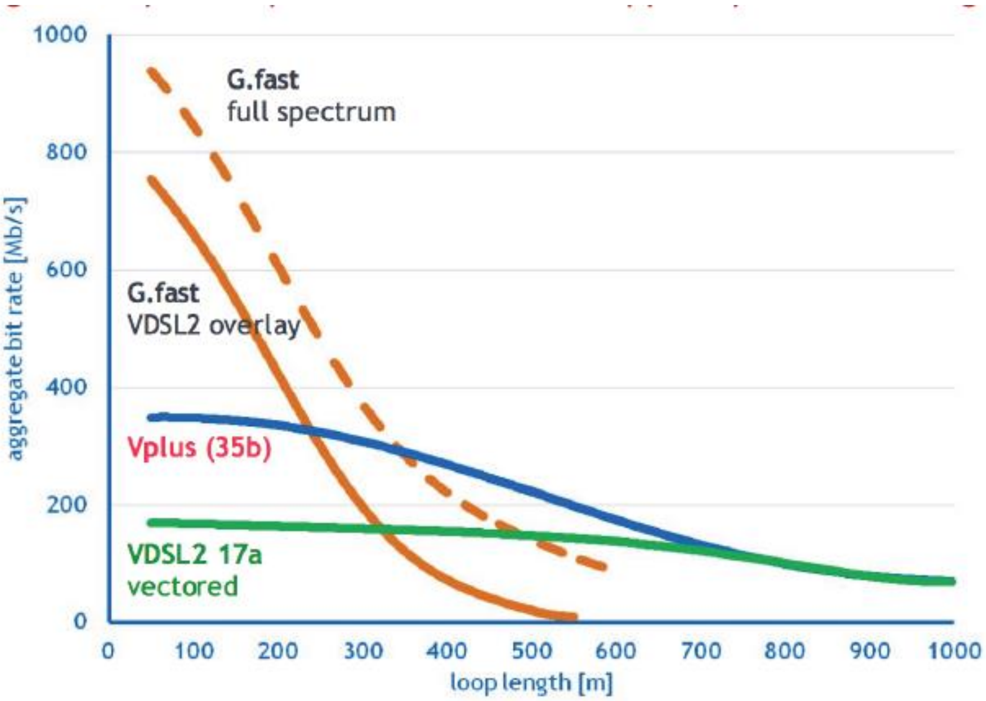

Figure 1: Speed capabilities over fibre-copper hybrid technologies (source: Williamson, 2017)

A recent report from Deutsche Bank (2016) shows the impact that geography/topography can have on the incumbents' decision to invest in fibre. Where there is a short sub-loop length (premises to cabinet) and a low number of lines per cabinet, the conditions are suitable for enhanced copper technologies, and this is in line with the push towards vectoring having achieved 59% coverage in Germany. Similarly, in Italy, Telecom Italia has progressed with an extensive FTTC roll out program having covered 56% of homes already.

In both these countries we note that there is a short loop length, 300m (Italy median 200m), as well as a low number of lines per cabinet, Germany with 130 lines per cabinet and Italy c.150 lines per cabinet. This favourable topography is as a result of a high proportion of apartments in these countries. The report also shows that, in Germany, c.60% of dwellings are flats, and in Italy this number is 50%. At the other end of the spectrum is the UK where only c.15% of dwellings are apartments, meaning a longer loop length and higher number of lines per cabinet, 500m and 300 lines per cabinet, respectively.

Differently from copper based technologies, fibre technology allows the delivery of billions of bits per second (10 Gbit/s) to the user's premises by means of long distance *glass fibre* connections. Fibre clearly is a disruptive alternative to the legacy networks. It changes the very structure of the network. There is no further need for a high number of hierarchically structured central offices; the ideal Next Generation Network (NGN) is "flat", with a limited number of central offices that are directly connected by long fibre tendrils to the user's premises. The so called *Fibre to The Home (FTTH)* solution is defined as being "future proof", in that it is expected to fully satisfy the (still uncertain) needs for bandwidth in the medium-long term. However, it also requires high investment and is disruptive for the incumbents, since the value of the "useless" legacy network is largely reduced by the advent of the fibre NGN. Boston Consulting (2016), for example, estimates a cost of €660 bln. to deploy FTTP/H networks in EU27, and 25 years to complete an FTTP network, given the current pace of realization.

The role of the drastic "game changer" of the FTTH solution has rapidly stimulated the development of an alternative technology that requires lower investment and that is less disruptive for the incumbent by making a clever use of the last mile of the legacy network. The rationale behind this alternative idea is simple: let us bring the fibre to a flexibility point, which is "not too far" from users' premises, install active devices in the flexibility point to code/decode the digital traffic, and route it through the last mile of copper (*secondary network*) by means of the VDSL2 technology or G.Fast (100 to 500 Mbit/s) up to the user's premises. The key question, then, becomes: where should we install the active devices of this mixed copper/fibre NGN?

Indeed, within the legacy networks there is a natural candidate for this role: the *street cabinets*. In the legacy network, the street cabinet had the role of being a *passive flexibility point,* where copper wires leading to the user's premises could be properly managed and flexibly connected to a central office and, from there, to the rest of the network. The number and topology of street cabinets differs from country to country. For example, Italy and Germany have a fairly dense distribution of street cabinets. In Italy, there are 168.500 cabinets (150.000 managed by Telecom Italia, 13.500 by Fastweb and 5.000 by Vodafone), with an average of less than 400 users per cabinet, and an average length of the secondary network of around 2-300 meters (Cambini et al., 2016). France, on the contrary, has longer secondary networks and a higher average distance between street cabinets and the users' premises. In Nordic countries, instead, due to the harsh climatic conditions, they make a limited use of street cabinets.

Street cabinets appear to be the ideal starting point for the creation of a mixed fibre-copper NGN network: they are already accepted in the urban landscape and are connected to the power network and the central offices by means of efficient ducts, in which fibre could be laid at minimum cost. This development requires the re-engineering of the cabinet to accommodate the active coding/decoding devices. However, these additional investment costs are drastically less than that of bringing the fibre up to the user's premises. Indeed, the Fibre to The Cabinet or Fibre To The Node (FTTC, FTTN) alternatives have been adopted in recent years in several European countries like Germany, Italy and the UK.

This solution is also emerging, at least partially, in Australia where, however, an original FTTH scheme, extended to the whole population, was converted to an apparently more rational, and definitely cheaper, mixed FTTN-FTTH scheme. The recent report of HSBC

(2017) shows that a cost-benefit analysis on the Australian plan indicated that FTTP's GBP12-18bn of additional expense, and the additional 6 to 8 years of deployment time, was simply not justified.

Such findings have been given further weight by the lack of interest in ultrafast services where these have been deployed. In practice, 80% of Australian customers take a line with a bandwidth of 25Mbps or less, and almost nobody asks for higher speed connections. Indeed, the distribution of customers across packages is consistent with the findings of Vertigan's (2014) research, which showed that the incremental willingness-to-pay falls to close to zero for speeds approaching 100 Mbps.

The problem of the low level of willingness to pay for very high speed connections is not only an Australian issue. Using data from a nationwide US survey that was administered during late 2009/early 2010, Rosston et al. (2010) found that a representative US household has a high marginal willingness to pay (WTP) for a high speed internet service, but a low marginal WTP for a very high speed service. According to the Authors, "*the representative household is willing to pay $20 per month for more reliable service, $45 for an improvement in speed from 'slow' to 'fast', and $48 for an improvement in speed from 'slow' to 'very fast'.*" This implies that a representative household is willing to pay a relatively higher premium for an upgrade of broadband speed from a "slow" service to a "fast" broadband service, but only a small additional premium for an upgrading from a fast to a 'very fast' service. This trend is similar also in the EU: a study by Frans van Camp (2012) based on data from a web-based survey of 3600 respondents in the Netherlands in 2010, showed that having a fibre connection that leads to symmetrical upload and download speeds appears to have limited appeal, given current bandwidth demand, and enjoys only a limited price premium of around 8%-15%, or around €5 in absolute terms. Overall, the existing evidence indicates that WTP is low, in particular for high-end FTTP-based services.

Moreover, there is no evidence that a larger capacity would boost broadband usage. In countries like Japan and Spain, which have widespread FTTP networks, data shows that actual usage per household is much lower than in the UK, where FTTC is the most prevalent high-speed technology. A report by HSBC (2017) shows that there is no current evidence of a correlation between the traffic generated by households and the FTTP/H coverage in a selected number of countries, as reported in Figure 2.

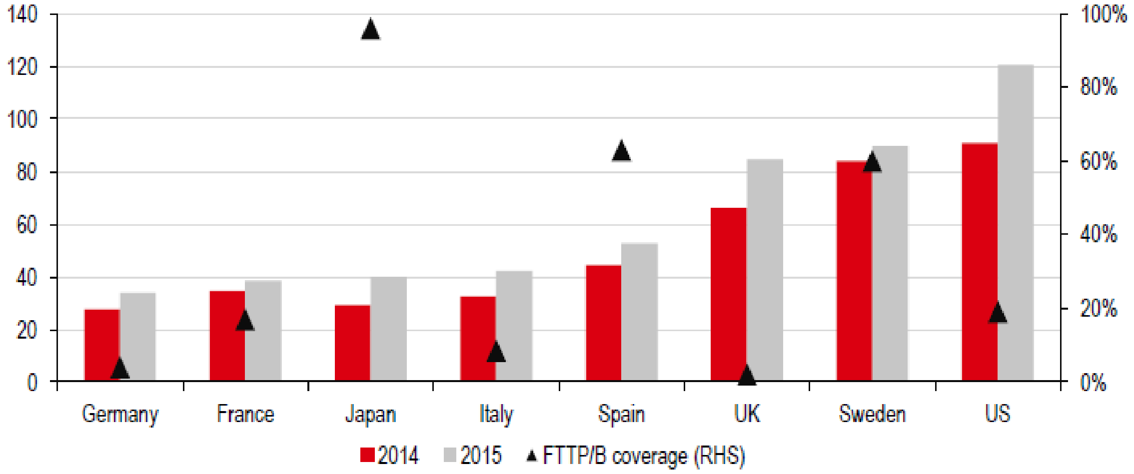

Figure 1: Traffic per household per month (in GB) and FTTP/H coverage. Source: HSBC (2017)

The technological scenario to provide fast and ultra-fast broadband connections to an EU citizen is not, however, restricted only to the FTTH-FTTC feud. The cable infrastructure, widely present in the US, but also in Germany, Belgium, The Netherlands, Portugal and, partially, in the UK, had been for many decades the preferred medium for the distribution of TV programmes. Technology, as in the case of the legacy copper network, immediately answered to the "*need for survival*" of the main cable operators (like Comcast in US) by turning the coaxial cable into a powerful broadband channel, able to deliver (with Docsis 3.0 protocol) hundreds of megabits per second to the user in an effective *triple pay scheme* (*TV+telephone+Internet*). Countries like Holland, Belgium or Malta have easily reached a 100% broadband coverage of the population, thanks to their legacy cable infrastructure. On the contrary, countries where the privileged TV distribution channel has always been *wireless broadcasting*, like Italy and France, have developed a limited or inexistent cable infrastructure and, hence, had to rely only on the legacy telecommunication network to reach the targets of European 2020 Agenda. Indeed, one particular relevant source of heterogeneity across EU countries refers to the geographic coverage of CATV networks and the associated intra-modal competition pressures (Vogelsang, 2015). Within Europe, CATV networks are predominantly relevant in urban regions.[7]

With this technological scenario in mind, let us now focus on the current European landscape by using the latest statistics released by the European Commission (2016).

Commission data show that *basic* broadband is practically universally available in the EU, when all major technologies (xDSL, cable, fibre to the premises (FTTP), WiMax, HSPA, LTE and Satellite) are considered. Fixed and fixed-wireless technologies cover 97% of EU homes. NGA technologies (VDSL, Cable Docsis 3.0 and FTTP), capable of delivering at least 30 Mbps download, are available to 71%. Moreover, 4G mobile coverage (LTE) increased by seven percentage points and reached 86% (see later). Due to the higher costs, coverage in rural areas is substantially lower for fixed technologies (91%), and especially for NGA (28%). In Figure 3, total coverage by technology at EU28 level is reported.

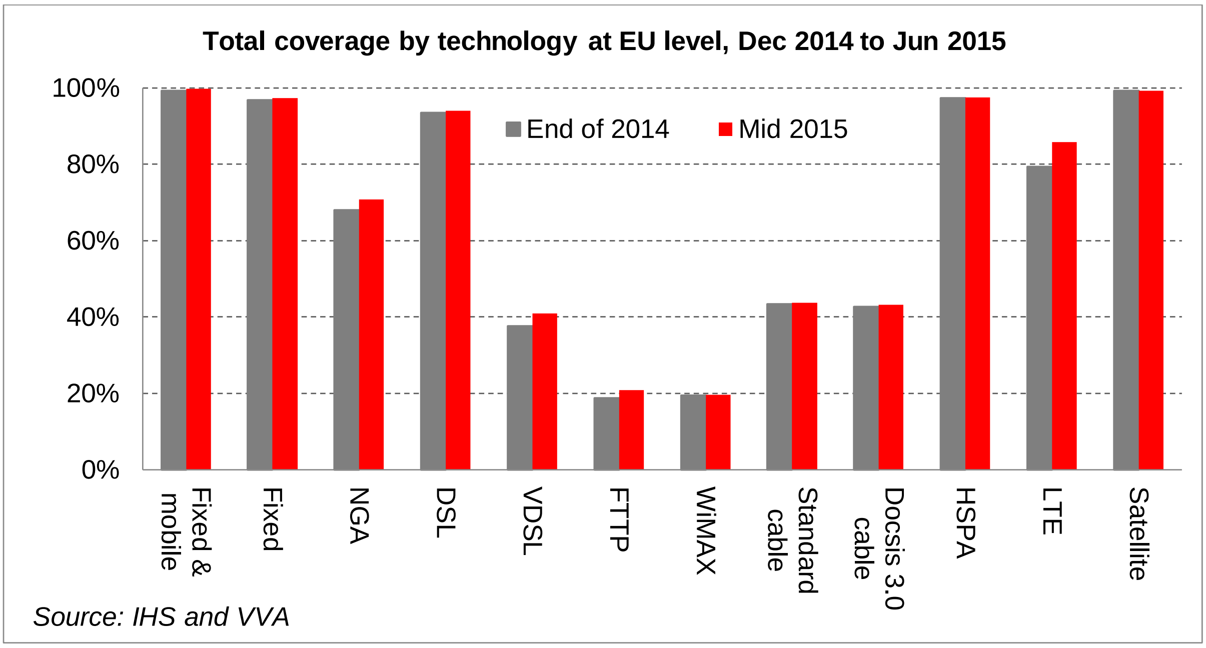

Figure 3: Total coverage by technology at EU level (July 2015, source: European Commission, 2016)

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[7] See, for example, the representation of Cable Europe on "Cable Facts & Figures". Available at: http://www.cable-europe.eu/wp-content/uploads/2015/12/CableEurope-FF-YE2014.pdf.

Figure 4 shows the diffusion of broadband services in EU28 based on all of the available wireline broadband technologies. According to this data, most broadband services are still based on various DSL connections (including FTTC), followed by broadband services from cable network suppliers (including DOCSIS). In contrast, it is only in a small number of countries that optical fibre-based FTTP Internet connections make up a substantial proportion of the total connections. A comparison of the EU Member states shows that the figures for a number of countries vary, sometimes considerably, from this average. In Belgium, for example, more than 50% of connections use the infrastructure of cable networks, whereas in other countries, such as Greece or Italy, DSL or VDSL is used almost exclusively.

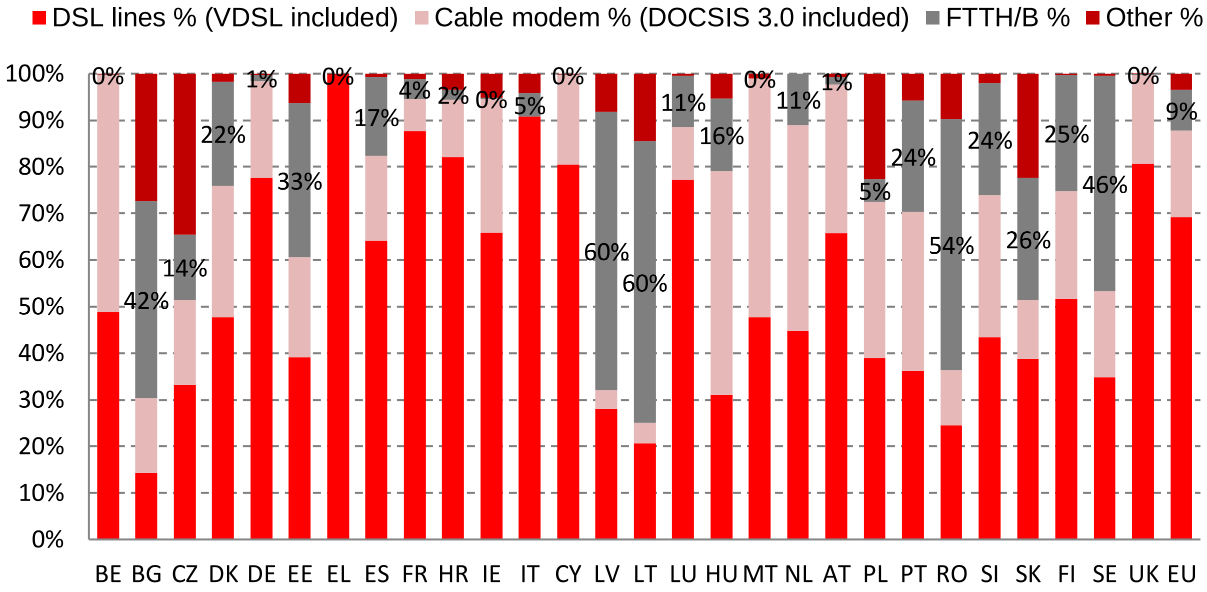

Figure 4: Fixed broadband subscriptions — technology market shares (July 2015, source: European Commission, 2016)

In contrast to Figure 4, Figure 5 shows the availability of ultra-fast broadband infrastructure coverage. It appears that countries leading the way in terms of the diffusion of FTTP connections are also among those who have high FTTP availability.

As Figures 3 and 4 show, in some northern and eastern European countries, FTTP connections account for a large share (say, above the EU average, i.e., >20%) of all wireline broadband connections. One basic difference can be attributed to the previously implemented public broadband incentive programmes and the far-ranging role of the public sector in the northern European countries. These were introduced in the Scandinavian countries at an early stage in relation to basic broadband connections (Briglauer and Gugler, 2013; Godlovitch et al., 2015). In terms of new FTTP broadband infrastructures, local authorities and utility companies are also strongly engaged in deployment activities in northern European countries (Crandall et al., 2013; Finnie, 2012). In the leading eastern European transition economies, the high-share of FTTP connections can largely be attributed to the poor quality of the first-generation network infrastructures. By contrast, the comparatively good quality of the copper-wire and CATV networks in western European countries represent high opportunity costs, particularly for investment in FTTP-based connection networks (Briglauer and Gugler, 2013).

As a consequence, in some of the largest western, central and southern European countries the existing FTTP deployment projects typically focus only on a small number of urban regions and are, on average, significantly below the deployment levels in eastern European countries (Figure 5).

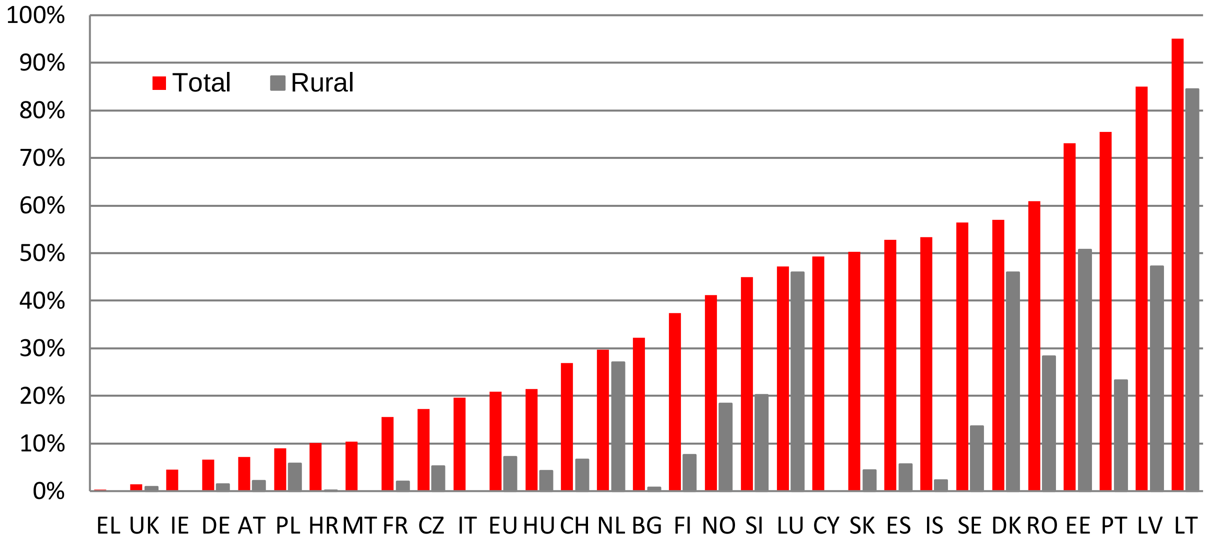

Figure 5: Fibre to the premises (FTTP) coverage (June 2015, source: European Commission, 2016)

It is important to note that this data is based on averages, and therefore do not necessarily indicate that all households apparently reached really have the indicated coverage, as requested by the EC's Digital Agenda for Europe (DAE) and gigabit strategy coverage targets. For example, households in urban areas, in particular, often have double levels of coverage with FTTC and DOCSIS cable Internet connections in most of the Member States (Figure 6).

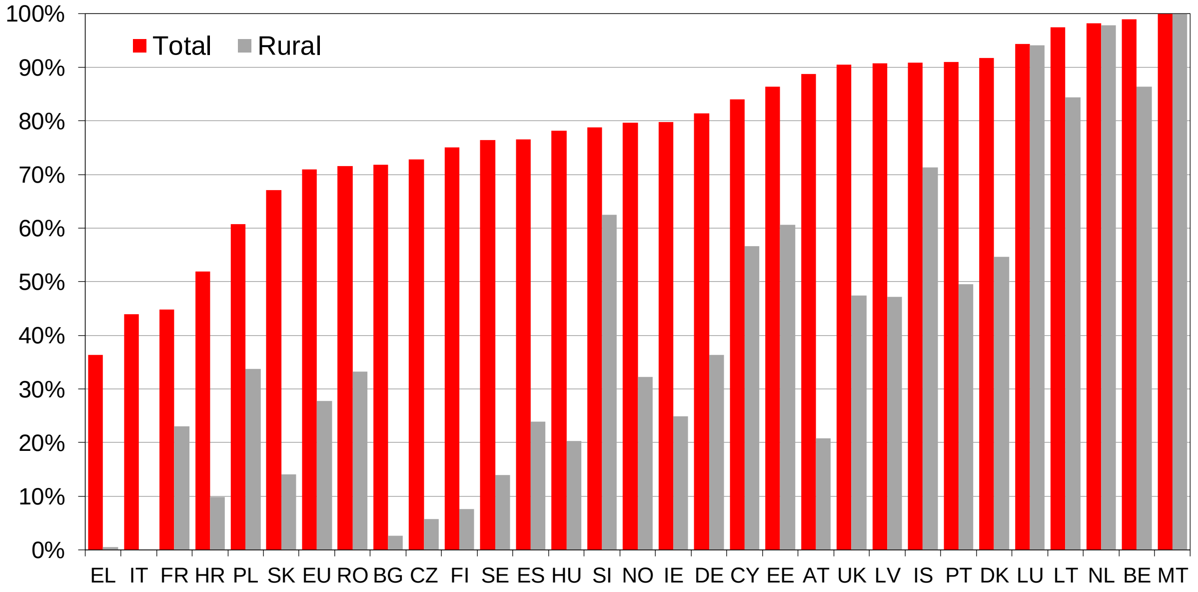

Figure 6: NGA coverage in rural areas and in total (mid-2015, source: European Commission, 2016)

The fixed network infrastructures that are based on different mixtures of cable, fibre and copper, and in different topological scenarios, like FTTH or FTTC, face a significant weakness: the high cost incurred by the operators in serving sparsely populated areas. The issue is not necessarily that of areas where the average population's income, or the "willingness to pay", is particularly low. Overly costly investments arise also in areas where the classical topology of the fixed networks (all of them, including NGN), are based on a structure of main central offices, hierarchically connected to smaller central offices and street cabinets, which has a roll out cost that is not recoverable on the basis of "reasonable" monthly tariffs being paid by the users. These areas are often called "market failure areas", or areas in the "digital divide", and it is tacitly accepted that only public intervention can lead to the coverage of these areas with high speed broadband.

However, the advent of wireless technologies, both *mobile* (LTE and 5th generation – 5G) and *fixed* (*Fixed Wireless Access* network that connects fixed points with a wireless link) may concretely change this point of view. LTE (Long Term Evolution) technology makes use of larger and larger amounts of spectrum to deliver hundreds of megabits per second in each cell through smartphones. This capacity has to be shared among the users within a given cell, and it is therefore stretched in densely populated areas, but it may easily deliver a very high performance in a rural or sparsely populated area.

European Commission data (2016) report that, in 2015, deployment of 4G (LTE) continued: coverage went up from 79 % of homes to 86 % in six months. As of October, 2015, 80 % of Mobile Network Operators in the EU offered 4G services on LTE networks. LTE is most widely developed in the Netherlands, Sweden and Denmark, while commercial 4G services were launched only last year in Bulgaria. LTE deployment has so far focused mainly on urban areas, as only 36 % of rural homes are covered. However, in 14 Member States, LTE is also already available in the majority of rural homes, with very high rates in Denmark, Sweden, Slovenia, Luxembourg and the Netherlands (Figure 7).

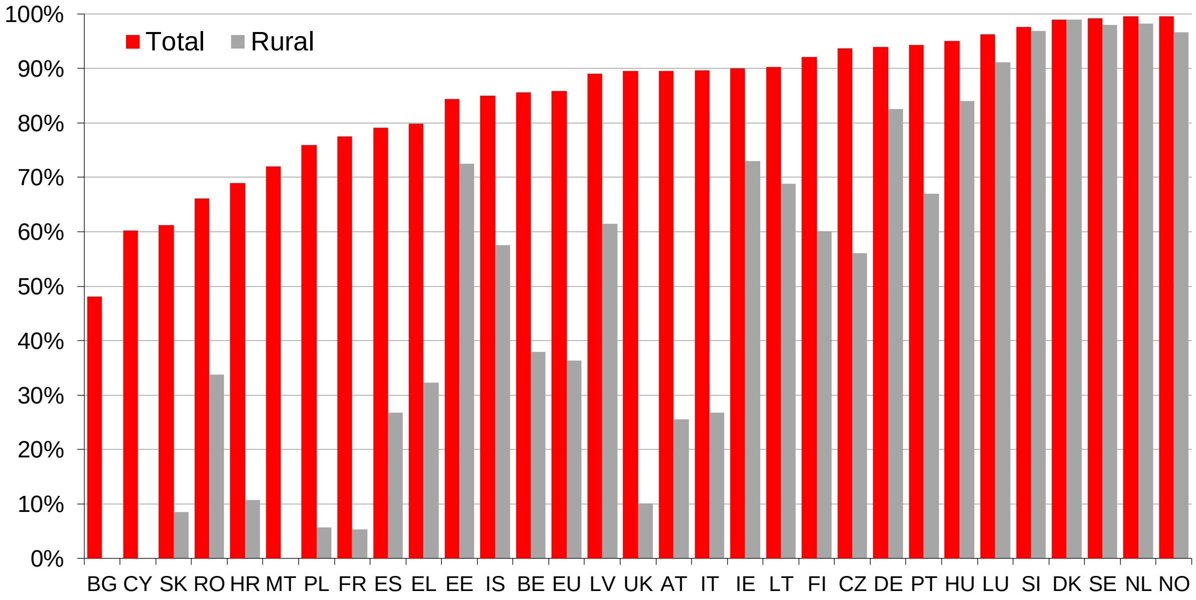

Figure 7: 4G (LTE) coverage in rural areas and in total (mid-2015, source: European Commission, 2016)

This implies that in the "market failure" areas, i.e., in all areas where fibre investments are not economically viable, or in all presumably profitable areas where ultra-fast fixed broadband demand is still lagging behind, LTE can be considered a feasible substitute for fixed copper or fibre networks, in terms of capacity performance, and can be provided at a noticeably lower cost. The issue to be solved, in this perspective, will be that of finding enough spectrum and designing innovative network topologies, with the fibre brought to the transmitting antennas in an FFTAS (*Fibre To The Antenna Site*) scheme (Cambini et al., 2016).

The relevance of ultra-fast broadband mobile coverage as a substitute for the fixed one is not a theme of secondary importance. As shown by Williamson (2017), most of the more relevant demand side applications that are used worldwide no longer require huge bandwidths to justify large investments in FTTP infrastructures only. As shown in his report, Williamson (2017) states that "*Skype recommends 1.5 Mbps for an HD video call, BBC iPlayer recommends up to 2.8 Mbps, Google recommends 2.5 Mbps for HD YouTube playback and Netflix recommend 5 Mbps for HD video. 4K video is more demanding, with Netflix recommending 25 Mbps*". Hence, improvements in compression limits, the need for substantial investment in ultra-fast fixed FTTP networks, whilst the shift to LTE and in perspective 5G mobile consumption will reduce bandwidth requirements, calling for the most time- and cost-efficient investment solutions that mobile broadband investments will certainly ensure.

Clearly, expensive fibre solutions through FTTP/H technologies may be required for a certain minority of highly demand users, but, in this case, it would be better to deploy the required technology in a highly targeted manner, rather than imposing such investment throughout a country. Should longer-term demand be the goal of the current EU policy, then it is more important to support any technologies that rapidly address current demand and the demand that will evolve in the near future. Once policy makers factor in such social requirements, as Williamson (2017) reports, it will be more relevant to "*focus on getting technology that substantially exceeds likely bandwidth requirements to as wide a portion of the population as possible, rather than deploying a still faster platform (albeit without there being use cases for the incremental speed) much more slowly (because of the additional civil works involved in FTTP).*"

From the policy side, the technology analysis previously reported provides interesting insights into the DAE targets. Public targets are meaningful economically if they solve a market failure, meaning that markets will not supply enough broadband coverage or quality. Assuming that public broadband targets, as stipulated by the EC in its DAE and gigabit strategy, are desirable in terms of welfare, various NGA technologies appear to be possible. In achieving these goals, Recital 175 of the draft EECC explicitly emphasizes the importance of infrastructure-based competition. However, pursuing the goal of "*incentivising investment in high-speed broadband networks"* (Recital 3) should not lead to distortions of market outcomes by engaging in "winner-picking" by explicitly favouring certain NGA technologies. Deviating from the principle of technological neutrality would, rather, require sound empirical evidence on the different welfare effects of the available NGA technologies, which is currently not available. Bertschek et al. (2016, p. 24) provide a recent review of the economic impact of broadband infrastructure deployment and adoption on various economic outcome variables. The authors conclude that "*[r]eliable and broad evidence on the economic impacts of high-speed wireline or wireless broadband infrastructure and adoption is still largely missing so far*" and that there are essentially no empirical studies that assess the differences in the impact of various NGA infrastructures.

As Williamson (2016 and 2017) points out "*the focus on the premise in relation to policy and target reflects priorities formed in an era when fixed access and the PC dominated […]. This focus is increasingly anachronistic*." Any deviation from a technological neutrality policy without any sound evidence, would thus only cause a shift "*away from a market driven approach and towards a planned vision*".

Despite considerable growth rates in recent years in the use of FTTP broadband in some EU countries, there is no question that the vast majority of companies and users are still utilizing hybrid NGA, or even older broadband technologies. It will therefore be an indefinite period of time before the switchover to an exclusively FTTP-based broadband network is made, which means that efficient use has to be made of the existing coaxial and copper cable networks, as well as mobile infrastructures, in the meantime. Existing and future "second-life copper/coax technologies" may, therefore, have a crucial role to play in an efficient migration process in view of substantial cost advantages and low current NGA take-up rates. LTE/5G networks could also be considered a substitute for the provision of ultra-fast broadband connections, especially in rural and non-profitable areas, and in areas where demand is still uncertain and low.

The market-driven speed of migration will, i*nter alia*, depend on country specific characteristics, such as the availability of ducts (favouring *ceteris paribus* FTTP deployment), or the number of street cabinets (favouring *ceteris paribus* FTTC deployment). Another fundamental technological change will occur with the roll-out of 5G mobile networks in the near future, which will unify wireline and wireless infrastructures and require an optimal integration of transport and access networks on the basis of different NGA architectures. Wireless broadband connections may limit the cost constraints involved with the civil works that are typically required for FTTP. It is therefore important from a social perspective to keep options open, where possible, taking incremental steps, where feasible, and learning from others and from early deployments of different technologies.

The notion of "efficient" investment implies that real investment meets real demand (rather than maximizing investment *per se*) for a specific technology. Except in the case of clear market failure, markets provide a more efficient investment, subject to the imperfect information that is available on future demand for high-bandwidth and technological progress. This implies that there is *no one size fits all* solution, and that a mix of technologies will be more likely to meet consumer requirements, including fixed wireless, copper-fibre hybrids and fibre.

To conclude, it is also relevant to consider financial constraints. Indeed, it is extremely unlikely that telecom companies have the financial resources both to build a dense LTE/5G network and to widely deploy FTTP by 2025. The obligation to invest in FTTP/H technologies only, simply *per se,* violates the principle of technological neutrality, but may also crowd out investment in different technologies, such as mobile ultra-fast broadband, that may bring far higher returns to the telecoms, thanks to the advent of new services, such as the Internet of Things (IoT). Focusing on fibre only solution would delay investment in alternative, but still relevant, technologies, and would crowd out or delay other investment options, including mobile.

In the chapters that follow we will concentrate attention on three themes that appear to be important for the correct policy orientation of the EU, and we suggest caution in imposing rigid directions for investment dynamics in broadband networks, namely, technological neutrality, path dependency and public financing.

CHAPTER III. Technological neutrality and EU targets

III.1 The technological neutrality principle[8]

Technological neutrality is one of the key principles of the European regulatory framework for electronic communications. It was first introduced in 2002 in a list of five principles underpinning the new regulatory framework.[9] The principle of technological neutrality is defined as follows, in Recital 18 of the Framework Directive:

> "*The requirement for Member States to ensure that national regulatory authorities take the utmost account of the desirability of making regulation technologically neutral, that is to say that it neither imposes nor discriminates in favour of the use of a particular type of technology (...)*"

The principle of technological neutrality was reinforced in 2009, with the revised EU telecoms legislation. Since the 2009 revisions, all of the spectrum licenses in Europe are supposed to be "technology neutral." Technology neutrality has also been recognized as a key principle for Internet policy (OECD, 2011). The concept also appears in the General Data Protection Regulation[10] and the Data Protection Directive,[11] adopted in April, 2016, and in the Directive on the Security of Network and Information Systems (NIS Directive), which was adopted in July, 2016.[12]

The objective of this section is to define the concept of technology neutrality, and discuss its meaning and utility in different possible contexts.

As discussed by Maxwell and Bourreau (2014), depending on the context, technology neutrality can have three different meanings:

- **Meaning 1**: technology neutrality means that technical standards designed to limit negative externalities (e.g., radio interference in telecoms or pollution in environmental regulation) should specify the performance goal to be achieved, but should then leave firms free to adopt any technology that they find appropriate to achieve it.
- **Meaning 2**: technology neutrality means that the same regulatory principles should apply regardless of the technology used.
- **Meaning 3**: technology neutrality means that regulators should refrain from using regulations as a means to push the market toward a particular structure that they consider optimal. In other words, regulators should not try to pick winners in the competition among technologies.

Note that these different meanings are not exclusive and can overlap in some contexts. We examine each of these meanings in more detail below.

a) Technology neutrality in standards to limit undesirable effects (Meaning 1)

A first approach to defining technology neutrality is to view it in the context of technical standards that are designed to limit negative externalities. Standard-setting is common in

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[8] This section is based on Maxwell and Bourreau (2014).

[9] See European Commission. *Towards a New Framework for Electronic Communications Infrastructure and Associated Services.* COM (1999) 539.

[10] Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data.

[11] Directive (EU) 2016/680 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data by competent authorities for the purposes of the prevention, investigation, detection or prosecution of criminal offences or the execution of criminal penalties, and on the free movement of such data.

[12] Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union.

environmental regulation, the regulation of product safety, or in telecoms, especially to limit radio emissions or interference. Two regulatory approaches are possible for the technical standard. The standard can specify the performance goals to be achieved ("performance standards"), or it can specify the processes or the technologies that should be used to meet these goals ("design standards"). In other words, *performance standards are technology neutral, while design standards are not*.

The concept of performance standards was developed in the United States in the 1980s in the context of the "better regulation" movement. Performance standards are deemed to be more efficient than design standards, because performance standards give flexibility to regulated firms to achieve the desired objectives in the most efficient way they can find (Breyer, 1982). By contrast, with design standards, it is the regulator who chooses the technologies that the firms should use to meet objectives. Due to limited information, in particular, the regulator may make inefficient technological choices. Design standards may also lead to technology lock-in, and may reduce innovation (Breyer, 1982). Moreover, the regulator’s choice of technology may be subject to regulatory capture by strong industry players, who have the resources to lobby for a particular technological solution.

Though performance standards, in principle, seem to have strong advantages over design standards, many regulators still use the latter type of regulation (Coglianese et al., 2002), which suggests that there should be trade-offs between performance and design standards for regulators. We discuss, below, some of the potential drawbacks of performance standards.

Performance standards require specifying, measuring and monitoring *performance goals*. This may be difficult and/or costly for the regulator (Coglianese et al., 2002). The regulator should also be able to set penalties that are large enough in cases of non-compliance, otherwise firms may prefer not to achieve the objective, and to pay a small penalty rather than making the necessary investments or actions (Besanko, 1987).

Performance standards can be costly for small firms, and hence may raise barriers to entry (Hemenway, 1980; Coglianese et al., 2002). If a standard requires the installation of a specific component, firms will have no difficulty in understanding the standard and implementing it, as long as the specific component is not too costly. By contrast, with a performance standard, firms have to find ways to cope with the standard, which may give an advantage to incumbent firms over small entrants. In order to address this problem, particularly for small companies, the performance standard can provide examples of technologies that will satisfy the performance objective, while giving firms the flexibility to use other technologies that can achieve the same goal.

Besanko (1987) also highlights that performance standards give incentives to firms to choose the most cost-efficient actions, but not necessarily to choose those that maximize social welfare. In a formal model, he compares the relative merits of performance and design standards for the regulation of pollution. He shows that performance standards are preferred if the regulator’s objective is to minimize emissions and pollution damage costs. However, if its objective is to maximize total surplus, design standards can be preferable in some cases. This is because, in his model, in order to meet the performance goal, firms not only invest in emission-reducing technologies, but also reduce output, which is harmful for welfare.

Coglianese et al. (2002) argue that performance standards and design standards should be thought of as two extremes on a continuum of regulatory approaches that runs from "pure" performance standards to "pure" design standards. In particular, hybrid approaches are possible that combine performance and design standards. For example, a regulator could require firms to use a specific technology (design standard), but introduce "equivalency clauses" that allow firms to use an alternative technology if they can demonstrate that it allows the same performance goal to be reached. In such cases, therefore, technology neutrality would be more a matter of degree than of kind.

b) Technology neutrality and the scope of regulation (Meaning 2)

The second context in which the concept of technology neutrality is used is in defining the scope of regulation. In the field of electronic communications, the European Framework Directive of 2002 makes "technology neutrality" one of its key principles for the regulation of the telecommunications sector in Europe. More precisely, the Directive states that it is "*desirable*" that regulatory rules are "*technology neutral*." The concept of technology neutrality that was introduced in the 2002 Framework Directive, is a response to the convergence of technologies and communications services, which allows the delivery of the same services over different network technologies. Until the new framework was put into place, each type of network (public switch telephone network, cable network, mobile network) was subject to a separate set of rules. The new "technologically neutral" approach means that all networks and services are subject to the same competition-law based test under which regulators identify relevant markets and dominant actors on the market, and apply appropriate remedies to address enduring competition problems.

The principle of technological neutrality is not a substitute for market definition (Kamecke and Körber, 2008). Market definition should be conducted using the principles of competition policy, and based, in particular, on demand-side substitutability. The market analysis process can therefore lead to market definitions that are not technology neutral. For example, if retail mobile and fixed-line services are not found to be substitutes, they should belong to different relevant markets. The technological neutrality principle does not stipulate that they belong to the same market. The same remark applies to the analysis of market dominance and remedies. Remedies often are also not technologically neutral. For example, access obligations, such as unbundling of the local loop, may be imposed on copper networks, but, in some instances, not on other kinds of networks.

In 2009, the principle of technological neutrality was pushed to a new level with the 2009 Better Regulation Directive. In this Directive, European lawmakers imposed the principle that spectrum licenses should be technologically neutral, except in limited cases (e.g., to limit radio interference). With this provision, regulators can no longer impose a particular technology on a spectrum user; mobile operators should be allowed to "choose the best technologies" (Recital 34). For example, in theory, a mobile operator with an old 2G GSM license should be able to deploy the 4G technology over its 2G spectrum. The 2009 Directive led to a wave of "spectrum refarming" in Europe. Nonetheless, operators are not allowed to convert to new technology unilaterally, but must ask permission from the regulator. The regulator then evaluates whether the change in technology would disrupt competition in the relevant retail market, and, if necessary, will rebalance the spectrum assignments so as to level the playing field. In 2012, the GSMA estimated that spectrum refarming accounted for 38% of the 4G market worldwide.[13] In the context of spectrum licenses, technology neutrality is close to "performance standards," i.e., Meaning 1 of our definitions: the regulation states the performance goal (i.e., to provide mobile services), but not how to achieve this goal (i.e., which specific mobile technology should be used).

For spectrum licenses, the 2009 Better Regulation Directive went further, recommending even the principle of "*service neutrality*." Service neutrality means that the holder of a spectrum license is allowed to offer any service on his frequency band. In theory, spectrum users could therefore offer mobile interpersonal communications, fixed communications, or even broadcasting services. The rationale for having both technology and service neutrality is to provide operators with full flexibility in designing their services, and to achieve an efficient of use of the scarce spectrum.

In practice, service neutrality is not easily applied to spectrum licenses because of the way the spectrum is divided into blocks. The organization of the frequency bands, in part, pre-

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[13] J. Gillet, 2012, "Spectrum refarming at 1800 MHz key to LTE device adoption", GSMA, Research Note, https://www.gsmaintelligence.com/research/2012/09/spectrum-refarming-at-1800-mhz-key-to-lte-device-adoption/349/.

determines the kind of service that can be offered. For example, the assignment of a duplex channel, including a return path, *de facto* means that the service will likely be two-way communications, as opposed to broadcasting. This principle also holds true, to some extent, for technology neutrality. The way the spectrum assignments are organized, including the size of guard bands and interference rules, will, to a large extent, predetermine the kind of technology that can be deployed by an operator. The engineers, who decide how the spectrum should be divided up and assigned to operators, will do so with one or more technologies in mind.

If regulation is technology-neutral, the regulator, if needed, can more easily expand its scope to encompass new players, new services or new markets. In a dynamic market, this flexibility which is offered to the regulator can facilitate its adaption to changes in supply or demand. The decree of application of the Creation and Internet Law in France provides an interesting counter-example. By restricting its scope to file sharing on peer-to-peer networks, the decree prevents HADOPI, the government agency created to administer the law, from taking action against other file-sharing techniques, such as direct download. The EU Data Protection Regulation would rather be technologically neutral in this sense.

The flexibility given to regulators by technology neutrality can help them put pressure on regulated firms to find self-regulatory solutions (Maxwell et al., 2000; Halftech, 2008). The threat of future regulation induces firms to voluntarily look for self-regulatory or co-regulatory solutions, which may be more efficient than command and control regulations. Self-regulatory solutions are, for example, envisaged in the General Data Protection Regulation in the context of "data protection by design."

On the other hand, a regulator could take advantage of technological neutrality to extend existing regulations to new markets or technologies (e.g., from "old" to "new" technologies), without clear evidence that these new regulations are actually needed. Unless certain safeguards are introduced, technological neutrality could therefore facilitate, or even lead to, over-regulation or inadequate regulation. Where technology neutrality creates uncertainty regarding the scope of regulation applied to new technologies, companies may react by deferring investments. In other words, there are cases where technological neutrality can slow down innovation. For example, in the past, a number of incumbent operators in Europe have complained that uncertainty regarding the application of access remedies to new fibre networks in Europe inhibits their investment decisions. The lawmakers in Europe who drafted the Framework Directive, were somewhat conscious of this risk, and they included in the Directive the principle that competitive or emerging markets should not be subject to inappropriate *ex-ante* obligations. However, this may not have been an effective or sufficient safeguard, especially if the ‘emerging market’ is not immediately perceived and separated by the regulator.

c) The absence of technology neutrality to nudge the market in a certain direction (Meaning 3)

The last context in which technological neutrality (or rather the absence of it) applies, is when policymakers wish to nudge the market in a certain direction, and consider that regulation is necessary for that purpose. For example, the regulators might have a particular vision regarding the importance of the deployment of fibre networks. In order to implement its vision, the regulator may have to adopt rules that are not technology neutral. An example of this approach is the choice of a harmonized standard, GSM, for mobile telephony in Europe in the 1990s. Whereas the US allowed mobile operators to choose different wireless telephony standards, Europe mandated the use of GSM in 2G bands. The imposition of a harmonized standard was considered critical for the development of a European market for handsets and interoperable mobile services. Whether the mandated GSM standard ended up working better than market-based standards is a question that goes beyond the scope of this Report.[14] The point is that the objective of the regulator, here, is not just to limit harmful interference (Meaning 1), but to structure the market in a certain way (Meaning 3).

Whether non-technologically neutral regulations are useful in this context depends a great deal on the risk of error in the policymaker's vision. If the evolution of the technology is well known to all (or the technology changes very little over time), the regulator takes less risk in setting up a regulation that is specific to a given technology. On the contrary, in a fast moving market with rapid technological change, the risk of regulatory error is high, making non-technologically neutral regulation more risky. In this case, technology-neutral regulation has the advantage of letting market participants experiment and select the most appropriate technologies.

A parallel can be drawn here with the debate surrounding government-imposed standards, such as UMTS, versus voluntary market-based standards, such as Blu-ray. The question is: in which cases are government-imposed standards preferable to market-led standards? In a recent article, Llanes and Poblete (2014) show that market standards are preferable where there is a high level of uncertainty surrounding the benefits of the technology. **A similar conclusion could be made for technology neutrality: the higher the level of uncertainty surrounding technological evolution, the more it becomes important to make standards technologically neutral.**

Kannecke and Körber (2008) argue that the definition of technology neutrality in the 2002 framework is based on two ideas, which are both consistent with Meaning 3: (i) regulation should not pick winners; and (ii) it should not distort the competition between technologies without appropriate justification.

To sum up, we have seen that the concept of technology neutrality can have different meanings: (1) technology neutrality can refer to the choice of performance standards over design standards; (2) it can represent and affect the scope or breadth of existing regulations; (3) it can mean that the regulator commits to not picking the winners in the competition between technologies.

Data protection law is already technology neutral (Meaning 2) in Europe, and that neutrality has been reinforced in the new EU General Data Protection Regulation. For standards developed in the context of cyber-security legislation (such as the EU NIS Directive), and for "privacy by design" (under the EU General Data Protection Regulation), technology neutrality in the sense of Meaning 1 will be critical in encouraging innovation and efficiency. Self- or co-regulatory instruments may be necessary to help give guidance to companies on technological options. Finally, in Internet policy, cyber-security and telecoms policy, regulators should not attempt to structure the market using technology-based regulation (Meaning 3), because such attempts are likely to create more harm than good in fast-moving innovative markets.

d) What role for technology neutrality in the development of super-fast broadband

We finally want to focus on the role of technology neutrality for the development of super-fast broadband networks in Europe. Should the technology neutrality principle be applied in a strict way in this specific case? Are there justified exceptions to the application of this principle?

A strict view of technology neutrality is that regulation should not interfere, in any way, in technology choices. As an example of this view, a recent report from HSBC (2016) highlights the "*importance of the principle of technology neutrality, especially given the inherently unpredictable nature of the way in which platforms evolve (…) Regulation should therefore not be used to direct technology decisions. The market is best suited to adapt technology choices to the evolving pattern of demand for high bandwidth offerings*."

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[14] For example, see Gandal et al. (2003) for a discussion.

Cave and Shortall (2016) defend a less strict view of technology, which seems interesting in the context of the Connectivity Package. Cave and Shortall argue that technology neutrality can be rejected if (i) it would lead to some market failure, or (ii) if there is an objective that forces to reject technology neutrality in order to be reached.

Market failures can arise, first, due to the presence of externalities, and second, when technology neutrality can have adverse effects on competition.

There may be externalities if the social benefits accruing from the deployment of broadband infrastructures are much larger than the private benefits. For example, broadband infrastructures can generate large gains in productivity, stimulate the entry of new ventures, boost job creation, and these positive spillovers may not be fully internalized by the operators (if at all). To the extent that different technologies may generate different degrees of externalities, and that firms do not internalize these externalities in their technology choice, they may not adopt the technology that yields the largest externalities, and hence the largest social benefits.

The second source of potential market failure is that different technologies may lead to different levels of competition *ex post*. The regulator's and the firm's objectives are not congruent in this dimension either: the regulator would like to have significant competition *ex post*, not the firms.

In a paper that compares the relative merits of performance standards (i.e., technology neutrality) and design standards (i.e., non-neutrality), Besanko (1987) also shows that, in some cases, non-neutrality can lead to higher social welfare than technology neutrality. In his model, this is the case when the regulated firms use the flexibility provided by performance standards to take actions that harm welfare.

In conclusion, both Cave and Shortall (2016) and Besanko (1987) point to the fact that technology neutrality involves trade-offs. On the one hand, it makes technology choices more efficient, by delegating these decisions to the firms, which are thus more informed and have incentives for taking efficient technology decisions. On the other hand, the firms do not (fully) internalize externalities, or the desirability of competition *ex post* (Cave and Shortall), or, more generally, social welfare (Besanko), and therefore they can make suboptimal technology choices from a social welfare point of view.

We now turn to the way in which these trade-offs are balanced in the new Commission's Connectivity Package.

III.2 The Commission's Connectivity Package: targets and technologies

In this section, we apply the previous categories to examine which role – if any – is assigned to technological neutrality in the Commission's new Package, and thus the role the principle is expected to play – if any – in the developments of the European technologies of tomorrow.

a) The Connectivity Package and its Targets

In its communication of 14th September, 2016, the European Commission proposed a new connectivity package, with legislative proposals and new non-binding connectivity targets that are to be reached by 2025. In the Communication on "Connectivity for a Competitive Digital Single Market",[15] the Commission insists on the importance of Internet connectivity for the Digital Single Market, and concludes that investments in high-speed networks are necessary for the delivery of full Internet connectivity across Europe. The Communication then proposes the following targets (or "strategic objectives") for the coverage and take-up of high-speed wireline and wireless networks by 2025.

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[15] "Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society", COM(2016) 587 final, 14 September 2016.

- *By that date, gigabit connectivity should be available at places driving socio-economic developments, such as schools, transport hubs or business parks;*
- *5G coverage should be available in all urban areas and in all major terrestrial transport paths;*
- *Finally, all European households (rural or urban) should have access to Internet download speeds of at least 100 Mbps, with a possibility of upgrade to Gigabit speeds.*

These objectives are not binding. However, the Commission argues that (i) they can serve as a reference point for public policy (e.g., for state-aid programmes); and (ii) they can serve as a performance goal for private firms in defining their investment plans.

5G is, of course, non-technology-neutral, by its reference to the fifth mobile generation, but the 5G standard is being established through cooperation among the different stakeholders, and the Commission's target does not state which specific elements should be included in the standard.

In the rest of the section, we focus primarily on the connectivity targets in terms of speed, i.e., the objectives that all European households should have access to 100 Mbps downstream by 2025, and that all places driving socio-economic developments should have a Gigabit connection by the same time, and on the legislative instruments needed for the development of this super-fast broadband.

b) Technological neutrality in the Connectivity Package

To determine if the connectivity package can be viewed as being "technology-neutral", we examine (i) if the package is framed in a technology-neutral way; and (ii) if it makes any reference to technology neutrality. We use, as a definition of "technology neutrality", the three different meanings that were introduced in the previous section.

To start, we examine how the principle of technology neutrality is addressed in the Communication on "Connectivity for a Competitive Digital Single Market".

In this Communication, the Commission frames the connectivity target for end-user broadband seemingly in a technology-neutral way: the target is defined in terms of (download) speed, not technology. Furthermore, the Communication points out that, in principle, the target can be achieved with any wireline or wireless broadband technology (and possibly, a combination of different technologies): "*All European households, rural or urban, should have access to a minimum level of fixed or wireless connectivity. (…) Covering the last 5% of homes and businesses remains the greatest challenge, but a cost-efficient upgrade path is possible based on wireless as well as fixed-line solutions*." (p. 8).

The Commission's proposal seems therefore "technology-neutral", according to Meaning 1: the Commission sets a performance standard (here: download speeds of 100 Mbps), not a design standard, and leaves operators free to choose the most efficiency technology solutions with which to reach this goal.

The Commission refers to "very high-capacity networks" as the networks that would be capable of delivering the required speed for the 2025 target. Very high-capacity networks are defined as follows:

> *"“Very high-capacity network” means an electronic communications network which either consists wholly of optical fibre elements at least up to the distribution point at the serving location or which is capable of delivering under usual peak-time conditions similar network performance in terms of available down- and uplink bandwidth, resilience, error-related parameters, and latency and its variation. Network performance can be considered similar regardless of whether the end-user experience varies due to the inherently different characteristics of the medium by which the network ultimately connects with the network termination point."* (p. 3)

This definition introduces a nuance to the apparent technology neutrality of the speed target. Within Meaning 1 of technology neutrality, the definition of very high-capacity networks seems to correspond to the hybrid forms of regulation that fall between performance-based and design-based regulation, where a given design is suggested (here, fibre up to the distribution point, at least), and "equivalence clauses" are introduced, whereby alternative technologies can be used, to the extent that they deliver a similar performance to the suggested technology.

As we discussed in the previous section, in environmental regulation it is considered that there is a continuum of policies running from "pure" performance standards to "pure" design standards. In a similar way, we may consider that there is a continuum between "pure" technology neutrality and "pure" non-neutrality. In this perspective, the definition of very high-capacity networks does not seem to be framed in a "purely" technology-neutral way. This impression is reinforced by the fact that the Communication, as well as the legislative proposal made by the Commission, contains many specific references to the fibre technology. For example, on page 4 of the Communication, the Commission writes that "*(…) many products, services and applications will only be sustainable where optical fibre networks are deployed up to a fixed or wireless access point close to the end user*" (our emphasis). On page 10, it also refers to "*very high-capacity fibre connections*" (our emphasis).

The Directive Proposal[16] explains more precisely the meaning of 'technological neutrality' in the context of 'very high-capacity networks'. Recital 13 of the Proposal indicates that "*(…) future 'very high capacity networks' will require performance parameters which are equivalent to what a network based on optical fibre elements at least up to the distribution point at the serving location can deliver. (…) In accordance with the principle of technological neutrality, other technologies and transmission media should not be excluded, where they compare with this baseline scenario in terms of their capabilities.*" In line with Meaning 1 of technology neutrality, this Recital clearly states a hybrid standard, with a preferred design ('a network based on optical fibre elements'), and an equivalence clause allowing firms to use alternative technologies with comparable 'capabilities'.

The Directive Proposal also proposes a slight change to the general definition of technology neutrality. As in the Framework Directive of 2002, in its Recital 25, the proposal reiterates that "*a national regulatory or other competent authority neither imposes nor discriminates in favour of the use of a particular type of technology*". As in the 2002 Framework, it goes with the caveat that it "*does not preclude the taking of proportionate steps to promote certain specific services where this is justified*".

The Proposal, however, adds to the definition of 2002 that a possible case where it could be "justified" to ignore the technology neutrality principle would be "*in order to attain the objectives of the regulatory framework*". This exception to the technology neutrality principle corresponds to a situation of non-neutrality, according to Meaning 3: the statement opens the possibility that in order to reach some specific objectives (i.e., to nudge the market in a certain direction), a technology can be picked by the regulator, in contradiction with the technology neutrality principle.

The Proposal also adds the following point to the definition of technology neutrality: "*Furthermore, it does not preclude taking into account that certain transmission media have physical characteristics and architectural features that can be superior in terms of quality of service, capacity, maintenance cost, energy efficiency, management flexibility, reliability, robustness and scalability, and ultimately in terms of performance, which can be reflected in actions taken in view of pursuing the various regulatory objectives*." In other words, if a given technology turns out to be superior in reaching certain regulatory objectives, the technology

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[16] "Proposal for a Directive of the European Parliament and of the Council establishing the European Electronic Communications Code", COM(2016) 590 final, 14 September 2016.

principle does not apply, and the policymaker is entitled to pick this superior technology. This statement seems to allow for non-neutral regulation according to Meaning 1 (the regulator can define a specific standard if it views it as being clearly superior to alternative standards), and Meaning 3 (non technology-neutral regulatory decisions may be justified to reach specific regulatory objectives).

Finally, the Directive Proposal proposes alternatives to standard access regulation, such as co-investment between infrastructure operators, which may seem at first sight not to be technology-neutral according to Meaning 2 (technological neutrality and the scope of regulation). However, as we outlined in the previous section, remedies are often not technologically neutral.

In sum, we have seen that the connectivity targets are defined in a way, which is not "purely" technology-neutral according to Meaning 1, but neither it is fully non-neutral, as they tend to point to a given technology (fibre-based), while allowing for alternative technologies with similar performance. However, the revision of the definition of technology neutrality opens the door to non-neutral regulatory decisions, according to Meaning 3, with a to meeting specific objectives. The risks of making the wrong technological choices nudged by regulators, therefore, will have to be carefully balanced with the social relevance of these specific objectives and any other possible, and less risky, alternative to reach them.

CHAPTER IV. The issue of path dependency and other relevant aspects at the Member States' level

The possibility to reach the connectivity targets and their adequacy, taking into account the technological neutrality angle, but also a realistic assessment of the current situation at the Member States' level, requires to be examined also against a different set of concerns. One core issue, which could also affect the possibility for national regulators to conform to the EU indications and targets, is related to the actual status of the networks and to the prevailing technological configurations in each country. In this context, one has to take accept that path dependency is a pervasive feature in network markets, due both to the supply- and demand-side factors. As we will argue, regulatory and political interventions can add an additional layer of path dependency. In high-speed broadband markets, we have identified a significant number of such path dependencies, e.g., i) geographical / legacy path dependency, ii) competitive path dependency, iii) regulatory path dependency, and iv) strategic path dependency. In what follows, we will discuss the main trade-off between FTTP (high bandwidth but slow deployment and high costs) and FTTC (lower bandwidth but faster and cheaper deployment) in the light of these path dependencies and then consider the specific situation in some representative countries.

a) The many dimensions of path dependency

Geographical / legacy path dependency occurs due the historical layout of towns and cities, which followed geographic circumstances and cultural patterns. While, in some countries population density is very high, in others, there are regions where it is very low. Even in more densely populated areas, the types of building can be significantly different; for example, in the UK it is most common to live in houses, while in Germany or in Italy the share of apartments is very high.

Legacy fixed networks were built with a layout that was adapted to local housing patterns, with a topology of street cabinets and access lines that provided the best solution for the service of fixed telephony. In countries with a high share of apartments, there therefore tend to be many street cabinets, with relatively few access lines per cabinet, and short access lines. These three factors strongly favour the roll-out of upgraded copper (FTTC) technology: Street cabinets can be cheaply upgraded with active components, and the short loop length makes very high (fibre-like) bandwidths feasible on upgraded copper, for example, through G.fast, as discussed in Chapter 2, above.

On the other hand, in countries with a low population density and towns that are characterized by individual houses, the local loops may be too long to allow high bandwidth on upgraded copper. Either more engineering work is thus necessary to bring the cabinets closer to homes, or, if that is not possible, then lower bandwidths must be accepted.

A related issue is the availability of ducts and in-the-air wiring. Local law and building traditions play a big role here. Ducts with additional capacity may have been laid by telecoms or other utility operators, instead of just burying their cables or tubes in the ground. These ducts, where they exist, strongly reduce the civil engineering costs of substituting the last copper mile with fibre and therefore favours an FTTH roll-out. On the other hand, in some countries, such as Portugal, wiring that is attached to the outsides of buildings is very common, while it is anathema in others. One reason for Portugal's quick roll-out of FTTH is certainly hat in urban areas fibre infrastructure was just strung alongside the many other (sometimes mysterious) cables that hang along the streets.

A different, but important, type of path dependency is the very extent of the legacy copper network to start with. While, in Western Europe, its coverage is universal, the same was not true in many of the countries in Eastern Europe. Since there is insufficient legacy infrastructure to build upon, FTTC loses its cost advantage over FTTH. As a result, NGA roll-out in these countries leap-frogs copper deployments and moves directly to fibre. The share of FTTH connections in the total broadband uptake is very high, even if NGA uptake, as such, remains low.

A second type of path dependency is ***competitive path dependency***, which captures the persistence effects that are created by market structure and the types of competitors. In particular, once competitors have sunk certain types of investment, a specific market structure is locked in, and this may only change in exceptional circumstances.

A clear case of this is the entry of a facility-based competitor, in particular, upgraded cable networks. Whether or not such a competitor is present can have a series of different effects. First, it seems clear that the presence of strong cable networks has provided a spur to NGA investment in Belgium and Portugal, while its complete absence did the opposite in Italy. However, the pattern is not universal: Shortall and Cave (2015) conclude that in their sample of countries no systemic relationship between NGA investment and cable coverage emerged.

A second effect is that the presence of a strong second infrastructure makes it very hard for other access-based entrants to survive. There thus will be a tendency towards a facility-based duopoly, and regulatory policies that attempt to maintain viable access seekers may be doomed from the outset. This implies that concerns about relative access conditions under copper upgrades or fibre roll-out are second-order, in particular when infrastructure competition is already intense.

There is also a path dependency that arises from access seekers' investment, in particular, in the access to unbundled local loops. This investment is sunk and makes the access seekers compete as long as access conditions remain sufficiently cheap. On the other hand, if access conditions worsen, or if local loop access is terminated, these assets become stranded, which may greatly increase potential entrants' uncertainty about regulatory commitment in the future and, accordingly, lead to less future entry.

Regulatory path dependency comes in several distinct flavours, all of which are relevant for NGA roll-out. First, there is a path dependency in regulatory vision, at EU and national levels. The target of universal NGA coverage had already been adopted a few years ago, and continues to be updated and strengthened to this day (see e.g., Germany's Digital Agenda 2025 from 2016). When these targets were formulated, high-speed broadband was synonymous with fibre (FTTH) – copper-based broadband offered no comparable solutions. The FTTH vision came to stick, and recent developments in copper upgrades, including vectoring and G.fast, could not dent its attractiveness. Instead of carefully comparing the cost-benefit trade-offs for FTTC and FTTH, the discussion is mainly about how to finance and provide incentives for FTTH roll-out.

A second type of regulatory path dependency arises from the fact that, under local loop unbundling (LLU) access, multiple entrants appeared, and regulators are very loth to see the number of competitors drop as the market develops. Local loop unbundling, as thought out under the ladder of investment model, led to entry, and the expectation that future competition would be greater not less. The total number of competitors may have become a more important measure of competitiveness than the existence of some strong competitors. For example, it has been widely discussed that the introduction of vectoring implies that access competitors will have to stop using the local loop and take up less customizable bitstream offers instead, which weakens access competition. This should be less of a concern in the presence of a strong cable network, in which case, the copper upgrade may precisely have the function of accompanying the former's NGA roll-out and keeping the fixed network competitive.

The necessity for regulatory commitment, which is a central issue in the literature on regulation and investment incentives, also creates path dependency. As mentioned above, in order not to damage incentives for future investment, regulators see themselves as being obliged to provide continued support for access-based business models. At the same time, various factors may make local loop-based competition more difficult, or even untenable, in the future: depending on the country, this may be due to facility-based competition by cable networks, or the transition to FTTH, or the transition to FTTC. The regulatory answer to this concern seems to cater for one of two types of access: access to passive infrastructure, which under FTTH provides entrants with a less costly roll-out of their own infrastructure (this works less well under FTTC, because entrants can more easily be underbid in the retail market); or potentially active access to fibre, options for which (in case it is regulated at all) are discussed in the Bundesnetzagentur consultation of March, 2017 (the central idea is regional retail-minus access pricing to deal with differing competitive conditions and to maintain the returns from investment).

The regulatory policies and incentive schemes adopted also create path dependence. As Shortall and Cave (2015) conclude, the deployment of FTTH, plus the provision of passive access in France, Portugal and Spain, have seen alternative operators capture a significant part of the respective markets, while in countries where FTTC was favoured, such as Belgium, Germany or the UK, very little access competition remained. While the overall level of NGA coverage is comparable in the two groups, the market structure and the maximum bandwidth is rather different. Their study does not cover the demand side, though, nor does it cover pricing and the intensity of competition. It is still thus an open question as to which consumers obtain a better deal, given their needs.

Finally, we consider **strategic path dependence**. This refers to the future path dependence created by today's investment decisions. An important issue in this respect is the possible up- and lacking downward flexibility of NGA investments. A full FTTH rollout sinks the high investment cost, without an option to scale down the network and get the money back if the expected demand were not to materialize. FTTC, on the other hand, provides an option for a further (possibly highly targeted) upgrade to FTTH, if the demand were to arise. From a real option point of view (dealing with uncertainty in the presence of sunk investments) a choice of FTTC as a first step thus avoids locking in potential over-investment.

On the other hand, as Cave and Shortall (2016) have pointed out, specific choices of technology by investing operators can lock in a specific market structure. The question here is whether this is a mere by-product of the above strategic considerations, or not.

In the following we consider a few specific countries in the light of the above discussion.

b) Examples of European countries' different paths to broadband

Belgium: Proximus (previously called Belgacom) upgraded copper with vectoring to more than 90% of the population, and has been planning to roll out fibre where it is commercially viable. Cable companies have almost 100% NGA coverage, while local loop access regulation was not successful in establishing viable access competition (so much so that the remaining access seeker, Mobistar, recently took up access to cable under the broadcast plus bitstream access offer that was mandated by the media regulators).

A close look at the market reveals that Proximus chose vectoring over large-scale investment in FTTH in order to respond quickly and cost-effectively to the competitive threat emanating from cable operators, rather than to foreclose potential access seekers. Indeed, the regulators understood that the presence of very strong cable networks justified deviating from the standard regulatory practice of putting onerous obligations on the fixed-line incumbent and ignoring the cable networks, on the one hand, and from insisting on full FTTH rollout, on the other.

France: France designed a fibre roll-out strategy that is based on a classification of areas into very dense, dense, and less dense, and includes the explicit promotion of co-investment arrangements. Investment in FTTH started early, but was quickly overtaken by other countries, so that in March 2016, 21% of households were covered with FTTH, 19% with FTTC and 25% with cable; overlap is significant, for a total coverage with high-speed broadband of 25% (HSBC, 2016). Take-up in covered households was below 30%, in each case, for a total of 14.3% of households (HSBC, 2016). Even though France has a well thought-out policy for structuring fibre investments according to regional specifics, and to reduce investment uncertainty, both NGA coverage and uptake are thus actually rather low.

At first, FTTH roll-out was clearly favoured, but in 2014 the regulator, ARCEP, allowed VDSL2. At this point, the deployment of FTTH almost stopped, for various reasons, which provide some insight into the differences between operators, even within the same country. First, the entrant operator, Free, moved to VDSL2, because it was cheaper and this was consistent with its price war in the mobile telephony market. Bouygues did not have the capacity to roll out FTTH, and this was also due to competitive pressure in the mobile market. SFR merged with Numericable in 2014, and dropped FTTH in favour of cable NGA. Finally, the incumbent operator, Orange, reduced its FTTH investments, possibly due to a lack of competitive pressure, or because of concern that having by far the largest fibre coverage would make it subject to additional access regulation (which is what happened afterwards).

Germany: In Germany, 60% of homes are apartments and therefore local loops tend to be short, with about 130 lines per cabinet (quite a low number). This makes the roll-out of high-speed copper upgrades technically possible (Deutsche Bank, 2016). Germany already has a high number of street cabinets, which can support upgrade equipment. A significant number of exchanges saw the uptake of LLU access offers, Vodafone still being a major client.

It is therefore not surprising that Deutsche Telekom’s NGA roll-out concentrated on upgrading its copper network and introducing vectoring. That is, given the favourable legacy network topology, the incremental cost of FTTH roll-out, as compared to FTTC, would have been higher than in other countries, while, at the same time, the existing demand for bandwidth was sufficiently covered by the existing FTTC technology. The German regulator supported this approach, while FTTH was rolled out in some urban areas by alternative providers.

In March 2016, Germany had an FTTH coverage of 4% of households, FTTC for 52% of households, and cable at 63% of households (HSBC, 2016), with a total NGA coverage of 81% (EC, 2016b). Take-up of fast broadband was at 31.6%, with two-thirds coming from cable operators and the rest FTTC (there is no information about FTTH take-up) (HSBC, 2016).

The Federal Ministry of Economic Affairs and Energy, in its Digital Strategy 2025, clearly sets out the vision of national gigabit fibre coverage by 2025, at a total estimated cost of 100 billion Euros (BMWi 2016). The underlying argument is that Germany needs to have the infrastructure in place before the demand for high bandwidth arises, rather than the certainty that such high bandwidth will actually be necessary. An identical vision is laid out in the “Zukunftsoffensive Gigabit-Deutschland” (something like Active Future Vision Gigabit Germany) of the Federal Ministry of Transport and Digital Infrastructure (BMVI). In November this vision was complemented with a new law guaranteeing access to passive network infrastructure (DigiNetz-Gesetz).

It became known in January 2017, that Deutsche Telekom is starting to cooperate with the energy providers Innogy and EWE, in order to use their fibre infrastructure to provide fast broadband services. At the same time, it began to team up with local fibre networks in order to meet roll-out targets.

On March 14th, 2017, the German regulator, Bundesnetzagentur, published a consultation document about potential pricing options of FTTH/B (fibre to the home or building). Clearly, this document is based on the implicit assumption that nationwide roll-out of FTTH is necessary – it does not even refer to FTTC-based models as potential alternatives. This is so even though one of the points to be discussed in the consultation is geographical regulation, i.e., regionally differentiated access conditions for fibre. In this context it would have seemed pertinent to also discuss the desirability of FTTC versus FTTH in a regionalized context.

Clearly the German government and communications regulator have thus committed themselves to an FTTH buildout, and no longer consider FTTC a viable alternative, while Deutsche Telekom itself is moving towards a flexible approach that takes in FTTH where it is attractive.

Italy: A special feature of the Italian broadband market is the complete absence of cable networks. In March 2016, fast NGA coverage was FTTH to 9% of households, and FTTC to 42%, for a total coverage of 45% (HSBC 2016). Take-up of covered households was very low, at 12%, resulting in a very low total take-up of only 5.6% of households (HSBC 2016).

In Italy, the number of apartments is high (50% of homes), which creates favourable circumstances for copper upgrades (short local loops, few lines per cabinet, large number of cabinets) (Deutsche Bank, 2016). However, Telecom Italia practically has a monopoly on the fixed network, and thus no competitive incentive to either speed up or upgrade its NGA roll-out.

ENEL (the electricity incumbent) recently created Open Fibre, a new subsidiary with the mission to speed FTTH deployment in dense areas and, using State or regional resources, also in less densely populated areas. The presumed business model is the roll-out of a national “wholesale only” network in competition with the telecom incumbent.

Telecom Italia and Fastweb launched a co-investment arrangement in order to advance FTTH network deployment in 29 important cities. While the agreement is presently subject to investigation by the competition authority, it has the potential to favour the creation of two end to end FTTH networks for both these two relevant competitors.

Portugal: Since before the 2010 NGA Recommendation, the regulator has followed a policy of imposing access to passive infrastructure, but not of imposing fibre access, against continuing pressure from the European Commission. Together with lax rules about infrastructure deployment (cables are often strung along buildings), this has led to the deployment of multiple fibre networks by PT, Vodafone and Sonaecom (previously Optimus, now NOS after merger with cable company ZON), some under cooperation agreements (which have turned sour recently).

The cable companies NOS and Cabovisão cover a large part of the country, and there is a large overlap with the fibre networks. According to ANACOM (2016), in the second half of 2016 about 5 million homes had FTTH coverage, and a little over 4 million had cable broadband coverage. The total number of broadband subscriptions is 3.1 million, which corresponds to about 85% of households. It is probably important to note that most broadband contracts in Portugal are sold as part of a triple- to quintuple-play bundle, which drives up the adoption numbers.

Portugal is a case where the regulator created a framework of access to passive infrastructure but otherwise let the market develop. These developments were rather turbulent, firstly with the split between the incumbent telecoms and its cable network, and then with the reconfigurations in the market towards operators that integrate both fixed-line and mobile business lines. FTTH investments arose naturally, as low-cost roll-outs were possible.

Spain: In March 2016, Spain had an FTTH coverage of 63% of households, FTTC of 4%, and 54% with cable, for a total high-speed coverage of 63% (HSBC 2016). Total uptake was a low 17.4% of households, half of which was provided by cable (HSBC 2016).

The Spanish regulator tried to support FTTH roll-out while giving in to Brussels’ insistence on fibre access obligations. It did so by imposing a fibre bitstream access obligation, but limiting its bandwidth to 30Mbs. As a result, Spain’s FTTH coverage has increased faster than that of probably any other EU country. Still, uptake continues at a low level, which may be a result of cultural and / or economic reasons.

UK: The UK had the following coverage of households with high-speed broadband in March 2016: a low 2% with FTTH, a high 86% with FTTC, and 46% with cable, for a total of 87% (HSBC 2016). Take-up on cable is higher, with 37% of covered households, as compared to 24% for FTTC (no data are available for FTTH), for a total NGA uptake of 37.8% of households (HSBC 2016).

The UK has a large number of individual houses, which tends to imply longer local loops. On the other hand, it has a large number of street cabinets. The legacy network case for FTTC is thus less strong than in Germany; still, British Telecom have opted for widespread copper upgrades. The public argument in the UK is now mostly about investments in further upgrades to increase bandwidth, often involving public money.

On March 10th, 2017, Ofcom and British Telecom (BT) agreed on the legal separation of BT’s network arm, Openreach. One of the issues that were underlined by Ofcom was its expectation that the investment incentives of Openreach would change under a less tight relationship with BT. Ofcom believes that Openreach will pay significantly more attention to the needs of access seekers, other than BT’s retail arm, and therefore will become much more interested in investing in full FTTH, rather than in more copper upgrades. The UK case highlights the importance of network ownership for investment incentives.

Summing up, market outcomes, both in terms of coverage and uptake, in the different countries that we have considered, are highly path-dependent, while, at the same time, the characteristics in each country are very different. Clearly, developments in each country should be judged based on history and national particularities; a one-size-fits-all vision for fast broadband does not result in optimal deployment and maximum consumer benefits. It appears that, in the face of such marked differences, national regulation needs to be flexible and realistic in its goals, accompanying and facilitating market choices with a view to consumers’ interest.

CHAPTER V. The Connectivity Package and public financing of network rollout

The final theme we want to discuss concerns the influence on, and interaction between, the Connectivity Package (CP) and the use of public resources to achieve its goals.

a) The EU legal framework for public support for network investments

It has long been acknowledged, in Europe and elsewhere, that broadband investment is exposed to market failures, primarily due to the pervasiveness of network effects, and that there may be also additional reasons that are linked to cohesion, equality of opportunity and other public policy objectives, that justify the direct engagement of public decision-makers in the support of network rollout. Equally widespread is the recognition that when public support takes the form of direct or indirect financing of network infrastructures, there is ample scope for a distortion of spontaneous market dynamics that may end up even being counterproductive, in some instances.

Different countries have experimented with different solutions to the many trade-offs that are involved with the more direct forms of public involvement. At the European level, the most relevant choices in this regard are perhaps reflected in the Broadband State Aid Guidelines[17], which were issued in 2009, and then revised in 2013, and in the definition of the framework for EU State Aid legislation.

The Guidelines appear, in general, to reflect a clear stance favouring market coordination and investment over public involvement at any time when this is feasible and likely. The primacy of the market over the state is evident in the well-known distinction between “white”, “grey” and “black” areas. For both basic broadband and NGA networks, State aid is likely to be compatible with the internal market in white areas, where no provider is operating nor plans to operate in the next three years; it has to be subject to a full compatibility assessment in grey areas, where only one provider operates and no other provider is likely to operate in the next three years; it is, in general, excluded in black areas, where there are, or there will be in the next three years, two or more operators providing basic broadband, although investment in an NGA network may be allowed under certain conditions (on which more below).

The design of the Guidelines certainly reflects an awareness of the risks of market distortions and of the crowding out of private investment, and appears to be inspired by the objective of channelling public resources where clear instances of market failure can be identified. Yet, on closer inspection, and considering the interplay between the Broadband Guidelines and other relevant EU policy documents, it appears that the prominence accorded to competition objectives is not without limits.

The design of the EU State Aid rules does indeed reflect the interplay between a clear market-oriented stance and industrial policy objectives that, in some instances, may conflict with an unequivocal endorsement of the market failure principle.

This tension is most clearly articulated in some passages of the 2013 revised version of the Broadband State Aid Guidelines, which states, among its aims, that the aim is to “*achieve the coverage objectives set at European level to spur economic growth and development*” and to “*facilitate well-designed aid targeting market failures or providing a more desirable, equitable market outcome from a cohesion policy point of view*”. The 2013 amendment is coherent with the more general process of State Aid Modernization that is inspired by the aim of fostering growth and cohesion.

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[17] Other relevant documents are the General Block Exemption Regulation (GBER), i.e., the Commission Regulation (EU) N°651/2014 of 17th June, 2014, declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty, and the Regional Aid Guidelines for 2014-2020 (Official Journal C209, 23.07.2013).

The State Aid guidelines should thus be read and interpreted in conjunction with the other EU documents, where the "*coverage objectives set at European level*" and, more generally, the digital targets set for EU-level broadband policy, are indicated. Until September, 2016, the main document of this sort was the *Digital Agenda for Europe (DAE) 2020,* one of the flagship initiatives of the Europe 2020 Communication (European Commission, 2010; Council of the European Union, 2010), setting the objective of the deployment of Next Generation Network (NGN) infrastructure that ensures the availability of Internet connection at a minimum speed of 30 Mbps for all European citizens, and above 100 Mbps for at least 50% of European households. With the issuing of the Connectivity Package in September, 2016, as discussed above, new and more ambitious targets have been set.

A detailed description of the new digital targets has been provided in the previous chapters. The objective of this section is to stress, once again (see FSR, 2016), that, in spite of the apparent market orientation of the Broadband Guidelines, that they explicitly incorporate industrial policy objectives among their aims creates the room for market distortions. This should be borne in mind when considering how to implement, in practice, and at the national and local level, the new digital targets of the CP.

The provision of the Broadband Guidelines that most clearly points to a rather flexible interpretation of the market failure principle in the application of State aid rules, is the one concerning compatibility with the internal market of direct public funding in black NGA areas. In principle, these are the areas where the availability of privately devised broadband solutions is greatest (they are defined as areas where at least two NGA networks of different operators exist), and public investment is therefore unlikely to be justified on the grounds of market failures.

In practice, according to the Guidelines, compatibility with State Aid rules is not compromised, even in black NGA areas, if the publicly financed new NGA network constitutes a "*step change*" and is able to provide ultra-fast speeds that are well above 100 Mbps. A "step change", as per the Guidelines, refers to the fact that public intervention is able to spur: (a) significant new investments; and (b) enhanced capabilities, in terms of broadband service availability, capacity, speed and competition (e.g., effective wholesale access and/or unbundling).

More precisely, in black NGA areas, the following cumulative criteria apply in order to substantiate the existence of a step change:

- the existing NGA networks and those planned for the next 3 years do not reach the end-user's premises with fibre networks;
- the market situation is not evolving towards the achievement of a competitive provision of ultra-fast services, above 100 Mbps, in the near future, through the investment plans of commercial operators;
- there is expected demand for such qualitative improvements.

The list of criteria that qualify a step change in black NGA areas clearly suggests that the notion of "market failure" underlying these provisions is particularly broad, to the point that it is unclear whether the features of this market environment can really be interpreted as giving rise to a "true" market failure. In this case, it thus seems that the industrial policy objective is dominant over the competition objective.

It is particularly important to explicitly acknowledge the tension between industrial policy and competition objectives in the Guidelines, now that the EU industrial policy goals have been revised and new ambitious targets have been set in the CP. The existence of this tension points to the fact that, within the EU legal framework disciplining public investment in network rollout, there is scope for the significant distortions that have been extensively recognized by the literature. Considering this, as will be argued in the next section, the new targets are likely to result in a drive towards increased public involvement in network rollout, and the risk of these distortions should be explicitly taken into account at the national level.

b) The Connectivity Package and the need for public investment

The Connectivity Package provides for a new set of objectives and measures regarding policy action in the European electronic communications markets. Such changes, in turn, affect national and local public policy in both direct and indirect ways, and, importantly, at the level of public investments. The aim of this Section is to understand what the main prospective effects that the CP measures will have on the public funding of broadband deployment are.

The CP assigns a prominent role to investments and the need for connectivity in the context of European electronic communications regulation. One of the main novelties introduced consists of a wide-ranging overhaul of the regulatory framework, which is now framed in one single directive that unites and recasts the 4 previous main Directives (Framework, Authorisation, Access and Universal Service): the European Electronic Communications Code (hereafter, the Code).

First of all, the Code explicitly redefines the main goals of European electronic communications regulation by adding, alongside the 3 former objectives of the promotion of competition, internal markets and end-user interests, the pursuit of an additional objective, which is to "*promote access to, and the take-up of, very high capacity data connectivity, both fixed and mobile, by all Union citizens and businesses*" (Art. 3, comma 2(a), Code). This additional goal is to be intended as the availability of connectivity "*on the basis of reasonable price and choice*", both in terms of "*aiming for the highest capacity networks and services economically sustainable in a given area*" and in terms of "*pursuing territorial cohesion, in the sense of convergence in capacity available in different areas*" (COM (2016) 590 final, 23).

Network investment has played a fundamental role in the European regulatory debate for several years now, taking its stance beside the more traditional competition objectives, which have become less stringent thanks to successful decades of pro-competitive regulation. The introduction of investment in the top-priority objectives is therefore certain to be regarded as the official acknowledgment of a historical change in the approach to electronic communications regulation.

The CP contains several measures that are aimed at setting the stage for a more solid investment effort in broadband networks. This, in turn, affects the role of national and local broadband public policies, in terms of their sizes and structure. The foremost, and most straightforward, policy instrument that has very well proved to impact on the amount of public funding that is supplied for broadband deployment, is the use of digital targets in terms of connectivity speed and coverage, which are set by the Commission.

As has been widely recognised in the CP's Staff Working Document, national and local policy broadband plans have been deeply informed by the Digital Agenda for Europe's (DAE) objectives – universal availability of connectivity at 30 Mbps download speed, and penetration of connectivity at 100 Mbps download speed for at least 50% of European households. The DAE targets have "*progressively become a reference for public policy*" (COM (2016) 587 final, p. 31). At the same time, the private sector's arrangements in relation to future network investment plans have also often been explicitly adjusted to the DAE's objectives (COM (2016) 587 final, p. 32).

Such digital targets, therefore, notwithstanding their non-binding nature, have a strong influence on private and public decision-making in setting the ambitions and the trajectory planning for network investments in the sector.

From the first adoption of the State Aid Broadband Guidelines in 2009 until mid-2016, 91 public funding plans for broadband deployment in 16 different Member States were approved by the Commission, the vast majority of which were approved without objections being raised. A detailed overview of the inherent structure and the amount of public funding in the various cases, is beyond the scope of this Report; however, it is worth noting that the specific design of public funding is not without implications, in terms of its effects on market dynamics and competition.[18] The structure and size of public intervention appears to vary greatly in accordance with local market conditions, as inspired by the Commission's approach in the above-mentioned Broadband State Aid Guidelines, which was discussed in the previous Section.

Funding from the European Structural and Investment Funds (ESIF) is also an option, particularly for rural areas, with the dedicated European Agricultural Fund for Rural Development (EAFRD), and through the European Regional Development Fund (ERDF). Qualifying for such funding generally requires co-funding by Member States, and therefore it does not substitute for national and/or local public subsidies.[19]

Public financial support for the deployment of high-speed networks has had an important role in the path towards reaching the DAE's objectives and it will continue to do so under the revised objectives that have been set by the CP. In line with the prospective changes in demand for connectivity and in the availability of bandwidth-intensive applications, and also to promote the competitiveness of European markets in the international arena, where several non-European countries seem to be going in the direction of laying down very-high-capacity (VHC) networks with significant public financing support, the CP has increased digital targets substantially.

Firstly, the focus of the Commission has switched from high-capacity networks to very-high-capacity (VHC) networks, which are defined as networks with best-in-class performance in terms of speed (i.e., significantly above 100Mbps)[20]. Besides, the CP stresses, at several points, the growing importance of other network features, such as latency, symmetry, jitter and efficiency range. All these factors seem to very much point in the direction of a preference for FTTH, rather than alternative technologies.

Secondly, the CP, as we explained in Chapter III.2, sets more far-reaching digital targets, in terms of both speed and coverage that are to be fulfilled by 2025.[21] As regards fixed broadband, the gigabit objective is new, and it closely concerns many areas that are managed by public entities, while the 100Mbps objective requires a great step forward, if compared to the previous DAE's objectives, where coverage with connectivity of equal speed was only demanded for half of European households.

This is an important respect in which the CP may affect the future scope of public funding. If everything else remains unchanged, in particular, private investment incentives and the costs of deployment, **an increase in the digital targets means greater scope and need for public financing**.

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[18] The next Section will look into the public funding design's impact on market dynamics and competition in more detail.

[19] Another European fund, the Connecting Europe Facility (CEF), has a very limited budget for broadband projects and a very specific scope aimed at supporting only state-of-the-art network upgrades for speeds above 100Mbps.

[20] Art 2, comma 2 of the Electronic Communications Code: "*'very high capacity network' means an electronic communications network which either consists wholly of optical fibre elements, at least up to the distribution point at the serving location, or which is capable of delivering under usual peak-time conditions similar network performance in terms of available down- and uplink bandwidth, resilience, error-related parameters, and latency and its variation. Network performance can be considered similar, regardless of whether the end-user's experience varies due to the inherently different characteristics of the medium by which the network ultimately connects with the network termination point*."

[21] To recall: (1) Gigabit symmetrical connectivity (upload and download) for all main socio-economic drivers such as schools, transport hubs and main providers of public services as well as digitally intensive enterprises; (2) All urban areas and all major terrestrial transport paths to have uninterrupted 5G coverage; and (3) All European households, rural or urban, to have access to Internet connectivity offering a downlink of at least 100 Mbps, upgradable to Gigabit speed.

Now, it is unlikely that the costs of deployment will sensibly decrease compared to the current estimates,[22] if not for the effect of synergies that may arise from the achievement of the 3 CP objectives, above, that may not have been properly accounted for, as they are difficult to quantify *ex-ante*.

It remains to be considered whether private incentives to invest will increase or not. A sensible increase in private incentives may, indeed, reduce the incremental need for public funding that has been caused by the CP's rise of digital targets.

There are two ways in which private investment incentives may increase. One is through a natural stimulus from market dynamics, caused by a rise in demand for value-added services that run on very-high-capacity (VHC) networks. This could certainly happen, but most estimates are very cautious and uncertain about the time frame of such demand development (see, for instance, those reported in Chapter II of this Report). It is widely recognised that it is only a matter of time until a more diffused use of IoT technologies, virtual reality, and other capacity-intensive applications, will spread. Still, experience seems to teach that, in communication markets, also owing to network effects, the demand responds to supply and *vice versa*. As a matter of fact, achieving take-up objectives has proven to be more difficult than providing for availability in the past, confirming the uncertain time frame that characterises demand development.

A second way in which private investment incentives may increase is by the provision of *ad-hoc* policy measures. The CP does indeed contain several measures that are aimed at mitigating regulatory constraints for investing private parties, giving them more certainty and flexibility, thus making network investment look like a better business case, and possibly minimising the role of public subsidies.

A first set of measures regards access regulation. The Code clearly aims at progressively reducing the scope for wholesale price controls in the sector. In particular, the Code postulates that such controls should be removed where there is a "*demonstrable retail price constraint*" and where effective and non-discriminatory access is proven by the economic replicability test (Art 72 Code). Wholesale price controls should remain active only for access to passive civil engineering where SMP exists, and discriminatory behaviour could indeed harm consumers (Art 59 and 70 Code). Furthermore, the Code extends the duration of the market analyses to 5 years, from the former 3-year period. This is in line with the purpose of giving companies a greater span of certainty regarding their regulatory obligations, in the view of decreasing the risk of medium-long term investment plans.

A second important set of measures in pursuit of boosting private incentives concerns co-investment. Network upgrades that significantly contribute to the deployment of VHC networks that are achieved through genuine co-investment agreements, receive a waiver from access regulation relating to new network elements if a series of cumulative conditions are met. These are that the terms offered by the SMP operator's deploying new network elements to potential co-investors must include, "inter alia, transparent, fair, reasonable and non-discriminatory terms, flexibility in terms of the value and timing of the commitment provided by each co-investor; possibility to increase such commitment in the future; reciprocal rights awarded by the co-investors" (art 74 1(a) Code); that the deployment of such new network elements must contribute significantly to the development of VHC (art 74 1(b) Code); and that outsiders to the co-investment agreement are guaranteed same conditions as available before the deployment, either through commercial agreements or, as a last resort, through regulation (art 74 1(c) Code). The need to meet all above-mentioned requirements might limit the scope and therefore the overall incentive effect of such provision.

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[22] Rollout of FTTH throughout Europe is estimated at €221 billion, while the same FTTC deployment would cost €50 billion (COM (2016) 587 final).

Other notable measures in the pursuit of the connectivity goal consist of: defining a clear regulatory setting for wholesale-only business models ("*vertically separated undertakings*"), which will be almost entirely exempted from regulatory obligations, requiring only that access is given by use of fair and non-discriminatory conditions (Art 77 Code); and, the opening of the possibility to allow for a sort of user's contribution to technological upgrades, exempting instalment contracts – where the user agrees to pay instalment payments for deployment of a physical connection – from the constraint of maximum contract duration of 24 months (Art 98 Code).

It is difficult to estimate by how much all these measures will succeed in boosting private investment incentives. Presumably, much will depend on whether a virtuous circle between take-up and availability will be ignited. All in all, to reach the CP objectives, there will certainly be a need for incremental, substantial, public financing for broadband deployment in Europe.

The CP has introduced some cornerstone changes in the electronic communications regulation, or at least it has officially integrated into the regulatory framework those substantial changes of the industry that had long informed the regulatory debate. The approach towards public subsidies, though, has not changed in the CP with respect to the first publication of the Broadband State Aid Guidelines in 2009, and its revision in 2013. The main spirit remains that of a market-based approach to public subsidies, with some evident openings to a more industrial policy approach – particularly when thinking of the concept of a "step-change" applied to black areas, as recalled above.

In a study commissioned by the EU in concomitance with the drafting of the CP, a point was raised about the possibility to minimise the need for public funds by allowing some form of cross-subsidisation between geographical areas, by means of financing projects with a geographical range comprising commercially attractive areas and challenge areas, as was done, in an extreme form, in the Australian case (SMART 2015/002 395). Reasonably, there exists a trade-off between the amounts of public funds needed, the width of coverage areas that are involved in bidding for public funds, and the risk of market distortions due to the provision of public funding: while allowing for wider areas in the public financing of projects could, overall, decrease the need for public funds, thanks to cross-subsidisation between challenging areas and commercially attractive ones, it would also be likely to increase market distortion and the "crowding out" effect.

The EU has maintained a rigorous application of the division in geographical areas, rather than allowing for cross-subsidisation. Actually, the CP contains specific provisions to tighten the geographical focus, assigning to NRAs the task of surveying every three years the state of broadband networks and investment plans across their national territory in order to identify "*digital exclusion areas*" and organise a call for interest to promote VHC networks therein (Art 22 Code). Compared to the Broadband State Aid Guidelines approach, which purports to be more market-based, where a geographical market survey is needed only as a pre-condition to apply the appropriate legislative framework for public investment at local level, this provision establishes a centralised monitoring of the whole national territory on a systematic and quite unflexible basis.

Another element contained in the CP that promotes a market-based approach to public subsidies concerns the inherent modes of financing. The financial structure of public subsidies may take different forms, mainly grants and/or financial instruments (soft loans, guarantees, etc.), but also tax rebates, the provision of physical resources and the involvement of a public procurement policy by becoming an anchor client. The CP explicitly calls for a broader use of financial instruments in the place of grants, whenever appropriate, by European funds as well as by Member States, when designing their broadband deployment's funding project(s). Financial instruments, in fact, are generally recognised as being able to provide incentives to better project performance, in the case of PPPs. Their repayable nature implies that projects financed with financial instruments must be expected to yield a higher future return, and they are therefore more in line with the Market Economy Investor Principle.

To conclude on the effect of the CP for public investment in the sector, it seems undeniable that there will be a need for substantial incremental public funds to reach the CP's targets set for VHC networks rollout in Europe. In practice, though, the actual amount of such additional funds will heavily depend on local and national conditions. The connectivity objective introduced alongside the other 3 objectives of the European electronic communications regulation is meant to balance the goal of providing citizens with the most future-proof technology and universality of connectivity. Member States will have to meet the challenge of striking the right balance between coverage and speed. Certainly, the benefit of public funds can be reaped fully if the technology chosen is the most future-proof one, but, at the same time, if such a technological choice has to be made at the cost of digital exclusion, then the spirit of the CP objective should be interpreted in the direction of choosing a less costly technological standard which still satisfies the CP's digital targets and that can be provided for all citizens.

c) How do technological choices underlying public investment affect the competition and investment objectives of EU regulation?

The specific design of the public subsidy is key to assessing its impact on competition and investment. There are several dimensions from which the public sponsor has the discretion to choose in order to shape its call for interest, and to better adapt the project to local market conditions. The most relevant are, in particular:

- the choice of geographical location: white, grey or black areas, following the State Aid Guidelines' terminology;
- the degree of involvement of the public entity: the local community model or PPP models, such as joint venture, public outsourcing, public or private build and operate models;
- the choice of financing mode: grants, financial instruments (with or without claw-back mechanisms), tax rebates;
- the choice of the recipient: only one/ multiple private investors; incumbent operator/alternative operators;
- the choice of technology: copper upgrades coupled with vectoring, cable or fibre (FTTC, FTTB, FTTH, and whether with P2P or PMP technology)[23].

All of these dimensions must be chosen with regard to their impact on market structure, with the view of satisfying the regulatory goals that are set by the Code. Indeed, each of them has a certain effect on incentives to invest and on competition.. A lower potential for market distortion is, for instance, related to directing funds towards challenging areas, rather than to more commercially attractive areas, and opting for a lower degree of involvement by the public entity, coupled with the use of financial instruments and claw-back mechanisms.

Furthermore, while the first 3 dimensions are somewhat discretionary and should be chosen as a result of a careful case by case analysis, the choice of the recipient and the choice of the technology are somewhat constrained by the obligation to be neutral and transparent in all cases. Nonetheless, care should be taken as to their impact on market structure.

Regarding competition, in particular, the Broadband State Aid Guidelines demand that access to the subsidised NGA must be offered under fair and non-discriminatory conditions to all operators who request it, providing them with the possibility of effective and full unbundling. Substantially, there must be open access for all operators on the subsidised network. In this respect, the choice of technology might have an impact on the future market

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[23] An additional dimension not mentioned here is given by the physical network level for which to provide financing: ducts and backbone, backhaul, or access level. This is no longer relevant in Europe, where the issue of public financing currently concerns only the access level.

structure: copper upgrades, in fact, would not remove the traditional dependence of alternative operators seeking access from the incumbent firm's network. Rollout of a full fibre network (FTTH) by alternative operators would, instead, remove it, but attention should be given to the specific topological designs, namely, the choice between point-to-point and point-to-multipoint, since the latter entails some limitations to physical unbundling (FSR, 2016).

All the above dimensions of public sponsorship must be also weighed against their effect on private investment incentives.

It is a solid result of the economic literature that access regulation obligations tend to decrease private investment incentives (Cambini and Jiang, 2009). While open access to the subsidised network is a necessary measure to avoid picking winners when assigning the public funding. It also decreases, everything else being equal, the future returns the investment for private operators. The same could be said about using claw-back mechanisms and financial instruments, rather than grants. While they reduce the distortionary effects of public intervention, they also make the PPP relatively less attractive for private parties, , something which should be carefully be taken into account in the overall design of public sponsorship measures.

Other noteworthy effects on investment incentives are generated by the public sponsor's choice of geographical location and technology.

Technological neutrality, as discussed in Chapter III, remains a baseline principle of the European electronic communications regulation. The way its objectives are specified, though, does rely heavily on quantitative targets relating to technological functionalities and therefore it is designed to necessarily affect the choice of technology in public sponsorship, yet leaving a certain room-for-manoeuvre.

While a point could be made that, in some cases, expressing technological preferences in public sponsorships might not entail great additional costs and departure from strict technological neutrality would not yield particular distortions (e.g., the choice between P2P and PMP in the topological design of FTTH, for instance), in some other cases, the risk of market distortion is undeniably very high. This is particularly true in the choice of which technology to subsidise between the best performing and incredibly more expensive, FTTH/B, and alternative technologies that are also able to meet the CP's digital targets, such as copper upgrades (FTTC/VDSL, G.fast) and cable upgrades (DOCSIS3.1), but that are less future-proof, if considering various quality parameters.[24]

It is coherent with the general market-based approach that informs the whole architecture of EU regulation, to aim for the least interventionist approach that still meets the objectives set by regulation (proportionality principle). In a market situation that is characterised by considerable market uncertainty which is caused by a very fast dynamic, from the point of view of technology, as well as the variety of supply and the evolution of demand, a choice of technology directed by public sponsors has the highest potential to distort market outcomes. It is therefore even more fundamental in this situation to keep a strict technologically neutral approach to public intervention.

Regarding the choice of geographical location, while the risk of crowding-out private investments is low or nil in white areas, where no commercial operator plans to invest in the near future, sensibly higher risks of crowding-out exist when public funds are directed towards helping "step-change" investments in areas where one (grey areas) or more (black areas) private operators have already deployed their NGA network. In these cases, indeed,

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[24] The first digital target requires a technology that is able to download at a symmetrical Gigabit speed, therefore only FTTH could satisfy this, while the third target requires a technology that can be upgraded to reach 1Gpbs speed, and therefore G.fast can comply, as it is foreseen that it will improve to that point by 2020. Certainly, when considered from aspects other than speed, such as latency, efficiency range, jitter, symmetry, FTTH appears to be placed in a decisively far better position than any other technology (COM(2016) 587 final).

a stricter set of conditions is required by the Broadband State Aid Guidelines,[25] as it is essential to examine the effective need and compatibility of public sponsorship projects together with the regulatory framework's objectives: not only does the inevitable risk of crowding out exist, but also the potential to displace past investment that has been made by private operators, thereby distorting competition in the market substantially more. Even when using claw-back mechanisms, in fact, due to the long payback period needed for such investments, there is the risk that past private investors will be disadvantaged in respect of the private recipients of public funds, if anything, at least for the lower investment risk faced.

In the expectation of such potential hold-up problems, the reaction of private investors is likely to be one where investment projects are postponed waiting for the right public funding for which to apply, even when there would be a good enough business case to proceed with private funds only. In other words, a waiting game between private investments and public funds may be generated, which clearly contravenes the goal of ensuring the deployment of VHC networks in the shortest possible time frame, while minimising public investments. The CP's increase in digital targets, in this sense, may just be worsening the waiting game problem, as private parties are expecting even more fuelling from public funds in the near future.

Implicitly acknowledging all of these issues, the Code stresses the importance of private co-investment agreements by adding some dedicated provisions, as explained in the previous Section. Co-investment, in fact, has the great advantage of reducing the investment risk an operator faces by sharing it with other market participants. It yields the highest benefit when co-investors can all use the shared network at either zero or cost-based charges, and the agreement conditions are balanced proportionately to each participant's relative financial contribution and the timing of entry into the co-investment project (e.g., latecomers who want to join efforts must have the chance to do so, but under reasonably different conditions than initiators). Careful attention from the authorities should therefore be directed towards the structure of the agreement, particularly in looking at the risk of collusion between co-investing parties (e.g., potential access charges between co-investors should not be higher than cost, to avoid the risk of using them as anti-competitive termination rates) and the risk of foreclosure of outsiders to the agreement.[26]

To sum up, technological choices underlying public investment affect competition and investment incentives in the market in ways that should be carefully considered by public decision-makers. Some of the technologies available are characterised by limitations to physical unbundling, which could instead be achieved easily with others, prospectively liberating the market from the traditional incumbent/access seekers structure. Moreover, public intervention is connected to a higher risk of crowding-out and displacing past private investments, when directed towards commercially attractive areas. Public funds provided through the use of financial instruments and claw-back mechanisms may have relatively less power to attract private investors, but, at the same time, they entail less risk of distorting private investments.

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[25] See Section 7.2.

[26] See theoretical contributions by Cambini and Silvestri (2012) and Cambini and Silvestri (2013).

CHAPTER VI. Conclusions

This Report discusses the complex and ambitious plan to reform and revamp the European regulatory framework, which is presented under the heading of the Connectivity Package, from an overly specific angle, the new treatment of technological neutrality. Many other topics that are included in the Package would deserve further examination and, clearly, the entire reform may succeed or fail along several other directions that are not dealt with in this present work.

The issue of departing and bending technological neutrality to push investments and markets in a direction that policymakers consider desirable is, essentially, what is discussed and challenged in the Report. In all sectors, a technologically neutral regulation and policy becomes more important the higher the level of uncertainty concerning the most likely technological evolution in a market. To examine the perils and trade-offs of departing from a technologically neutral policy and regulation in the electronic communications sector, the Authors, especially in Chapter III, have recalled the relevant literature on the impact that technological neutrality has had on telecommunications markets, in terms of structure, competition and regulation.

Of course, regulations that are not technologically neutral are less of an issue when, because of the characteristics of the industry, the risk of error is low. However, in the broadband market, where technological evolution is rapid, especially in the context of mobile broadband, with its relatively short technological cycle, the risk of regulatory error appears to be significant. Abandoning technological neutrality as has been done, in part, in the Connectivity Package is thus a risky choice.

The bases for justifying the policy change seem to be the rhetoric of an impelling need to assure ‘future proof’ networks for Europe, which appears to be more important than other competition and market dynamics’ considerations.

It is undeniable that investments in FTTH are ‘future-proof’, in the sense that they represent a technological solution for fixed connectivity that is unlikely to be rendered obsolete by other solutions for fixed connectivity at any time soon. Yet, the fact that the objectives set by the Connectivity Package are very likely to entail greater public involvement in network financing suggests that a more refined notion of ‘future-proof’ technology should be applied. In particular, whenever public investments are involved, “future-proof” choices should be taken to refer to investments that maximize overall benefits for society over a long foreseeable timespan.

A policy that disproportionately focuses on the promotion of an all fibre fixed network risks nudging the evolution of the market in a single direction, which can result in the creation of new market bottlenecks and forestalling innovation in other technologies.

In the Report, the role of technological neutrality as a policy instrument has been explored in its interaction with different dimensions of the industry. Furthermore, the relationship between the support of a specific technology and market structures, also in terms of the foreseeable effect on regulation, competition and private investments has been recalled.

As explained at length in Chapter V, the Connectivity Package is a very comprehensive set of documents that incorporates to a large extent the insights as regards the interplay between regulation and private investment as well as the insights on the trade-offs involved by public investment in more advanced networks that have emerged from a longstanding European debate.

The many nuances of this debate have clearly informed the policy stance taken by the Connectivity Package, yet a reading of the relevant texts conveys a strong overall feeling that the Package’s emphasis remains mostly on the objective to stimulate investments, mainly, if not only, in FTTH technologies. Whereas efforts are made to provide for a set of measures reflecting a balanced view of the different relevant objectives and tools the Package focuses on, its fil rouge appears to be a propensity to weaken the principle of technological neutrality, that has so far played such a prominent role in policy choices so as to ensure the achievement of a specific technological solution. In other words, while elements of caution, as regards the possible implications of an excessive emphasis on FTTH, are present in some passages of the Package, the underlying preference for FTTH is, nonetheless, quite explicit.

The discussion in the previous Chapters, and especially the analysis of path dependency in Chapter IV, however, casts doubts in many regards on the fact that such an emphasis – and the correspondent departure from the principle of technological neutrality – is warranted. A comparison, based on country-specific examples, examines the different international approaches to broadband development that are presently in place in Europe. The result is a clear diversity of starting points and paths of development that cannot be easily ignored without risking increasing, instead of reducing, the divergences in broadband coverage and speed among the Member States.

Technological neutrality is, of course, a notion that is implicit in the European rules on State Aid that legally frame public investments in network rollout. Yet, as explained in the Report, there are ways in which it is possible for national decision-makers to depart from strict market-competition and welfare-maximizing approaches, in the pursuit of the industrial policy objectives that, since the beginning, have permeated the State Aid Guidelines. These ways out seem to have found new prominence, thanks to the indications of the Connectivity Package.

It is thus important, in this conclusion, to be very explicit about the meaning that should be attached to the notion of 'future-proofing'. Even from the strictly technological standpoint, if one broadens the view as regards the range of technologies whose diffusion may be welfare-enhancing, it is all but clear that a strong preference for FTTH only should emerge. Fixed connectivity technologies are only one of a set of relevant technologies, albeit, of course, one that has so far been prominent, in terms of quantity and quality, across the EU Member States. However, surprising changes have been brought about, and are about to further materialize, due to the increased performance of wireless technologies, both mobile (LTE and 5th generation – 5G) and fixed (Fixed Wireless Access networks that connect fixed points with a wireless link).

Recent studies have shown that a mix of wired and wireless technologies may constitute a cheaper and safer option for enabling Member States to reach the most difficult targets, especially in terms of rapidly covering the areas of persistent digital divide. This should very well be taken into account especially in the pursuit of the third new digital target that has been set by the Connectivity Package: all European households, rural or urban, to have access to Internet connectivity offering a downlink of at least 100 Mbps, upgradable to Gigabit speed. It is in rural areas that wireless solutions show the greatest technical performance (mostly because the underlying spectrum capacity is shared among a lower and more sparsely distributed population) and they appear to be more cost-effective.

The case for seriously considering the cost-benefit implications of wireless technologies, along with fixed technologies is, however, more general. Wireless solutions may turn out to be 'future-proof', from a more classical dynamic perspective: whenever uncertainty about the real extent of demand for VHC is binding for operators' investment policies, meaning that investment would only be undertaken in a potentially profitable area if demand reaches a given threshold, wireless technologies may be a solution that allows to dynamically discover the real extent of demand at significantly lower cost than fixed connectivity solutions.

This points to the other key element that should always be taken into account in policy design in this domain: the key role of demand. "Future-proof" technological choices should be, as mentioned, those that maximize overall welfare. This entails that public policies should aim to address circumstances in which various sorts of market failures prevent an efficient match between supply and demand.

Yet, this matching presupposes that a demand exists for the chosen technology, or that it may exist if appropriate measures are taken. This is inevitably more likely to be the case the lower the price at which demand can meet supply. The empirical evidence reported in Chapter II clearly points in this direction: there is, at present, only a very low willingness to pay for FTTH infrastructures. One piece of evidence even points to the fact that the incremental willingness-to-pay falls close to zero for speeds approaching 100 Mbps (Vertigan, 2014).

Prospectively, this willingness to pay may hopefully grow, if new uses and applications develop, but it may even decrease, as the bandwidth requirements of the main applications that may entice demand are reduced by technological progress. In the end, at present, there is not enough certainty about the degree to which different existing technologies may prove capable of substantial enhancement, and how they will be able to address future demand needs.

Some investments that are foreseen by the Connectivity Package appear, from this perspective, to be justified on more solid grounds. This is the case for the new digital target of Gigabit connectivity for the main socio-economic actors. In this case, the underlying demand is, in good part, expressed by the public decision-maker itself, presumably based on the conclusion that the range of externalities that may be generated by this technological choice is wide enough to justify the investment on cost-efficiency grounds. One of this important sort of externalities may reside in the fact that a high connectivity performance of key socio-economic actors may be a driver of adoption, and may thus contribute to igniting a more general investment-adoption dynamic.

However, even in this regard, doubts may still be expressed on the preference accorded to Gigabit symmetric connectivity, which again entails a clear departure from the principle of technological neutrality in this domain, considering the mentioned effects of technological evolution that are progressively decreasing bandwidth requirements for consumers, and, in all likelihood, also for most of the key socio-economic actors.

Moreover, considering the profound differences in the current availability of connectivity solutions to key socio-economic actors within and across EU countries, and the limited public resources, this digital target may induce the making of choices that are not necessarily advisable in terms of the trade-off between coverage and network performance. Whether it is more welfare-enhancing to ensure better connectivity for a wider range of socio-economic actors, or FTTH connectivity for a more limited number of these actors, should be carefully considered.

Making the right choices in allocating the new inflow of public funds that, as the Authors have argued, will be necessary to meet the new ambitious targets included in the Connectivity Package, is no easy task. There are many trade-offs to consider, and plenty of room for distortions of private investment, even within a legislative framework that is designed in a way that is meant to privilege market-based solutions.

One good rule of thumb to adopt, in order to orient public policy choices towards the real ‘future-proof’ objective of welfare maximization, is to keep clearly in mind the overarching objective of generating the maximum amount of positive externalities and minimize distortions of private investments. In this equilibrium, an open mind to innovative solutions, no matter what the technology employed, a respect for converging but different Member States’ paths to broadband development, and permanent attention to demand needs and evolutions, should always be at the core of any healthy relationship between a sound economic and market-based regulation, and any kind of soft industrial policy.

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Marc Bourreau is Professor of Economics at Télécom ParisTech. He is also a Research Associate at the laboratory of industrial economics (LEI) of the Center for Research in Economics and Statistics (CREST). His main research interests are in industrial organization, regulation and network economics. Marc Bourreau is the Editor of *Information Economics & Policy,* and a member of the Editorial Board of *Telecommunications Policy*. He has published several articles in peer-reviewed economics journals, such as the *American Economic Review, the European Economic Review, the Journal of Industrial Economics, the International Journal of Industrial Organization, Information Economics & Policy,* and *Telecommunications Policy.* He received a Master's Degree in Engineering Science from Télécom ParisTech and a Ph.D. in Economics from Université Paris 2 Panthéon-Assas.

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Steffen Hoernig is an Associate Professor at the Nova School of Business and Economics, Lisbon, Portugal. His research area is Industrial Organization, with particular emphasis on network economics. He is Associate Editor of *Information Economics & Policy* and Review of Economics. He has been a consultant for ICP-ANACOM and various international companies and institutions on issues in network competition. He was a jury member for the rural next-generation broadband competition in Portugal. Steffen obtained a Degree in Management at the U. Bielefeld (Germany); a Master's in Applied Mathematical Sciences at U. Georgia, (Athens, USA); and a PhD in Economics at EUI (Florence, Italy).

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Pier Luigi Parcu is part–time Professor at the European University Institute, where he directs the Communications and Media Area at the Florence School of Regulation, the Centre for Media Pluralism and Media Freedom and the Florence Competition Programme. Since 2004, he has been the chairman of a consultancy company specialized in antitrust and regulatory issues of network industries. Previously, he was CEO of the Independent System Operator running the Italian Electricity Grid (GRTN), and the Director of Investigation at the

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Maria Alessandra Rossi is Associate Professor of Economic Policy at the University of Siena. Her research interests include: the law and economics analysis of innovation, telecommunications & media economics and digital economics, with specific regard to open source software. She was a visiting researcher at the University of Oxford, the Council of Europe, the Department of Economics at UC Berkeley, the Santa Fe Institute, at the University of Paris X and at the Florence School of Regulation. She has carried out research and written reports for OECD, the Italian Telecommunications NRA (AGCOM), the Italian Ministry of Finance, and the Independent Regulatory Group (IRG). She has written numerous articles in national and international journals, such as: *Journal of Economics and Management Strategy, Cambridge Journal of Economics; Telecommunications Policy; Economics of Innovation and New Technologies; Communications & Strategies; European Journal of Law and Economics*. Maria Alessandra holds a Ph.D. in Law and Economics from the University of Siena.

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Virginia Silvestri's field of research is Industrial Organisation, with a particular focus on competition and regulation issues in Telecommunications and Media markets. Virginia obtained a Degree in Economics and Social Sciences from Tor Vergata University in Rome in 2007. She then continued her studies at PhD level at IMT Lucca Institute for Advanced Studies and spent the academic year 2009-2010 as a visiting research student at University College London. She obtained her PhD in 2012, with a dissertation on investment and network regulation in broadband markets. She has several work experiences in the field of telecom regulation and antitrust consultancy. She published in peer-reviewed journals and taught courses in Competition Economics and Microeconomics. Since 2011, she has worked as a research associate at the Florence School of Regulation, based at the European University Institute in Florence. In September 2015, she started teaching at John Cabot University.

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