The Role of Regulation in Incentivizing Investment in New Communications Infrastructure

Study carried out on behalf of Deutsche Telekom AG by

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April 25, 2017

Disclaimer: The information and views set out in this study are those of the authors and do not necessarily reflect the official opinion of Deutsche Telekom AG.

Acknowledgements: The authors would like to thank Kai Hüschelrath and Ingo Vogelsang for their valuable comments and insights!

IN BRIEF

THE ROLE OF REGULATION IN INCENTIVIZING INVESTMENT IN NEW COMMUNICATIONS INFRASTRUCTURE

On September 14, 2016, the European Commission published its proposal for a directive establishing the European Electronic Communications Code ("CODE") with the intention of substantially revising the existing regulatory framework for communications markets. Originally, one of the European Commission's main goals was to incentivize investment in new high-speed broadband infrastructure. However, the European Commission's proposals fall short of fostering investment in high capacity networks in Europe – in essence because of the complexity of the new regulatory measures envisaged and the resulting predictable difficulties to implement these measures in practice.

In particular, three major shortcomings of the European Commission's proposals are identified:

- The CODE's provisions on co-investment model are very prescriptive, excluding many voluntary, market-driven cooperation models from benefitting from regulatory relief. Co-investment will only induce additional infrastructure investment if regulatory requirements are not overly restrictive in terms of accruing future investment rewards. Therefore, requirements on cooperation agreements to qualify for regulatory relief should be considerably eased.

- Although the CODE´s proposals on symmetric access obligations were intended to allow for less asymmetric access obligations, thereby reducing the overall intensity of regulation, they will most likely result in a significant expansion of current regulations to a large number of operators and access infrastructure elements. Additional regulatory burden, plus the lack of clarity with regard to scope and implementation of symmetric regulations, raise serious concerns about investment incentives for high capacity network deployment. Another concern is the CODE´s aim to extend asymmetric access regulations to infrastructure elements outside the scope of the relevant market concept.

- Public broadband targets as stipulated by the European Commission's gigabit strategy bear the risk of distorting market outcomes by "picking winners", explicitly favouring particular broadband access technologies. However, deviating from the principle of technological neutrality can only be justified in light of sound empirical evidence on differing welfare effects of distinct access technologies – evidence which is currently not available. Without sound evidence of comparative economic advantages no particular network architecture or technology should be favored above others. In fact, the notion of 'efficient' investment implies that real investment meets real demand – rather than choosing a specific technology in case of high market uncertainties.

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Executive Summary

On September 14, 2016, the European Commission published its proposal for a directive establishing the European Electronic Communications Code, which will substantially revise the existing regulatory framework for communications markets (hereinafter referred to as "CODE"). One of the CODE's main goals is to incentivize investment in new high-speed broadband infrastructure in view of its particular economic importance. The aim of this study is to provide a critical appraisal of the future regulatory framework set out in the CODE in terms of their expected impact on investment incentives and dynamic efficiency.

The study examines (i) broadband market structures and relevant market developments, (ii) competition factors within and outside of the market and (iii) underlying access regulations, highlighting policy trade-offs and deriving policy recommendations. Recent academic analysis points at dynamic efficiency as principal regulatory goal. Our analysis confirms:

- Less intrusive approaches replacing existing asymmetric access obligations – ranging from soft regulations to full deregulation – enhance investment incentives.
- Co-investment, reducing deployment costs for very high capacity networks, could further boost investment. An inclusive framework ensuring fair risk and cost sharing between investing firms and access seekers has a positive impact on invest.
- To enhance deployment of very high capacity networks, no particular network architecture or technology should be favored above others (unless there is considerable and sound evidence of its comparative economic advantages).

Partly, the measures set out in the CODE point in a similar direction – but they also raise serious concerns. In particular, a closer examination of the detailed regulatory provisions envisaged in the CODE reveals that the substantial amount of complexity might seriously hamper implementation, thereby jeopardizing the goal to encourage investment.

Full deregulation of fiber access provides most incentives for both new and incumbent operators to invest in high-speed broadband network infrastructure.

Why soft regulation enhances investment

Economic theory and empirical evidence suggests that relaxing regulation of fiber-based access infrastructure is essential to encourage investment. Full deregulation of fiber access provides most incentives for both new and incumbent operators to invest in high-speed broadband network infrastructure. However, if full deregulation is not feasible due to monopolistic market structures, a less intrusive regulatory approach abandoning cost orientation contributes to an increase in investment incentives (albeit not to the extent of full deregulation). On the one hand, cost-based access prices inevitably shift market dynamics away from investment to "wait-and-see" strategies. On the other hand, access

prices that include a premium for demand risk and uncertainty induce more investment, since investing network operators are compensated for running significant risks.

The drawbacks of myopic asymmetric regulation

Asymmetric access regulation is based on firms' dominant market position in the relevant market. Consequently, market definition plays a crucial role. Beyond defining product and service markets, more emphasis should be put on a methodically sound definition of geographic markets. Today, in most EU member states competitive conditions between urban and rural areas differ considerably. A lift of access regulation in competitive areas will substantially enhance incentives to invest and increase social welfare. Only in case of persistent, monopoly-like bottlenecks asymmetric access obligations may be justified to safeguard competition.

Limiting access regulation to obligations to share passive elements of the network only (i.e. duct access) could be conceived as an intermediate step towards deregulation. In particular, this regulatory remedy appears to avoid duplication of fixed costs. In contrast, stricter regulatory conditions for active infrastructure may limit incentives both for the incumbent operator and for access-seeking newcomers to invest, favoring (unregulated) firms that already have their own infrastructure in place, typically infrastructure that can be upgraded easily.

Symmetric obligations to share passive infrastructure as second best option

If full deregulation is not desired, access regulation should at least be symmetric, i.e. applied to all operators – incumbents, cable operators and access-seeking new entrants alike. Asymmetric regulation of dominant operators (typically incumbents) substantially reduces the incumbents' incentives to invest and does not incentivize additional investment from other market players such as cable operators. A symmetric regime, replacing asymmetric regulation, is all the more pertinent when some firms (such as cable operators) have substantial cost advantages deploying new high-speed broadband networks.

The potential for cost synergies when sharing passive infrastructures also speaks in favor of imposing regulatory conditions on passive elements for all network-based operators. It should be noted however that potential cost reduction benefits might be outweighed by investment-diminishing incentives resulting from network sharing obligations.

The CODE falls short of limiting and re-focusing regulation

The regulations governing symmetric access obligations set out in the CODE (Art. 59) are supposed to allow withdrawing more restrictive asymmetric access obligations (Art. 71), thereby reducing the intensity of regulation. However, the envisaged symmetric access regulations might lead to a significant expansion of current regulations, covering a larger number of operators and access infrastructure elements, without alleviating intrusive asymmetric access obligations. As applying symmetric access regulations will not require conducting an extensive market analysis, the likelihood they will be implemented in practice seems high.

The new symmetric regulations tool kit, overall broadening the scope of regulatory intervention, raises serious concerns about its effect on investment incentives. The lack of clarity in some of the CODE's relevant provisions further exacerbates regulatory uncertainty. Of equal concern is the CODE´s aim (Art. 70 (2)) to extend asymmetric access regulations to new infrastructure elements, beyond the scope of the relevant market concept.

Co-investment: a magic wand to foster fiber investments?

Especially in areas with limited scope for infrastructure competition co-investment seems a promising concept to foster network investment. Sharing risks related to future demand and market exposure, cost reductions, capital formation in case of capital market imperfections, and the primacy of voluntary agreements are salient features of effective, successful co-investment models.

Economic analysis suggests co-investments perform better providing high-speed broadband coverage than the conventional mandated wholesale access regime. Mandating open access leads to lower investment and lower coverage because the access option constitutes an opportunity cost that makes co-investment less attractive.

When it comes to new investments, the risk of imposing stringent open access requirements, or the potential threat of it, may discourage operators from agreeing to invest in the first place.

Coming from a common mandated access regime, welfare typically increases if co-investment occurs. However, mandating open access if there are network sharing or co-investment arrangements in place reduces welfare if the access price is comparatively low (e.g. cost-based). In case of demand uncertainty, the entrant can simply wait until real demand manifests itself, and then benefit from mandated access without incurring any risks. When it comes to new investments, the risk of imposing stringent open access requirements, or the potential threat of it, may discourage operators from agreeing to invest in the first place. Hence, from a policy perspective, co-investment obligations without access should be preferred over a pure mandated access regime or a regime with co-investment plus open access. This holds in particular when demand uncertainty is high.

Whether co-investment models subject to ex ante approval are in fact suitable instruments to promote investment depends to a very large extent on the precise implementation in individual member states. The stricter ex-ante conditions for co-investment approvals are applied, the smaller the investment promoting effect will be.

The CODE's provisions on co-investment: a tight regulatory corset

The CODE´s regulations of co-investment models (Art. 74) represent a rather tight regulatory corset, with the result that CODE-complying co-investment models will substantially differ from commercial market solutions. However, co-investment models will only induce additional infrastructure investment if regulatory conditions, set out ex-ante, allow for

sufficient flexibility, holding out the prospect of accruing future investment rewards, fair risk sharing and realizing cost reductions. The positive risk-sharing effect increases (i) the longer participating parties are able to co-operate, (ii) with the extent commercially negotiated terms prevail and (iii) the smaller the scope for regulatory gaming.

Co-investment and sharing agreements are complex, diverse, and have often proven difficult for operators to commercially agree in practice.

The design of commercial co-operation models should not be subject to specific ex-ante restrictions. Regulators need to take note of the fact that co-investment and sharing agreements are complex and have often proven difficult for operators to commercially agree in practice. Co-investment agreements can involve several operators investing jointly in different infrastructure components and then granting access to each other (or to third parties) – as well as different versions of volume-discount models, with only one firm deploying the infrastructure. Whatever the model is, a co-investment agreement can only work if all participants bear and commit themselves to the investment risk.

Imposing access obligations on co-investments may considerably increase competition. However, access obligations will inevitably reduce investment and coverage. In case of co-investment with mandated open access, entrants enjoy a 'cream-skimming' option when demand soars. The network investor bears all the downside risk, while the upside benefits are shared. Therefore care is required that the regulator does not stymie investment in the first place by overly rigorous requirements for mandated sharing.

Imposing open access accompanied by complex pricing rules entails high transaction costs and substantial regulatory uncertainty, seriously jeopardizing incentives to commit at an early market development stage.

The CODE (Annex IV lit. a) imposes an open co-investment agreement on the dominant operator, allowing new entrants to join the co-investment at any time. To a certain extent, keeping co-investment agreements open on a non-discriminatory basis during their entire period of validity corresponds to mandating open access. The granted option for late entrants to join the co-investment, paying an access fee that includes a dynamic risk premium, requires the regulator to precisely assess investment risks and calculate an adequate risk premium for any point in time when a new entrant may join the co-investment. In both theory and practice, this is an extremely difficult and complex task. Nonetheless, the CODE requires a dynamic adjustment of access prices (Annex IV lit. c), reflecting lower risks for new entrants committing themselves at later stages. In sum, imposing open access accompanied by complex pricing rules entails high transaction costs and substantial regulatory uncertainty, seriously jeopardizing incentives to commit at an early market development stage.

Technological neutrality: don't say goodbye, it's wrong to let you go

The CODE emphasizes the importance of infrastructure-based competition in incentivizing investment in very high-capacity broadband networks (recitals 3 and 175). Assuming that public broadband targets as stipulated by the European Commission´s Gigabit Society strategy are desirable in terms of welfare, various fiber-based access technologies contribute to deploy next-generation communications infrastructure. However, pursuing Gigabit Society targets should not lead to distorting market outcomes by "picking winners", i.e. explicitly favoring certain access technologies. Deviating from the principle of technological neutrality would require sound empirical evidence on differing welfare effects of distinct access technologies – evidence which is currently not available. Without sound evidence of comparative economic advantages no particular network architecture or technology should be favored above others.

It is safe to assume that existing and future 'second-life' copper/coax technologies will have a crucial role to play in an efficient migration process to next-generation networks, in particular due to their comparative cost advantages. Among other factors, efficient migration will depend on country-specific characteristics such as the availability and quality of ducts or the number of street cabinets. In the near future, another fundamental technological shift can be expected with the advent of 5G networks. 5G networks will most likely lead to a convergent wireline and wireless infrastructure; wireless links to the premise may offer an alternative to fiber and copper.

The notion of 'efficient' investment implies that real investment meets real demand – rather than choosing a specific technology.

In fact, the notion of 'efficient' investment implies that real investment meets real demand – rather than choosing a specific technology in case of high market uncertainties. Markets provide more efficient investment decisions in a world with considerable uncertainty about future demand for high bandwidth and fast technological progress.

1 Introduction

On September 14, 2016, the European Commission (EC) published its proposal for a directive establishing the European Electronic Communications Code (EECC), which will substantially revise the existing regulatory framework for communications markets (European Commission, 2016a, hereinafter referred to as "CODE"). One of the CODE´s main goals is to incentivize investment in new high-speed broadband infrastructure. In order to achieve this goal, the CODE suggests various regulatory schemes, which are subjected to critical assessment in this study. The aim of this study is to provide a comprehensive description of relevant market characteristics and underlying regulations and policies in broadband markets as well as a sound theoretical analysis on the role of future regulation in incentivizing investment in new communications infrastructure. Although there already exist numerous theoretical and empirical contributions that address the relationship between investment and regulation both in general and also with respect to electronic communications markets in particular, this topic gains new significance in the context of the current review of the regulatory framework.

The study is divided into two major parts: Part I contains all the policy relevant background information, institutional descriptions and relevant market developments and builds in part upon a previous study conducted by ZEW on behalf of the German Federal Ministry for Economic Affairs and Energy (BMWi). Chapter three of the BMWi study (co-authored by Wolfgang Briglauer and published in German as Bertschek et al., 2016a; hereinafter referred to as "meta-study") also addresses the issue of regulation and investment but with a particular focus on the market situation in Germany.[1] In contrast, Part I of this study takes a European and more general view and offers further insight into specific regulatory policies, explicitly incorporating a critical appraisal of the measures as set out in the CODE at the end of each section. Other policies covered in chapter three of the meta-study, such as public funding in particular, are only mentioned in passing in this study. Taking the relevant characteristics of the policy analysis in Part I into account, Part II presents game theoretic models examining the relationship between investment and various regulatory schemes. The models are all based on some analyses developed as part of previous papers co-authored by Carlo Cambini, which were recently published in relevant economics journals.

The structure of this study is as follows: Section 2 briefly provides relevant technical definitions, market developments related to various types of broadband infrastructure and the diffusion of broadband services as well as the role of infrastructure investment and dynamic efficiency as a guiding policy goal underlying the EU regulatory framework. The basic mechanism and institutional design of the EU sector-specific regulatory framework is presented in Section 3. Various regulatory schemes are then discussed against the background of increasing levels of policy intervention in Sections 4 (competitive safeguards),

[1] Wolfgang Briglauer is very grateful to Dr. Peter Knauth and Dr. Andreas Hartl from BMWi for granting permission to build upon parts of the meta-study.

5 (co-investment models), 6 (symmetric regulation) and 7 (asymmetric regulation). To round off Part I, Section 8 provides interim conclusions summarizing the main policy trade-offs and recommendations for future regulatory policies. Section 8 also provides an immediate jumping-off point for the theoretical analysis in Part II. Part II first briefly summarizes the theoretical literature on migration to new broadband networks and the role of regulation in the old (copper-based) infrastructures (Section 9). Building on this, the study then extends the results to account for the following policy relevant features in Sections 10 through 12: i) the presence of geographical regulation, i.e. access charges that differ according to the degree of infrastructure-based competition prevailing in different areas of a country; ii) the role of co-investment in encouraging investment in new fiber-based technology, especially in the face of demand uncertainty. We then extend the analysis to account for iii) the presence of cable operators and study the impact of fiber regulations imposed on the existing infrastructure, thus investigating the potential effect of asymmetric access regulation. Section 13 provides interim conclusions from the reviewed theory models. The final section 14 summarizes and concludes by outlining the most relevant policy implications and recommendations resulting from our analysis in Part I and Part II. The concluding section ends with a critical appraisal of the CODE in view of our analysis in Part I and Part II.

Part I:
Institutional background and regulatory developments

2 Definitions, current status of modern broadband networks and the role of infrastructure investment

This section sets out, on the one hand, the investment activities on the part of broadband providers which provides evidence of the actual availability (=coverage) of broadband infrastructure. We further outline the significance of infrastructure investment as a guiding principle in the current and upcoming EU regulatory framework. On the other hand, this section presents evidence on the demand side in terms of diffusion (=adoption) of broadband connections. The adoption of services illustrates whether there is also sufficient willingness on the part of consumers to pay (or rather "subscribe to") corresponding broadband services based on the connections provided. Take-up rates are defined as the ratio of adoption to available connections. These take-up rates are thus between 0 and 1 (since adoption cannot exceed the capacities that are available) and provide information on the extent of migration to new services on the demand side and existing overcapacities on the supply side.

2.1 Relevant technical definitions

Historically, fixed-line "first-generation" ("legacy") networks based on copper-wire infrastructure were built to support narrowband voice telephony services only. These legacy networks were later upgraded to what are known as xDSL technologies to deliver first-generation broadband services.[2] However, the performance of xDSL technologies based on copper infrastructure, as well as coaxial cable data transmission technologies (i.e. for cable television, CATV), is greatly limited by the length of the remaining local access loop. Hence, for xDSL to yield higher bandwidth levels, fiber-optic cables have to be deployed closer to the customer premises in the access networks, as shown in Figure 1.

Depending on the fiber reach, different "next generation access" (NGA) broadband network architectures are distinguished: One refers to FTTC (fiber to the cabinet or curb, sometimes also referred to as fiber to the node, FTTN) when the modern VDSL technologies, such as VDSL2 and VDSL2 vectoring, are run on a hybrid fiber-based network, which extends to street cabinets, and copper lines, which typically cover around several hundred meters from street cabinet to the customers´ premises. Fiber to the distribution point (FTTDp) supported

[2] xDSL is a generic term used for the Digital Subscriber Line technologies, which provide internet access by transmitting digital data over copper lines. A modern example is VDSL, which stands for Very-high-bit-rate Digital Subscriber Line.

by VDSL/XGfast stands for another recent hybrid copper-fiber transmission technology. FTTDp is similar to FTTC/N but is one-step closer to the customer with copper lines normally less than 200 meters in length. Hybrid solutions can currently provide bandwidths of up to several hundred Mbit/s. Forthcoming technological innovations may bring further significant improvements, e.g. XGfast. Fiber to the building (FTTB) requires the fiber-optic cables be located close to or inside a building, e.g. in the basement of a multi-dwelling unit. In this architecture, the only copper-based connections remain between the customers´ premises and the building's switch. FTTB yields bandwidths of up to 1 Gbit/s. When technical and economic considerations render it feasible to completely eliminate copper lines, then each subscriber can be connected by a dedicated fiber access line, a system referred to as fiber to the home (FTTH). FTTH is said to be "future proof", because data transmission speed is limited by the terminal equipment rather than by the fiber infrastructure. The resulting FTTH bandwidth capacity is almost unlimited in terms of its potential applications (Briglauer et al., 2015a, p. 13; FTTH Council Europe, 2014, pp. 13-14; Wikipedia "Fiber to the x").

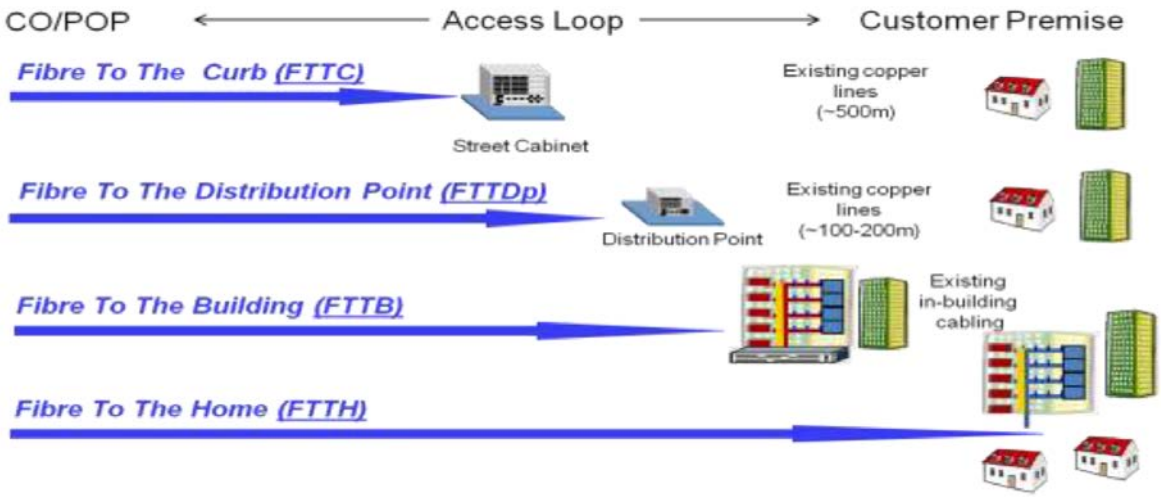

Figure 1: Relevant fiber network architectures (FTTH Council Europe 2014, p. 14)

Besides the FTTx (=FTTC/N/Dp/B/H) architectures, NGA networks might also be realized by upgrading CATV networks. This architecture is called fiber-to-the-last-amplifier (FTTLA) and means high-speed access enabled by the DOCSIS 3.0 technology on hybrid fiber-coaxial cables.[3] In principle, this cable transmission architecture is able to provide bandwidths between 100 and 200 Mbit/s. As the customers share cable coax infrastructure, however, they may be confronted with a reduction in bandwidth at peak times. In addition, CATV networks are optimized asymmetrically for downstream usage and thus upstream capacity is more limited than in the FTTx technologies (FTTH Council Europe, 2013, p. 11). The newer version of DOCSIS, the 3.1 version, which is to be deployed on a larger scale soon, can theoretically provide speeds of up to 10 Gbit/s. Many of the major cable operators have already fully integrated the technological DOCSIS 3.0 standard into their networks as far as is possible and have fully equipped their networks in terms of broadband capability. By

[3] DOCSIS stands for Data Over Cable Service Interface Specification.

contrast, the proportion of VDSL technology is at just 40% of all xDSL connections on average across the EU (Briglauer et al., 2015a, p. 13; European Commission, 2016b, p. 19). The latter appears to be due to the comparatively higher costs associated with upgrading copper-based networks to FTTC/FTTN hybrid networks, which typically involves a physical migration of access infrastructure elements towards the direction of the customers' premises.[4]

Mobile broadband services are also widely available. In particular, the 4th generation (4G) mobile networks technology "Long Term Evolution" (LTE) offers data transmission rates in ranges comparable to fixed-line hybrid-fiber NGA systems. Mobile broadband represents a shared resource, however, because the access quality parameters depend heavily on the number of concurrent users at a given location. Available bandwidth for the individual mobile broadband user also largely depends on the distance from the nearest cell tower. For these reasons, the EC considers 4G/LTE to be a viable outside option to wireline NGA broadband services but still not a close enough substitute for most consumer segments, at least not in the medium term.

Below we use the term FTTP (fiber to the premise) to refer to FTTH/B networks in the narrow sense ("ultra-fast Internet"), while all wireline deployment scenarios as described above are referred to with the abbreviations FTTx or NGA ("fast Internet"). FTTx includes all fiber scenarios as described in Figure 1, whereby NGA additionally includes the DOCSIS technology standard. According to the above discussion, hybrid "Second-life copper/coax" technologies can therefore effectively contribute to delivering not only the bandwidth levels for all households formulated in the targets of the EC´s Digital Agenda for Europe (European Commission, 2010a, DAE) but also – in view of the considerable innovation potential of second-life broadband technologies – the more ambitious bandwidth targets recently formulated as part of its 2025 "gigabit strategy" (European Commission, 2016c).[5]

2.2 Relevant market developments

Figure 2 shows the diffusion of broadband services based on all 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, there are only a small number of countries in which optical fiber-based FTTP Internet connections make up a substantial proportion of the total

[4] For comparisons of investment costs of different access technologies the reader is referred to Taga et al. (2009).

[5] The DAE "*seeks to ensure that, by 2020, (i) all Europeans will have access to internet speeds of above 30 Mbit/s and (ii) 50% or more of European households will subscribe to internet connections above 100 Mbit/s*" (European Commission, 2010a: p. 19). Building upon these objectives, the EC expresses longer-term objectives for 2025 emphasizing the promotion of very-high capacity fiber-based networks, which enable gigabit-connectivity via wireline and/or wireless communications infrastructures. The European Commission (2016c) proposed three strategic objectives for 2025: i) Gigabit connectivity for the main socio-economic drivers, ii) 5G mobile data connectivity for all urban areas and transport paths, iii) access to internet connections offering at least 100 Mbit/s for all European households.

connections. A comparison of 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 from cable networks, whereas in other countries, such as Greece or Italy, DSL or VDSL is used almost exclusively.

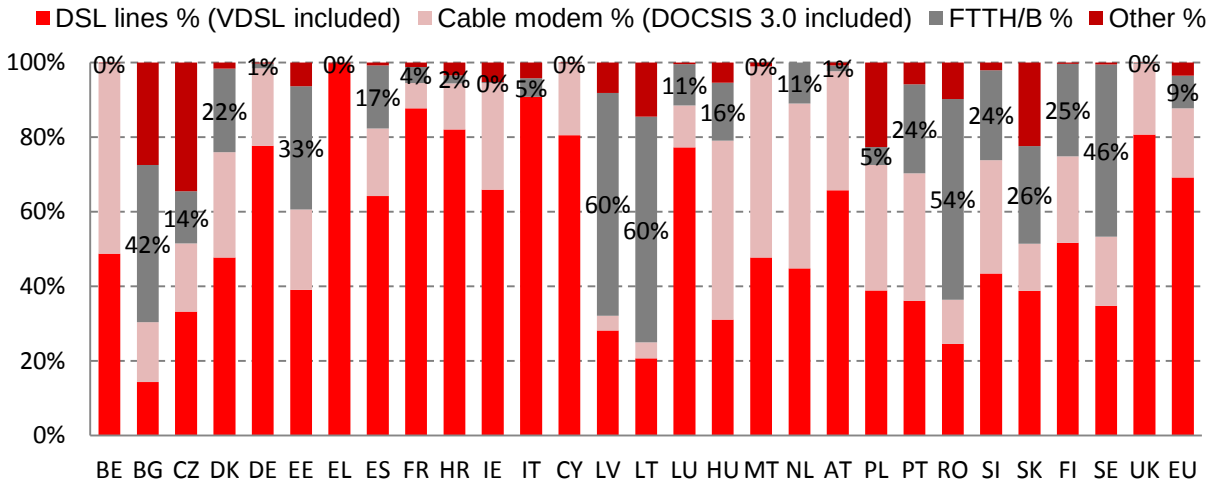

Figure 2: Fixed broadband subscriptions — technology market shares (July 2015, source: European Commission, 2016b)

In contrast to Figure 2, Figure 3 shows the availability of ultra-fast broadband infrastructure coverage. It appears that the countries leading the way in terms of the diffusion of FTTP connections are also among those with high FTTP availability. As Figure 2 and Figure 3 show in more detail, it is primarily in Northern and Eastern European countries that FTTP connections account for a large share (above the EU average in Figure 3, i.e. >20%) of all wireline broadband connections. One basic difference can be attributed to previously implemented public broadband incentive programs and the far-reaching role of the public sector in Northern European countries. Such programs related to basic broadband connections were introduced in the Scandinavian countries at an early stage (Briglauer & Gugler, 2013; Godlovitch et al., 2015a; Picot & Wernick, 2007). In terms of new FTTP broadband infrastructures, local authorities and utility companies are strongly engaged in deployment activities in Northern European countries (Crandall et al., 2013, p. 274; Finnie, 2012, p. 8). 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 & Gugler, 2013). Consequently, in some of the largest Western, Central and Southern European countries existing FTTP deployment projects typically focus on only a small number of urban regions and are on average significantly below the deployment levels in Eastern European countries.

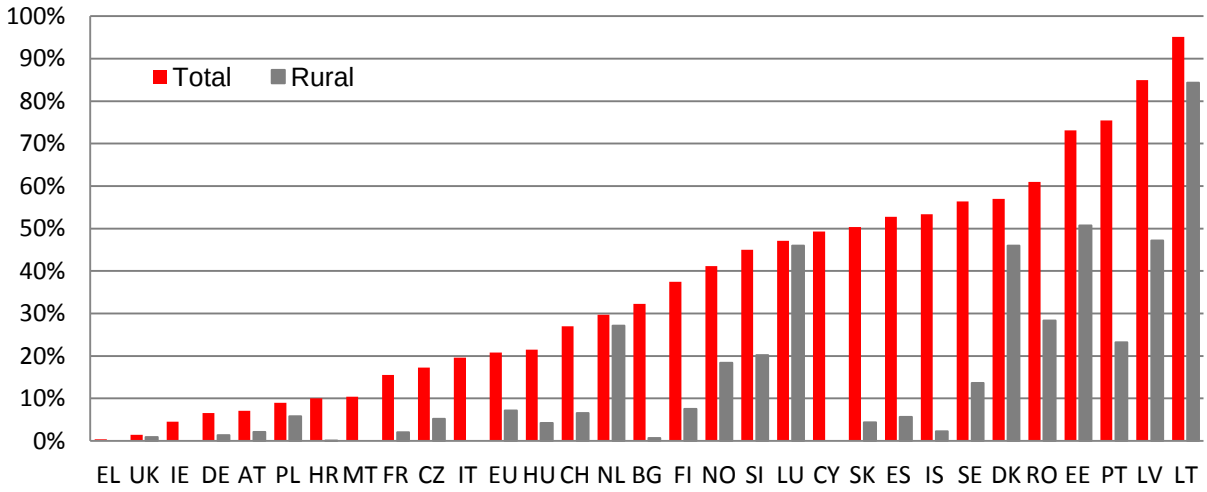

Figure 3: Fiber to the premises (FTTP) coverage (June 2015, source: European Commission, 2016b)

It is important to note here that the reported data is based on averages and therefore does not indicate that all households have guaranteed coverage (as requested by the EC´s 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 member states. Figure 4 and Figure 5 show that there is indeed substantial geographical intra-state variation between rural and urban as regards both NGA and 4G(LTE) coverage and also substantial inter-state coverage variation between EU member states.

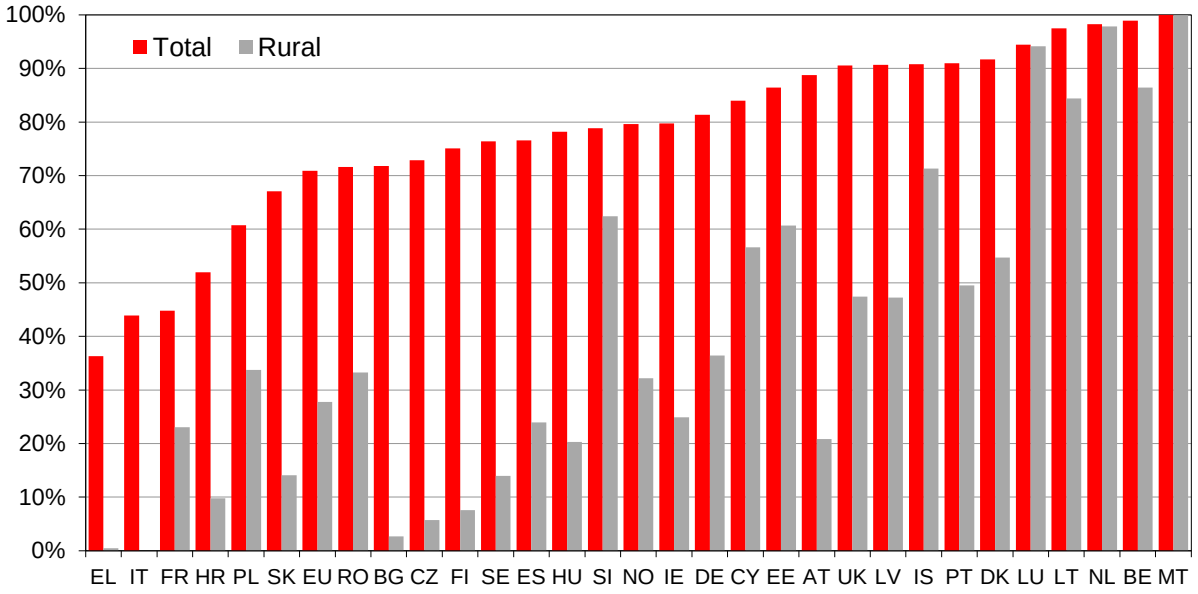

Figure 4: NGA coverage in rural areas and in total (mid-2015, source: European Commission, 2016b)

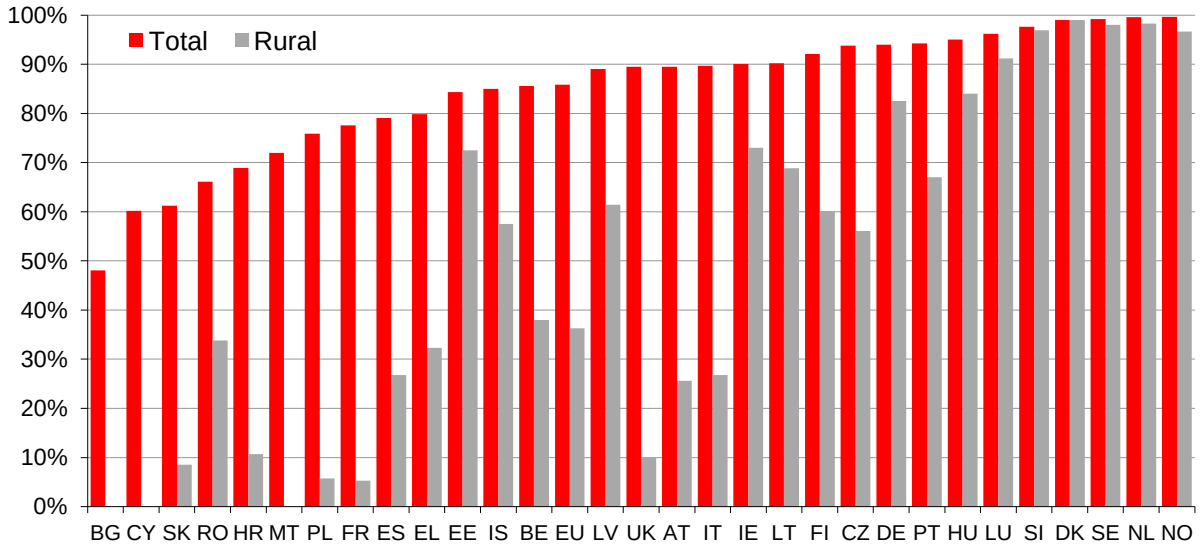

Figure 5: 4G (LTE) coverage in rural areas and in total (mid-2015, source: European Commission, 2016b)

Figure 6 displays the take-up rates, which are defined as the number of subscribed connections ("homes connected") in relation to the number of connections available ("homes passed") as a percentage. As one can infer, the take-up rate is still at a rather low level of 35% in 2015 after years of moderate growth since 2011. This suggests that there are substantial switching costs for consumers, who appear to be largely content with basic broadband services. Conventional broadband packages enjoy broad acceptance among many consumers in most of the EU Member States, which leads to significant switching costs on the part of the consumer and thus hinders migration to new technologies and leads to low NGA take-up rates. The exception to this rule is when the benefits of migration are significant enough and transparent enough for consumers (Grajek and Kretschmer, 2009; Briglauer, 2014). However, most of the empirical evidence so far suggests that "*customers are likely to have a high incremental willingness to pay for a high speed service, but a low incremental willingness to pay for very high speed services*" (Parcu, 2016, p. 52). On the part of operators, Figure 6 also points to substantial, persistent and costly over-capacities related to fast (NGA) broadband infrastructure.

Furthermore, switching costs are comparatively low in Eastern European countries with less developed first-generation infrastructure and much lower consumer acceptance of basic broadband services (Briglauer & Cambini, 2016). Eastern European transition economies are among the leading countries in FTTP connections, both in the case of investment (low "replacement effect"; see discussion in Section 4.2) and in the case of demand-side diffusion (low "switching costs").

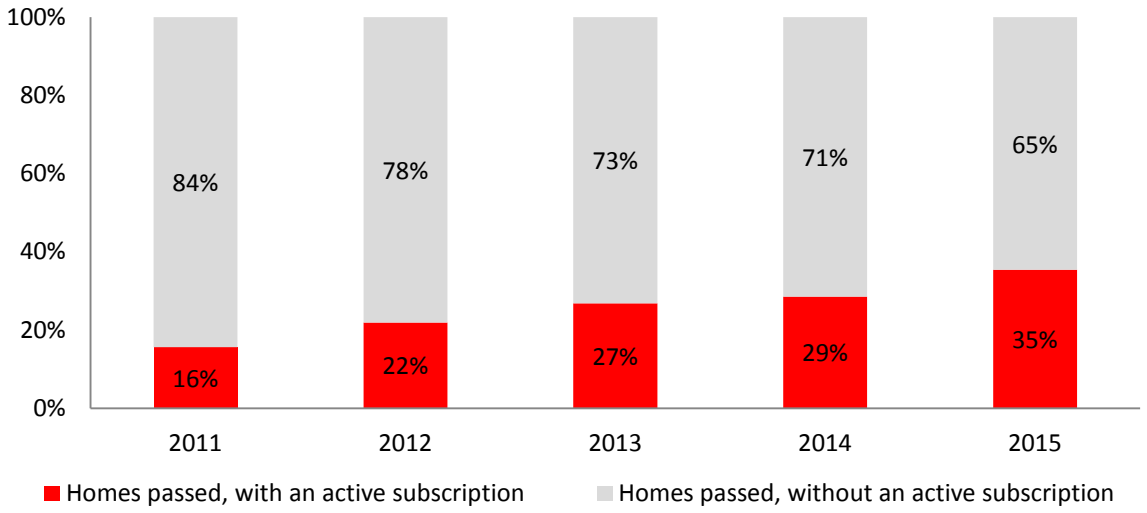

Figure 6: Take-up of fast broadband subscriptions as a % of all homes passed at EU level (2011-2015; source: European Commission, 2016b)

2.3 Infrastructure investment as a guiding principle

The EU regulatory framework for electronic communications focuses in large part on regulating access infrastructures which form the basis for the entire digital economy and are therefore of particular technical and economic importance. In recent years, in a time of increasing digitalization, operators of first-generation broadband networks have been faced with the need to upgrade their networks due to an overwhelming increase in demand for bandwidth and real time criteria. NGA broadband networks based on fiber-optic technology enable a massive increase in bandwidth capacity and the adoption of completely new services and applications on the demand side such as streaming video content on demand, file sharing, online gaming, and high-definition television, as well as specific business applications, such as cloud computing services, FinTech, smart manufacturing or machine-to-machine communication. The availability of high-speed broadband networks is a crucial prerequisite for the digital economy and its associated potential to enhance economic prosperity. Investing in new infrastructures will, however, only give rise to economic prosperity if new services and applications are also accompanied by substantial monetary savings, increased productivity and other positive externalities in other industries. Given sufficient availability and adoption, many consider this to be the most promising way to increase long-term productivity and prosperity.

One fundamental regulatory goal is therefore to accelerate the deployment of innovative and high-performance communications infrastructures. As part of a previous consultation to review the regulatory framework, the EC highlighted the importance of the availability and connectivity of high-performance communication networks and services: "*The telecoms review therefore offers an opportunity to recognize achieving access to such high-performance connectivity, on terms which would enable widespread take-up by end-users, as the main substantive policy priority sought by the Commission and as one of the main*

objectives of the regulatory framework."[6] This normative objective was later integrated into the CODE as a guiding principle. However, given the high levels of investment that a comprehensive NGA/LTE deployment requires, investment incentives are essential. Furthermore, if we take into account all the market developments to date related to declining communications revenues and actual NGA coverage and adoption patterns in most EU Member States (Section 2.2), it cannot be assumed that the existing market and competition conditions will result in broad-scale coverage – including rural areas – with NGA infrastructures and high take-up of NGA services in the foreseeable future.

Assuming that NGA/LTE deployment indeed goes hand in hand with substantial welfare gains, the question arises as to which regulatory schemes enhance (or diminish) investment incentives. Answering this question also addresses trade-offs between static and dynamic efficiency as will be discussed at several points in the analysis below.

2.4 EECC: Intended measures and critical appraisal

Reviewing the current coverage and adoption levels of various fast and ultra-fast broadband technologies, the following issues emerge that appear to be of critical relevance in view of the core objectives as outlined in the EECC. In particular, in its directive the EC is pursuing three core objectives (recital 3): i) incentives for investment in high-speed networks; ii) equal baseline conditions for all market participants; and iii) uniform application of the legal regulations.

Firstly, public targets are economically significant if they compensate for a market failure, i.e. if markets do not supply sufficient broadband coverage or quality. Assuming that the 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 feasible. In achieving these goals recital 175 explicitly emphasizes the importance of infrastructure-based competition. However, pursuing the goal of "*incentivizing investment in high-speed broadband networks"* (recital 3) should not lead to the distortion of market outcomes through engaging in "winner-picking", i.e. explicitly favoring certain NGA technologies. Deviating from the principle of technological neutrality would instead require sound empirical evidence on the differential welfare effects of available NGA technologies – evidence that is currently not available. Bertschek et al. (2016b, 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 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 differential impact of various NGA infrastructures. Deviating from technological neutrality without sound evidence would thus cause a shift "*away from a market driven approach and towards a planned vision*"

[6] Public Consultation on the Review of the Regulatory Framework for Electronic Communications Networks and Services, Section 3.2.2., consultation document available at: https://ec.europa.eu/digital-agenda/en/news/public-consultation-evaluation-and-review-regulatory-framework-electronic-communications.

(Williamson, 2016, p. 6). Despite considerable growth rates over recent years in the use of FTTP broadband in some EU countries, there is no question that the vast majority of users are still utilizing hybrid NGA or older broadband technologies. Therefore, an indefinite period will pass before the switchover to an exclusively FTTP-based broadband network is made, which means that efficient use must be made of the existing coaxial and copper cable networks in the meantime. Existing and future "second-life copper/coax technologies" 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. The market-driven speed of migration will depend on, among other factors, country specific characteristics such as the availability of ducts (favoring ceteris paribus FTTP deployment) or the number of street cabinets (favoring ceteris paribus FTTC deployment). Another fundamental technological change will arrive 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 with different NGA architectures. In fact, 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 more efficient investment subject to the imperfect information available on future demand for high-bandwidth and technological progress.

Secondly, the adoption and coverage of fast and ultra-fast broadband technologies exhibit substantial heterogeneity, in particular among Western, Eastern and Northern European member states. This circumstance represents a clear milestone on the way to achieving the goals of policy harmonization strongly emphasized in the CODE, which aim to "*deliver conditions for a true single market by tackling regulatory fragmentation … and consistent application of the rules*" (recital 3). Applying the same rules to the same conditions is of course reasonable but harmonization must not become a goal in and of itself that ignores the empirical market conditions and specific characteristics of individual member states.

Thirdly, Art. 1 (2) of the CODE explicitly highlights the availability and take-up of networks with very high capacity as a core regulatory objective. The specification of availability and take-up makes it clear that the CODE is not just aimed at stimulating the supply side for high-speed networks, but is also factoring in the demand side more than has previously been the case (recital 23). Focusing on the demand side appears to be reasonable and justified in view of persistently low take-up rates in many member states (Section 2.2) and the importance of demand-side adoption in accruing welfare gains. With respect to the CODE´s definition of very high capacity networks on the supply side, it is necessary to differentiate available FTTx technologies described in Section 2.1. As regards the availability objective, the CODE legally defines "*very high capacity networks*" in Art. 2 (2) as follows: "*[V]ery high capacity network means an electronic communications network which either consists wholly of optical fiber 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.*" As argued above, enhancing the deployment of very high capacity networks

should not automatically favor a certain network architecture or technology unless there is considerable and sound evidence of its comparative economic advantages. Although the CODE does not explicitly refer to certain NGA technologies as being particularly desirable and it is unclear whether very-high capacity networks refer only to FTTP connections, several places (e.g. recital 13 and Art. 2 (2)) suggest that FTTP connections are to be treated as a preferential deployment target. However, subordinating technological neutrality to the dominant goal of deployment and connectivity targets, as foreseen in Art. 3 (3) lit c, is so far not supported by sufficiently convincing empirical evidence. This has also been pointed out critically in a recent study published by the Florence School of Regulation (2016, p. 4): "*As for targets specified in terms of extended coverage of ultra-fast broadband technologies, we can conclude that the existing evidence is not sufficient to make a case for expressing a preference across the board for FTTH solutions. To clearly support the view that an extension of ultra-fast broadband targets would be justified, it would be necessary to find evidence either of the fact that significant positive externalities are not reflected in the current level of demand for ultra-fast broadband, so that there is a wedge between social goals and individual choices, or that a sufficient willingness to pay exists that is not met by private demand. The available empirical evidence does not confirm either of these elements.*" It is noteworthy that the concerns expressed in this study corroborate the findings of the literature review by Bertschek et al. (2016) cited above.

3 The EU sector-specific regulatory framework for communications markets

Steps to liberalize the electronic communications markets were first taken in the form of the ONP regulatory framework. ONP stands for Open Network Provision and describes the "*Council directive 90/387/EEC of 28th June 1990 on the establishment of the internal market for telecommunications services through the implementation of open network provision*". This was the "first package" of measures introduced at the outset of liberalization in order to create the single market for telecommunications services by introducing open network access. Both the ONP regulatory framework and the 2002 regulatory framework ("second package") were already founded largely on the concept that firms with significant market power (SMP) are subjected to certain restrictions and obligations ex ante and that, contrary to competition law, no actual abuse of market power is required for these restrictions and obligations to apply (European Commission, 2002, "SMP Guidelines", section 3.1). In contrast to the ONP regulatory framework, the 2002 regulatory framework brought a more sophisticated and fundamentally different approach with regard to electronic communications markets,[7] touted primarily as "a more economics-based approach". The

[7] The "Telecoms Package", adopted in 2002 and amended in 2009 ("third package") includes the following specific directives in order to establish a harmonized framework for the regulation of electronic communications networks: i) directive 2002/21/EC or "framework directive"; ii) directive 2002/20/EC or "authorization directive"; iii) directive 2002/19/EC or "access directive"; iv) directive 2002/22/EC or "universal service directive"; v) directive 2002/58/EC or "directive on privacy and electronic communications".

latter primarily meant adopting standard methods of market definition and competition or dominance analysis as used in competition law; what is known as the "Hypothetical Monopolist Test" (HMT) was first introduced by the US Department of Justice (1982 Merger Guidelines, revised in 1992 and 1997) and is currently applied by competition authorities worldwide to delineate relevant markets. The SMP-Guidelines explicitly refer to the HMT in §§40-43. The SMP-Guidelines explicitly refer to the concept of SMP in §§70-88 which essentially corresponds to market dominance under Art. 102 TFEU. This more economics-based approach underpins market analysis procedures to this day, with Art. 14 to 16 of the framework directive being of central importance. According to these articles, national regulatory authorities (NRAs) have to carry out market analysis procedures at regular intervals that comprise a *three-stage* market analysis sequence. The first stage involves a definition of relevant communications markets that could be subject to sector-specific regulation. In the second stage, NRAs then investigate whether there is effective competition in these markets and/or whether (at least) one firm in these markets has SMP.[8] In case of SMP findings, iii) NRAs impose sector-specific ex-ante obligations in the third stage, in accordance with the specific competition problems identified in the relevant market. These obligations are to be proportionate to the competition problems and their imposition is to be justified in detail by the NRAs with reference to the market analysis. Ex-ante regulation has to be taken into consideration for as long as no self-sustaining competition is sufficiently established at the end-user level in relevant markets. Accompanying forms of regulation at wholesale level would then need to be imposed in a way that could ensure adequate correspondence with (current and potential) competition problems at the end-user level.

The methods described above are more or less standard tools borrowed from competition law. Besides the more economics-based approach at the level of market definition and dominance analysis, however, the 2002 regulatory framework also introduced the so-called *three-criteria* test (Art. 15 (1) framework directive) which is supposed to be carried out by NRAs as an initial check prior to the *three-stage* market analysis sequence. According to the three-criteria test the following criteria have to be met cumulatively and in advance to justify the implementation of regulatory obligations: i) high and non-transitory structural, legal or regulatory barriers to entry are present; ii) there is a market structure which does not tend towards effective competition within the relevant time period with regard to the state of infrastructure-based competition and other sources of competition behind the barriers to entry; iii) competition law alone is insufficient to adequately address the identified competition problems in the markets in question. Note that the criteria in the three-criteria

[8] The European regulatory framework (framework directive Art. 14 (1)-(2)) fundamentally differentiates between two elements that can each constitute SMP: "Single dominance" and "joint dominance". Framework directive Art. 14 (3) also mentions the circumstances of transferring market power ("leveraging"). However, since it is already possible to identify leveraging as a relevant competition problem that constitutes SMP on the relevant markets, the latter has proven to be of far lesser importance in previous market analysis procedures.

test do not refer to market definition analysis in terms of assessing demand- or supply-side substitution, but rather already presuppose a specific market definition.

Another key innovation of the 2002 regulatory framework lay in ensuring that the ex-ante obligations for a firm with SMP are no longer imposed rigidly, but in proportion to the competition problems identified. This resulted in significant regulatory flexibility, but it also brought some challenging requirements for NRAs in terms of analytical and procedural complexity.

By issuing a recommendation for applicable communications markets, the EC initiates the market analysis process that has to be carried out regularly by NRAs. Table 1 provides an overview of previous market definitions, the number of market analyses as well as the final conclusions reached by NRAs in terms of no regulation (deregulation), partial regulation and full regulation. The first two market recommendations came from 2003 and 2007 (European Commission, 2003; 2007). When it issued the 2014 market recommendation (European Commission, 2014a; 2014b), the EC initiated a further deregulation process, since the end-user access market (market 1) – which had been retained in the 2007 recommendation – and the structurally related wholesale origination market (market 2) were no longer classed as relevant for sector-specific ex-ante regulation. There were no similarly comprehensive deregulation steps regarding the relevant broadband wholesale access markets. Consequently, market 3b of the 2014 market recommendation ("Access provided centrally at fixed locations for mass products at the wholesale level") is largely equivalent to market No. 5 of the 2007 market recommendation. Unlike the previous market No. 4 of the 2007 market recommendation, the new market 3a ("Access to local loops provided locally at fixed locations at the wholesale level") can also include virtual access products. Finally, the 2014 market recommendation views market 4 as "a wholesale market for access to high-quality business data connections", which is largely equivalent to market No. 6 of the 2007 market recommendation ("leased lines").

The previous market recommendations substantially reduced the number of markets that are relevant from an ex-ante perspective, which represented a fundamental step in terms of deregulation. But still, electronic communications markets in EU member states are subject to a regulatory framework that is complex and comprehensive in comparison to other non-EU nations (see Section 4.3). It is important to note also at this point that the deregulation steps mentioned, i.e. reducing the number of relevant communications markets, are in part countered by the fact that remaining wholesale access products are subject to increasingly intricate and comprehensive technical annex regulations.

3.1 EECC: Intended measures and critical appraisal

The CODE integrates sector-specific regulations that were previously divided across separate directives (cited in footnote 6) and combines them in one directive. Only the aspect of data protection regulations is not included in it, since this is still covered by the ePrivacy directive.

The CODE also contains the three-stage market analysis concept of the 2002 regulatory framework but modifies it with regard to the broadband connectivity objective. Another change is that market regulation will in future be tackled in two different ways when it comes to imposing obligations. While the implementation of obligations as per Art. 66 of the CODE remains largely unchanged for pre-existing infrastructures, Art. 74 of the CODE provides for new network components in addition to the existing approach. According to Art. 74, an exemption from ex-ante regulation may be granted under certain circumstances. Differentiated regulatory approaches appear to be meaningful in view of different ex-ante investment incentives related to old and new infrastructure. The main argument here is that the investment in NGA is more likely to suffer from the hold-up problem, because a large part of the legacy networks existed prior to the implementation of access regulation, whereas the fiber-optic elements of the access network need to be built anew and new investments might be thus subject to ex-post expropriation by NRAs in the form of strict access regulations.[9] Anticipating this, infrastructure operators would then not invest. This problem might only be mitigated if NRAs can and do commit ex ante to not expropriating in the form of no or softer regulations.

With regard to the third stage of market analysis, the CODE sets out a so-called "double-lock" system (explanatory memorandum reason, p. 13) which provides a first-time veto power for the EC in cases where the Body of European Regulators for Electronic Communications (BEREC) and the EC agree on their position regarding the draft remedies proposed by an NRA. Under this system, the NRA could be obliged to amend or withdraw the draft measure. Of course, the double-lock system (Art. 33 (5) lit. c) would supply the EC with additional institutional power over NRAs in order to achieve its harmonization goal.

Regarding the three-criteria test, the CODE now lends this test as it is explicitly laid out in a directive (Art. 65) higher legal standing. On that basis, the EC will issue a list of relevant communications markets susceptible for sector-regulation at irregular intervals also in the future to initiate market analysis cases in individual member states. NRAs may then either adopt the underlying list of relevant markets as is – essentially stipulating that the three criteria are full-filled – and assess competition and dominance issues within these pre-defined markets. In case of NRAs deviating from the EC`s market definition, however, the individual NRA faces the full burden of proof in the form of sound empirical analysis related to market definition. This represents an informational and time-demanding task for most NRAs and thus creates an institutional bias towards confirmation of the three-criteria test in light of the EC´s market recommendations. In fact, the majority of European NRAs, in particular smaller and medium-sized institutions, have been reluctant to deviate from the

[9] The most intense wholesale access regulations refer to mandatory cost-standards that have been based on different versions of "long-run-average-incremental costs" (LRIC or LRAIC) to regulate broadband access since the introduction of the 2002 regulatory framework. LRAIC has already been used since the beginning of sector-specific regulation and market regulation to calculate interconnection charges for narrowband voice telephony services.

EC´s recommendation on relevant markets in the past (Renda, 2016, p. 8). This effect will most likely be reinforced now that the three-criteria test is to be given higher legal standing.

The CODE also envisages that market analyses should take greater account of competitive constraints at the end-user level, which constitutes a restriction on wholesale access regulation, according to the regulatory objective of Art. 3 (3) lit. f). In future, ex-ante obligations are only to be imposed if they are also required to safeguard effective and sustainable competition on end-user markets (Art. 66 (4)). This further implies that no wholesale access regulation will be imposed even where there is a lack of competition in the wholesale market, since this is not to be seen as an end in itself. This is a meaningful step toward keeping regulations proportionate and an explicit shift in focus back to one of the principles of the 2002 regulatory framework. According to this, identification of effective competition at the retail level not only implies deregulation at the retail level but also a corresponding removal of any related wholesale access regulations. In turn, identifying any absence of retail competition should become a prerequisite for imposing wholesale access regulations.

Table 1: Overview of market recommendations and analyses in EU member states (March 2016, source: European Commission, 2016b)

	Effective competition - no ex ante regulation
	No effective competition - ex ante regulation
	Partial competition - partial ex ante regulation

1	1st round-competition/regulation
2	2nd round-competition/regulation
3	3rd round-competition/regulation
4	4th round-competition/regulation

	2014 RECOMMENDATION					2007 REC.		2003 RECOMMENDATION								
	Call term. on fixed network	Voice call term. on mobile networks	Wholesale local access	Wholesale central access	Wholesale high-quality access	Access to PSTN for res & non-res.	Call orig. on fixed network	Local/nat. Call for res.	Internat. call for res.	Local/nat. call for non-res.	Internat. call for non-res.	Retail LL	Transit on fixed network	Trunk segments LL	Access & call orig. on mobile network	Broadcast Transmis.
	Market 1	Market 2	Market 3a	Market 3b	Market 4	ex-Mkt 1	ex-Mkt 2	ex-Mkt 3	ex-Mkt 4	ex-Mkt 5	ex-Mkt 6	ex-Mkt 7	ex-Mkt 10	ex-Mkt 14	ex-Mkt 15	ex-Mkt 18
Austria	3	4	3	3	4	3	3	3	2	4	3	4	1	2	1	3
Belgium	2	2	2	2	1	2	1	3	1	3	1	1	2	1	1	w
Bulgaria	3	2	2	2	2	1	2	1	1	1	1	1	1	1		
Croatia	1	1	1	1	1	1	1	1		1		1		1		
Cyprus	2	3	3	3	2	2	2	2	2	2	2	2	2	2	3	3
Czech Republic	4	4	3	3	3	4	4	2	2	2	1	2	1	1	1	2
Denmark	3	3	3	3	3	3	3	2	2	1	1	2	1	1	1	1
Estonia	3	3	3	3	3	3	3	1	1	1	1	1	1	2	1	3
Finland	2	1	3	3	1	2	3	2	1	2	1	2	2	1	V	3
France	4	4	4	4	2	4	4	1	1	1	1	2	1	2	W	4
Germany	3	4	3	3	1	3	2	2	1	2	1	2	2	1	1	3
Greece	3	3	3	3	2	2	2	3	1	3	1	2	3	2	1	1
Hungary	3	5	3	3	3	4	3	2	2	2	2	3	2	2	2	2
Ireland	3	1	2	2	2	3	2	2	2	2	2	2	2	2	1	2
Italy	2	3	3	3	2	3	2	2	2	2	2	2	2	2	2	2
Latvia	5	4	3	3	3	1	2	3	3	3	3	3	2	1	1	1
Lithuania	4	3	3	3	2	1	2	3	2	3	2	1	2	2	1	5
Luxemburg	2	3	2	2	2	2	2	2	2	2	2	2	1	1	1	
Malta	3	3	2	2	2	3	3	2	2	2	2	2	2	2	2	1
Netherlands	4	4	4	3	3	3	2	2	2	2	2	2	2	2	1	2
Poland	2	3	2	3	1	2	2	2	2	2	2	2	1	1	2	2
Portugal	1	2	2	2	2	2	2	2	2	2	2	1	1	2		2
Romania	2	2	2	1	1	2	2	1	1	1	1		2			1
Slovakia	3	3	2	2	2	4	4	2	2	2	2	2	2	1	1	2
Slovenia	2	5	3	3	2	3	3	2	1	1	1	2	3	1	3	2
Spain	3	3	3	3	3	3	2	2	2	2	2	2	2	3	1	3
Sweden	3	3	3	3	2	2	2	1	1	1	1	2	2	1	1	3
United Kingdom	3	4	2	3	4	4	3	2	2	2	2	3	2	3	1	1

4 Market structure, asymmetries and competitive intensity

This section presents the market structure according to market shares of broadband providers and underlying broadband technologies. The description of market structure also includes the dynamics of the consolidation process that has been observed for years in the fixed-line and mobile markets. In fact, merger and acquisition (M&A) activity has continued to be significant over recent years with several high value deals. We also describe competition and various forms of regulatory asymmetries in broadband markets.

4.1 Market shares: mobile and fixed broadband operators

Table 2 ranks the market shares of network operators (colors indicate rank) that offer both mobile telephony and mobile broadband. In most member states market shares are asymmetrically distributed with typically one leading operator with about 40% market share on average followed by a small number (typically up to 3) of other operators. This results in a narrow oligopoly structure in most markets. Mariniello and Salemi (2015, p. 5) examine major M&A transactions in the EU and US and find that mobile markets have become more concentrated in both jurisdictions in recent years. As one can further infer, a few major European operators (Vodafone, Deutsche Telecom, Telia-Sonera, Orange, Hutchison) have a presence in several European countries. And yet, there is still greater fragmentation in the mobile market in the EU as a whole than in the US where there are four nation-wide operators (AT&T, Verizon, Sprint and T-Mobile) with ubiquitous coverage (Mariniello & Salemi, 2015, p. 4).

Figure 7 depicts market shares for wireline broadband access held by incumbent firms and firms that entered the market later on ("entrants") in the EU member states. As in Table 2, these market share values are measured by the number of subscribers registered with the relevant firms. Market shares of incumbent operators vary considerably from 24% in Bulgaria up to 67% in Luxembourg as of July 2015. Like the mobile market, the fixed-line market has been undergoing a period of consolidation for years. In particular, there has been a massive increase in aggregated transaction volumes since 2013, which has seen mergers of primarily larger firms. One example of this is the takeover of Dutch company Ziggo by Liberty Global, which had also previously taken over Kabel BW in Germany. Besides takeovers within the wireline operator sector, the increasing convergence of fixed and mobile networks has also seen an increasing number of takeovers aimed at linking these two infrastructure components together. Examples of this include the takeover of SFR (second-largest mobile network provider) by Numericable Group (the largest cable operator) in France in 2014 and the takeovers of Kabel Deutschland (the biggest cable operator in Germany) and ONO (the biggest cable operator in Spain) by Vodafone in 2013 and 2014.[10] Further "fixed-mobile convergence M&As" occurred in both the UK and in Belgium. In the UK

[10] Information from ZEWnews October 2015 | M&A Report ("Concentration in European Landline Communication Markets Increasing").

the incumbent fixed operator acquired the largest mobile operator, Everything Everywhere, a joint venture between Deutsche Telekom and Orange. The deal was agreed in 2015 and resulted in one of the leading fixed-mobile operators in the UK. Similarly, Liberty Global acquired the mobile operator Base in Belgium. These examples suggest that fixed-line operators expect to benefit from the ability to offer both wireline services as well as hybrid fixed-mobile services (European Commission, 2016b).

Table 2: Market shares (% SIM) of mobile network operators that provide both mobile telephony and mobile broadband in EU member states; * Pre and ** Post: data for Germany and Ireland shows the situation both before and after the Hutchison 3G UK/Telefónica Ireland and Telefónica Deutschland/E-Plus mergers. Malta and Cyprus are not included. * 50% DT, 50% Orange. (Q1/2014, source: Table 2 (incl. Table notes) is directly taken from Mariniello & Salemi, 2015, p. 4)**

	AT	BE	FR	DE		IE		IT	LU	NL	PT	ES	UK
				Pre*	Post**	Pre*	Post**						
Vodafone				29.5%	29.5%	40.9%	40.9%	26.4%		30.3%	39%	28.8%	25.2%
Telefonica				17%	37.8%	29.2%						42.3%	29.5%
Deutsche Telekom	33.8%			32.6%	32.6%					26.1%			
Everything Everywhere***													33.6%
Orange		27.7%	41.2%						10.6%			22.9%	
Hutchison	22.9%					9.3%	38.5%	11%					11.7%
KPN		28.2%		20.8%						43.6%			
Belgacom		44.1%							37%				
POST Luxembourg									51.7%				
Luxembourg Online (LOL)									0.7%				
Telecom Italia								37.5%					
VimpelCom								25.1%					
Telekom Austria	43.3%												
SFR			32.3%										
Bouygues			17.1%										
Illad			9.4%										
TelliaSonera												6%	
Eircom						20.6%	20.6%						
Portugal Telecom											45.4%		
NOS Comunicações											15.5%		

	BG	HR	CZ	DK	EE	FI	GR	HU	LV	LT	PL	RO	SK	SI	SE
Deutsche Telekom		46.6%	40.3%					44%			28.4%		33.9%		
TelliaSonera				22.9%	45.8%	34.3%			41.6%	34.8%					46.2%
Telenor	34.7%			16.6%				32.2%							16.7%
Tele2		13.5%			27.6%				40.3%	42.8%					26.1%
Vodafone			23.7%				30%	23.8%				31.4%			
Telekom Austria	43.5%	40%												30.3%	
Orange											27.4%	39.7%	43.2%		
Elisa					26.6%	40.4%									
Hutchison				9.7%											10.9%
OTE (40% DT)							49.2%					23.8%			
PPF			36%										22.9%		
BITE									18.1%	20.4%					
ONA						25.3%									
TDC				50.8%											
Play											18.7%				
Polkomtel											25.6%				
Wind Hellas							20.7%								
Telekom Slovenije														58.2%	
Tušmobil														11.5%	
RCS-RDS												5.1%			
Teledema										2.1%					
Bulgaria Telecom	21.8%														

A similar consolidation process can also be observed outside Europe. In the US markets, in particular, activities are strategically targeted to expand portfolios beyond the classical areas of telecommunications and Internet services ("IP-convergence M&As"). This suggests that traditional network operators are responding not only to challenges such as the demand for ever larger capacities but also to new competitors from the Internet economy such as online streaming services Netflix and Amazon Prime Video.[11]

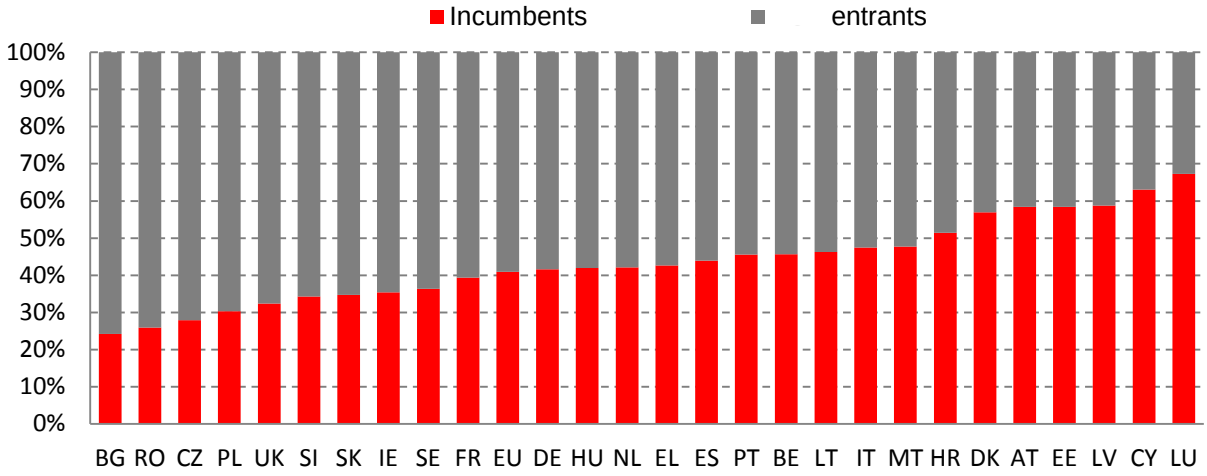

Figure 7: Market shares by fixed broadband subscriptions (July 2015, source: European Commission, 2016b)

Figure 8 (a) shows that the fixed-broadband market shares do not just vary significantly between different member states but also in terms of the underlying technologies. As a result, there are clear differences in the market shares of regulated incumbents by technology. This is especially relevant for the analysis of dominance (SMP) on the related wholesale markets and in relation to the high de facto significance of the thresholds of market share values as established in case law and adopted in the regulatory framework (SMP Guidelines, §75): "*In the Commission's decision-making practice, single dominance concerns normally arise in the case of firms with market shares of over 40 %, although the Commission may in some cases have concerns about dominance even with lower market shares, as dominance may occur without the existence of a large market share. According to established case law, very large market shares - in excess of 50 % - are in themselves, save in exceptional circumstances, evidence of the existence of a dominant position. An undertaking with a large market share may be presumed to have SMP, that is, to be in a dominant position, if its market share has remained stable over time*." Consequently, this strong emphasis on market share re-emphasizes the role of market definition in the first stage of the overall market analysis procedure.

According to Figure 8 (b), the majority of NGA subscriptions are based on cable FTTLA/DOCSIS technology which is quite considerable given that total EU cable coverage is on average only about 20% (European Commission, 2016b). Note that cable access infrastructure has not been subject to asymmetric access regulations until now. One (other)

[11] Information from ZEWnews November/December 2016 | M&A Report ("Few Large-Scale Acquisitions in the US Telecommunications Market").

reason for the success of NGA cable take-up is likely related to the comparatively low network upgrade costs. Consequently, CATV operators were able to charge only a modest "fiber premium" to consumers in order to overcome switching costs.

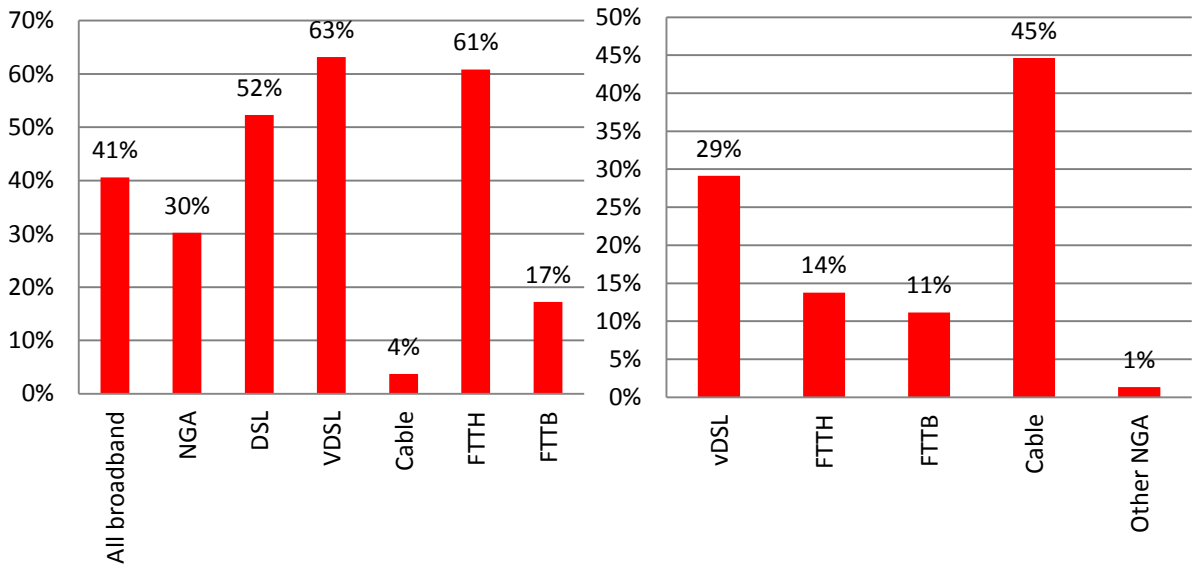

Figure 8:

(a) Incumbent's average market share by technology (% of subscriptions) at EU level (July 2015, source: European Commission, 2016b)

(b) Share of different NGA technologies in total NGA subscriptions at EU level (July 2015; source: European Commission, 2016b)

Table 3 shows the accumulated market share for FTTP connections (homes passed) of the incumbents in a total of 39 countries (EU27 plus twelve more (non-)EU countries) in relation to the main types of competitors in FTTP infrastructure deployment. These competitors are primarily alternative broadband suppliers (CATV operators and utility companies[12] in particular), municipalities and housing companies. Although the incumbent has certain comparative cost advantages in connection with its legacy infrastructure, it nevertheless does not possess a modern communications infrastructure when it decides to invest, which creates a corresponding symmetry in terms of ex-ante investment decisions (Bourreau et al., 2010, p. 693). Furthermore, in urban areas CATV operators have often become the leaders over incumbent operators due to lower costs of upgrading their legacy networks. Municipal providers are typically active in small and less densely populated regions and less focused on short-term profitability as the average FTTP investor and instead more concerned with other objectives such as external effects related to longer-term regional policies.[13] In turn, the incumbents´ focus on FTTC deployment is due to, among other things, the fact that many of these firms are publicly listed and hence subject to the external evaluations of capital

[12] These groups include what are known as city carriers, regional Internet and telephone suppliers usually founded by regional electricity, gas and water companies on the basis of existing physical infrastructure elements.

[13] See FTTH Council Europe (2012, p. 66-69) for a description of the FTTH operators and investors.

markets, which tend to be critical of long-term investment projects that involve delayed capital returns and high risks (Neumann et al., 2016, p. 40). Added to this advantage related to long-term projects are comparative advantages for municipalities in the local planning and implementation of FTTP projects (Neumann et al., 2013, p. 40).

Table 3: Categories of FTTP providers and average market shares in 39 European countries (December 2015, source: FTTH Council Europe, 2016)

Type of provider	Incumbents	Municipalities	Alternative Operators/ Cable	Housing Companies/ Others
Share [%] of FTTH/B Infrastructure Providers	10.4%	45.5%	42.3%	1.8%
Share [%] FTTH/B homes passed	45.1%	4.1%	50.8%	n.a.

4.2 Competition and investment

The communications sector (fixed and mobile) has become one of the most dynamic and competitive industries since the onset of market liberalization in 1997/1998 (European Commission, 1998). Innovation and future investment have been driven by infrastructure-based competition, and particularly by mobile networks (intermodal),[14] which have proved extremely dynamic in terms of both technological innovation and changes to market structures. The latter has helped to significantly intensify competition across the entire fixed network sector. Even when operators first started deploying fiber-optic networks (around 2006), the phenomenon of fixed-mobile substitution had already been very intense regarding narrowband telephony services and it has continued to exert a growing competitive pressure on broadband services since then.

However, there is no clear method for predicting the functional relation between competition and innovation or investment activity (Sacco & Schmutzler, 2011), since the relationship depends on the relevant oligopoly framework model. Accordingly, investment can both strengthen and weaken competition. Moreover, an "inverted U-shaped" dependency, as described in the general equilibrium analysis in Aghion et al. (2005), is not necessarily more probable than a U-shaped dependency in a partially analytical consideration. Although Aghion et al. formulate the non-linear relationship for innovation activities and competitive intensity on product markets, this can also be applied to the investment activities on electronic communications markets (Bauer, 2010). Figure 9 shows this stylized, non-linear relationship, which implies an optimum competitive intensity (denoted with w* on the horizontal axis) in regard to the resulting investment incentives in a

[14] "Intermodal" refers to the competitive forces between fixed and mobile networks, i.e. the competitive restrictions that emanate from the wireless sector. By contrast, "intramodal" hereinafter refers to all the forms of wireline competition, i.e. competition based on connections at fixed locations within the fixed network sector.

particular market (displayed on the vertical axis). There are two contrasting effects that underlie the non-linear relation. The first is the "Schumpeter effect", which states that future profits resulting from an investment would be biggest in the case of an (efficient) monopoly and consequently so too would be the ex-ante investment incentives. In turn, a highly competitive environment decreases the ex-post applicability of the investment rewards. In the extreme case of perfect competition with price equal to marginal costs and in view of the cost structure in communications, there would be essentially no surplus generated for infrastructure investment or technological innovation. The second is the "escape competition effect", which states that innovation gives a firm an advantage over its competitors, thereby enabling it to escape competition and/or low profits to a certain extent and for a certain period of time and achieve higher profit margins as an innovative (and unregulated!) firm ex post, i.e. after making the investment. Another justification for the existence of an optimum competitive intensity where technology-intensive industries are concerned is that co-ordination and co-operation (such as when deploying or co-investing in new infrastructures) can be organized best when there is a medium level of competition (Bauer, 2010, p. 69).

Ultimately, the functional relation is dependent on the structural characteristics of the relevant industry and thus is to be determined on an empirical basis. The same applies when determining the optimum point w*, which is of special interest from a regulatory viewpoint. The massive concentration trends discussed in Section 4.1 in conjunction with high investment requirements for broad-scale NGA and LTE roll-outs suggest that an adjustment process from high competitive intensity w^H towards a market structure optimal for investment (w*) has taken place in the industry in recent years.

As mentioned in Section 2.2, ex-ante investment incentives are also heavily influenced by the existing first-generation broadband infrastructure, which is based primarily on the copper wire infrastructure of incumbent firms and the coaxial cable infrastructure of CATV operators. NGA investment would "cannibalize" economic benefits from the first-generation broadband infrastructure, which represents corresponding opportunity costs associated with investment in new infrastructures. This "replacement effect" (Arrow effect) is of practical relevance to the 27 EU member states that have a very well established first-generation infrastructure. Besides a high level of network coverage, this has been further strengthened over recent years through technological advances (second-life copper/coax technologies) and most likely will be even further reinforced in the medium term because of upcoming technological advances such as VDSL/XGfast or DOCSIS 3.1. A strong replacement effect increases intramodal competition from old broadband or advanced hybrid-fiber broadband products and thus lowers incentives to invest in FTTP infrastructure. A strong replacement effect also signals that the advantage to society from a move toward FTTP may not be that great.

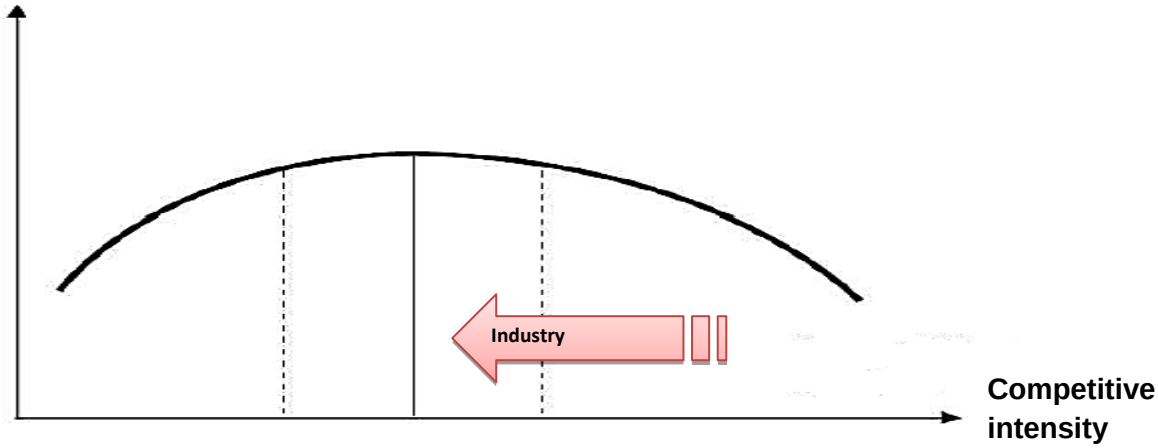

Figure 9: Non-linear relation ("inverted U-shape") between competitive intensity and investment (source: author´s own graph)

4.3 Competition and regulatory asymmetries

Besides the competitive dynamics that come from the mobile sector, the competitive intensification in the fixed-line sector is also characterized by new business models associated with the advent of IP convergence. *OTT services* (such as Skype, FaceTime, Viber, WhatsApp, and many more)[15] have played a key role in the spread of IP-based communications services. The competitive pressure generated by both mobile and OTT services is illustrated in Figure 10 using the example of voice telephony minutes in Germany. It clearly shows the contrasting development in the fixed network sector on the one hand and in the mobile sector and OTT services on the other.

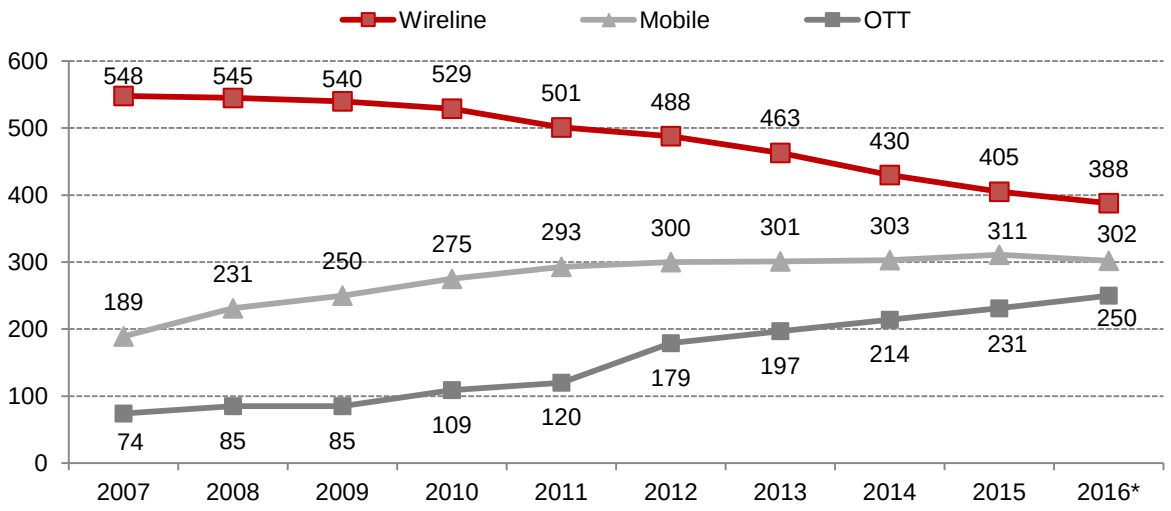

Figure 10: Voice calls made in Germany over fixed and mobile connections in millions of minutes per day, mobile without roaming (2006-2015, estimates for 2016, source: VATM, 2016)

[15] OTT stands for Over-the-top referring to third party content delivered over the Internet to the end user utilizing the network infrastructure, which is under control of the network operator who transports the content.

It should be noted here that only wireline network operators with a dominant market position (SMP) are subject to asymmetric access regulations and that they are also – such as all other (non-SMP) telecom providers – subject to a wide range of additional sector-specific regulatory requirements (e.g. regulations related to network integrity and minimum quality standards, emergency calls, data storage and data protection regulations or obligations of transparency and co-operation in terms of providing data). As a consequence, wireline (and wireless) communications service providers feel that the regulatory framework needs to be harmonized due to the fear of unfair competition. This is because the services offered by OTTs, which appear to be replacing the existing, regulated services of traditional providers, have so far been subject to far less restrictive regulations. This points to the issue of achieving a "level playing field" in which individual market participants are ideally not subject to any advantages or disadvantages that cannot be justified on an objective basis.[16]

Next to market asymmetries surrounding OTT players, infrastructure operators are also confronted with market asymmetries related to *service-based telecom providers* due to underlying ex-ante access obligations, which provide an immediate make-or-buy option to this group of operators and impact on investment incentives. Alternative service-based telecommunications providers have their own transmission network and/or regionally limited access networks. However, to reach subscribers in other networks/regions, they need to rely on regulated wholesale access from incumbents (and potentially from other operators based on voluntary market arrangements). Therefore, a constituent feature of the definition of (regulation-induced) service-based competition is that it is dependent on forms of asymmetric access regulations (such as the level of monthly fees for bitstream products, for full or shared unbundled access, arrangements for co-location conditions, etc.). From the discussion in Section 4.1 it appears that NGA investment is largely driven by infrastructure operators with prior physical access infrastructure either in terms of legacy networks (incumbent and cable-TV operators in particular) or passive infrastructure elements (municipalities, utilities and housing companies in particular). Apparently, service-based entrants reported only limited ambitions and ability to deploy access infrastructure themselves to either substitute or to geographically complement regulated access. This is confirmed by empirical evidence on the dynamics and development of wholesale access remedies and reinforced by the economics of these networks (Section 7.2) as well as by the academic literature examining the impact of wholesale regulations on (NGA) investment incentives (Section 7.1).[17] Against this background asymmetrically imposed wholesale access regulations appear to exert an investment-diminishing effect overall – alongside market distortions – which has to be accordingly taken into account in the regulatory decision making process.

[16] For a more detailed discussion on competition and regulatory asymmetries related to OTTs the reader is referred to subsection 4.3.2 of the meta-study and to Krämer & Wohlfahrt (2015).

[17] Notable exceptions refer to FTTP deployments targeted at high volume / high ARPU business customers in predominantly urban areas.

Finally, besides ensuring a level playing field between OTT services and electronic communications services (ECS) and between infrastructure- and service-based operators, the question of a level playing field also applies to the relevant policy frameworks of "*global ICT markets*". In terms of access obligations for old and new broadband infrastructures, there have already been, for example, moves toward far-reaching and ultimately comprehensive deregulation in the US from as far back as mid-2000 (Briglauer & Gugler, 2013; Vogelsang, 2014; Yoo, 2014). Similarly, (ultra-)fast broadband infrastructure has not been subjected to any sector-specific regulation in Canada since it was first introduced (Godlovitch et al., 2015a, p. 39). Intensive industrial policy support measures were implemented very early on in the eastern Asian countries of Korea and Japan, which are leading in FTTP deployment. In the case of Japan, these measures were also combined with sector-specific access obligations (Godlovitch et al., 2015a, p. 62-66). In Korea, unbundling obligations were implemented relatively late on and no access regulations were implemented for new infrastructures deployed after 2004. In comparison to the EU approach, broadband has never been heavily regulated in either of these East Asian countries (Crandall, 2013; Renda, 2016). The EU regulatory framework can thus be viewed as a "*middle course between full deregulation and interventions by governments motivated by industrial policy*" (Cave & Huigen, 2008, p. 715) or, in other words, it stands "between" the regulatory frameworks in North America (market driven, no regulation) and those in the Eastern Asian countries leading in ICT (public policy driven, soft/no regulation). In addition, the EU approach suffers from a complex institutional framework with NRAs and competition authorities involved at the national level and the EC and BEREC at the EU level which not only results in high transaction costs for national and EU level consultation mechanisms but also in lengthy market analysis procedures. The latter is even more the case for major revisions of the EU regulatory framework as can be seen from the current telecoms review which was formally initiated in 2015[18] and will not be submitted before end of 2017/2018 at the EU level and will not come into force before 2019/2020 according to the EC´s plan/industry estimates.

4.4 Competition and market definition

In designing regulatory interventions, competition factors both *inside* and *outside* the relevant market are to be taken into account. In the case of the former, competition from substitute products is strong enough to constitute a common market. In the latter case competition from imperfect substitutes falls below this threshold but they still exert important competitive safeguarding functions from outside the relevant market. This source of competitive pressure should not be underestimated: "*Telecommunications services through different kinds of networks may not be perfect substitutes, but, even so, the imperfect substitutes that are available can impose effective constraints on the behavior of*

[18] The review has been formally initiated by the EC´s "Digital Single Market Strategy" on May 6 2015, wherein the EC foresees "*an ambitious overhaul of EU telecoms rules* as a key issue under "Pillar II"; the reader is referred to the corresponding press release available at: http://europa.eu/rapid/press-release_IP-15-4919_en.htm).

the presumed network monopolists. If so, we should be thinking about the industry as being in oligopolistic competition between network providers, rather than network monopolists holding sway over facilities that are essential to the provision of services downstream" (Hellwig, 2008, p. 3-4). Similarly, HSBC (2016, p. 25) argues that in view of "*the increasingly converged nature of the telecoms sector and the way in which neighboring services – even if not full substitutes for one another – nonetheless act as partial substitutes and so constrain pricing.*" Below we discuss the most relevant sources of competition functions that can safeguard deregulatory approaches.

4.4.1 Fixed-mobile substitution

As already mentioned on several previous occasions, mobile broadband services are playing an increasingly important competitive role. Primarily, the mobile communications technology based on 4G/LTE already offers bandwidths that are increasingly comparable with wireline NGA hybrid networks. Fixed-mobile convergence M&A transactions (Section 4.1) represent another competitive force, which increasingly unifies both networks. Nevertheless, there are still differences from a technological perspective (i.e. shared use of the air interface of all subscribers to a specific cellular access point), which result in differences in quality. There are also major differences on the demand side, in terms of customer segment-specific adoption. Acceptance is low among some customer groups, while others use mobile broadband services in addition to, or even instead of, wireline broadband services. Since, on average, complementary usage still seems to dominate and given the persisting technological differences, the EC has expressed in its past and current market recommendations that mobile and wireline broadband services – at least at present and in the medium term – are not sufficiently substitutable and thus cannot be allocated to the same product market. Nonetheless, it should be noted that there is no sufficient valid empirical evidence currently available and proper empirical demand analysis is typically not carried out by NRAs in the first stage of market analysis procedures, i.e. market definition. When it comes to specifying products/services in relevant markets, there is at least a lack of empirically valid evidence in relation to two issues. The first of these is the question of fixed-mobile substitution in the case of broadband access. The second refers to the question of whether all wireline broadband products – from very basic broadband to high-end FTTH based broadband products – can actually be allocated to the same market. In the latter case, when defining the product/service market, NRAs and the EC argue either explicitly or implicitly that there is sufficiently seamless substitution (a "substitution chain") between all broadband connection products based on copper, cable and optical fiber infrastructures, i.e. all xDSL and NGA products. Given that issues of market definition such as those mentioned above are of critical importance in assessing market dominance and regulatory policies (the second and third stages of the market analysis procedure), purely descriptive findings combined with plausibility arguments are insufficient. In a similar vein, HSBC (2016, p. 16) finds that currently "*[m]uch regulatory intervention is justified by analysis that rests on excessively narrow market definitions that have yet to adequately reflect today's reality that mobile, Wi-Fi, cable and conventional fixed-line platforms represent at the very least partial*

substitutes for one another (and in many instances direct substitutes), and thus constrain one another's pricing."

As explained, however, the EC and the majority of NRAs still do not consider wireless broadband access connections as a sufficient substitute to assign these products to the same product/service market (*competition within the market*). Even if this assumption is correct, mobile broadband technologies have already exerted a considerable competitive force towards wireline broadband access services (*competition outside the market*) and will increasingly continue to do so in the future (competition outside/inside? the market). This implies that consumers have access to a direct "outside option" for fast broadband services, at least since the deployment of 4G/LTE. The same applies to a growing extent to OTT services, which are competing with ECS and fixed-line (intramodal) legacy broadband technologies which exert competitive pressure on new NGA-based products.

4.4.2 Geographic market delineation and geographically uniform pricing

If regulated infrastructure operators are confronted with the need for geographically homogeneous pricing due to demand-side restrictions ("uniform pricing constraint"), market results in competitive regions carry over to some extent to less competitive regions as part of an average pricing strategy (for a similar argument see HSBC (2016, p. 25)). In many EU member states, there is for the most part indeed an average price level.[19] Similar to competition from mobiles outside the market, uniform pricing constraints exert pressure on the pricing of broadband/NGA operators even in monopolistic or uncovered areas.

Furthermore, as suggested by Figure 4 and Figure 5 in Section 2.2, the competitive situation will typically be quite different in urban and non-urban (rural) areas. To avoid inappropriate regulations, NRAs have to perform an adequate assessment as part of the market definitions in order to identify geographic market delineation on solid empirical grounds. In particular, the presumption is that in most member states urban areas are often already characterized by (narrow) oligopolistic market structures, which would thus no longer leave room for sector-specific ex-ante access regulations according to the EU regulatory framework.

It appears, however, that NRAs are lagging behind when it comes to giving adequate consideration of both the significance of uniform pricing constraints as well as the assessment of regional differences in terms of substitution patterns and competitive intensity. A first approach to regional differentiation has been already provided by the EC in distinguishing so-called "black", "white" and "grey" areas in its guidelines for the application of state aid rules in relation to the rapid deployment of broadband networks (2013/C 25/01); the guidelines provide the following distinction of competitive NGA areas: "*Accordingly, for the purposes of assessing State aid for NGA networks, an area where NGA networks do not at present exist and where they are not likely to be built within 3 years in line with paragraphs 63 to 65 by private investors, should be considered to be a 'white NGA' area*" (§75) ... "*An area should be considered a 'grey NGA' area where only one NGA network is in*

[19] For the case of Germany the reader is referred to the Monopolies Commission (2015b, p. 34).

place or is being deployed in the coming 3 years and there are no plans by any operator to deploy a NGA network in the coming 3 years" (§76) … "*If at least two NGA networks of different operators exist in a given area or will be deployed in the coming 3 years, such an area should be considered a 'black NGA' area"* (§77). At this point, it is important to note that classifying (NGA) areas as black, grey and white always presupposes a certain preliminary definition of coverage quality parameters.

As a simple starting point, NRA´s could apply a similar distinction when designing access remedies. Such an approach would already capture most of the regional heterogeneity and at the same time limit administrative burdens in carrying out market analysis procedures for a number of relevant geographic markets. But even if geographic market delineation and regionally differentiated market analysis are informational demanding and time-consuming tasks, it is the obligation of NRAs to define relevant markets which exhibit sufficiently homogeneous conditions within and sufficiently heterogeneous conditions between relevant markets (§55 SMP-Guidelines).

4.5 Competition law and sector-specific law

The process of transforming ex-ante regulated markets towards a pure ex-post regime depends not least on the de facto institutional power of the respective competition authority in the individual member state (e.g. regarding disclosure and notification rights, staffing and financial resources, institutional independence etc.). With regard to competition problems at the retail level, the third criterion of the three-criteria test (Section 3) explicitly refers to the subsidiarity of competition law. Only if competition law is proven to be insufficient, might NRAs consider sector-specific access regulations to address actual or potential market-structure related competition problems at the retail level.

Moving away from sector-specific ex-ante regulation towards an ex-post regime results, on the one hand, in more flexibility for the regulated firm with regard to its pricing strategy. On the other hand, in terms of procedural requirements, too, the regulated firm can gain additional flexibility (such as "time-to-market") depending on the specific formal design of disclosure and authorization obligations. In cases where possible investigations of anti-competitive conduct were to arise exclusively on the basis of competition law, the responsible competition authorities would have to produce evidence of such conduct, with the corresponding basis of information being gathered only when the incident actually occurs. While the latter (by definition) takes effect only when an abuse has taken place, expected abuses of market power can constitute a justification for ex-ante sector-specific regulation, insofar as competition problems result from specific characteristics of the market structure. In the case of network industries, features of the market structure can generally be attributed to the fact that one firm (incumbent) possesses the infrastructure elements

that are essential to alternative competitors and are economically very difficult to replicate ("essential facility").[20]

4.6 Competition in narrow oligopolies

The increasingly oligopolistic structures of (sub-)national communications markets in both the mobile and fixed network sectors raise new questions relating to sector-specific (de)regulation, competition law and market dominance (BEREC, 2015b). BEREC believes that the tendency towards ever narrower oligopolies can be attributed to the growing trend of consolidation in the fixed and mobile network sectors, the technological convergence of IP-based platforms and services, and limited replicability when deploying NGA networks. All this leads to ever more concentrated market structures with a low number of players and rather symmetrically distributed market players (Section 4.1). This leads to an increased risk of collusive behavior ("joint dominance of firms") in narrow oligopolies, while reducing the risk of an individual dominant market position ("single firm dominance"). In specific terms, BEREC sees a potential risk of oligopolistic – however not necessarily collusive or coordinated – market power[21] in markets 3a and 3b of the 2014 market recommendation for the fixed network sector and in the ex-market 15 of the 2003 recommendation for the mobile sector (BEREC, 2015b, p. 8-10). Consequently, BEREC (2015b) began to pursue a new concept of so-called "tight oligopoly" which refers to imperfect oligopolistic competition and might require ex ante regulation including incumbent but also non-incumbent infrastructure operators such as CATV or mobile operators.

The phenomenon of narrow or tight oligopolies gains practical relevance since effectively all key sector-specific ex ante regulations have been based on single dominance SMP positions.

[20] The underlying essential facilities doctrine has its origins in US law (Arreda, 1987; Lipsky and Sidak, 1999) and in principle applies to markets exhibiting natural monopoly characteristics, which give rise to monopolistic behavior such as refusal to deal. The specific conditions of an essential facility were laid out in the case MCI Communications Co v. AT&T (708 F.2d 1081) in 1982. According to this decision, to establish obligatory access to an essential facility there must be i) a control of the facility by a monopolist; ii) economic inability to reasonably replicate the facility iii) feasibility to supply the facility to alternative operators. According to Motta (2004, p. 68) one also has to determine whether an essential facility is the result of risky firm investment or whether it represents a legacy infrastructure obtained without prior investment or innovation activities. In the former case, granting access to the facility would discourage ex ante investment incentives as the firm might be subject to expropriation ex post. Under EC law the essential facilities doctrine has been based on Art. 82 (Art. 102) of the EC Treaty (TFEU) which prohibits the abuse of market dominance. The doctrine has since become part of the EU regulatory framework (European Commission, 2002a, recital (6) and Art. 12). Moreover, when applying the essential facility doctrine of Art. 102, the absence of replicability is not enough on its own to make the provision of access mandatory. The European Court of Justice (ECJ) further requires that refusal of access is likely to eliminate all competition in the downstream market and that the refusal to grant access cannot be objectively justified (ECJ, November 26, 1998, case No. C-7/97, Report of Cases I 7791 – Bronner).

[21] In an oligopolistic market, only a small number of firms are responsible for the majority or all of production and substantial entry barriers mean that some firms can experience economic profits in the long term as well (oligopolistic market power). Even without any explicitly coordinated conduct ("cartelization"), the firms can realize the maximum monopoly profits for the industry ("tacit collusion", which equates to the position of "joint dominance").

In turn, it appeared that proving a jointly dominant market position is particularly difficult. For example, according to BEREC (2015b, p. 27), only eight cases of joint dominance were identified in all the market analyses carried out in EU member states between 2004 and 2012 and reported to the EC, with a final joint dominance decision reached only in three cases. The debate initiated by BEREC regarding the intervention options of NRAs in the case of suspected oligopolistic market power should be viewed against this background. So far, the EU regulatory framework has not provided any sector-specific intervention options for such cases. In this regard, it is important to bear in mind that the potential for sector-specific intervention in the case of oligopolistic market power would drastically extend the concept and scope of the existing regulatory framework. It is also worth noting that, during any regulatory interventions into narrow oligopolies, the oft-cited trade-off between static and dynamic efficiency would need to be taken into account. Narrow oligopolies can make a major contribution to dynamic efficiency, particularly in investment- and innovation-intensive industries (BEREC, 2015b, p. 15), as has been shown in the discussion of the non-linear relationship between competitive intensity and investment activity (w* in Figure 9 above which indicates an optimal but not maximal level of investment). As suggested in Section 4.2, the tendency towards narrower oligopolies, which has been massively driven by M&A transactions, might be the result of undue weight given to static efficiency.[22]

4.7 EECC: Intended measures and critical appraisal

Two relevant features emerge from the discussion of NGA market structures: Firstly, reinforcing the point made in Section 2.4, NGA related market shares on the basis of fixed-line vs. mobile, NGA technologies and geography ((sub-)urban vs. rural) vary significantly among member states. This represents a clear limitation to the goal of harmonizing regulatory policies as set out in the CODE (recital 3) in cases in which heterogeneity is due to differing demand and cost conditions. Only in the case that market outcomes are different due to different applications of regulatory tools despite similar market conditions, is a more consistent regulatory approach appropriate and necessary.

Secondly, high variation in market shares re-emphasizes the crucial role of the first stage in the market analysis procedure, i.e. market definition. In fact, a proper empirical analysis alongside main market delineation dimensions such as geography, fixed-mobile substitution or the relevance of services from OTTs can be considered increasingly important (as evidenced by convergence M&As in section 4.1) and combinations of these dimensions, e.g. in rural areas where building NGA infrastructure might not be economically sensible, 4G/LTE could soon become a sufficient substitute. An empirical analysis is also requested in determining the relevance of competitive constraints outside the market (stage two of the market analysis). The institutional strength and power of the competition authorities in individual member states constitutes another decisive factor in the transition from partial to full deregulation.

[22] For evidence of the impact of assigning frequency spectrum to mobile market structures see Gebhardt and Wambach (2008) and Bichler et al. (2015).

With respect to conditions of fair competition between ECS and OTT services (level playing field), the CODE (Art. 2 (4)-(7); core objective in recital 3) sets out a range of categorizations regarding functional and technical considerations such as using number dependency as a distinctive characteristic. However, the latter is of little importance from a consumer perspective. Unfortunately, the CODE lays no explicit emphasis on the necessity for an adequate demand-side analysis as an integral part of the market definition to be carried out by the NRAs. When considering the level of regulation, it is also important to note that a level playing field cannot be achieved solely by expanding or reducing relevant regulatory obligations. Rather, a more important approach is to question the purpose of existing ECS regulations.

Finally, the discussion on the relation between competition and investment indicated that several opposing effects will ultimately determine the market outcome. In conjunction with uncertainties surrounding the extent of externalities related to new infrastructure, this makes it very difficult to predict optimal levels of NGA investment, let alone the future innovation potential of NGA technologies, which further increases the risk of policy failure in the case of too dirigiste regulations as set out in several places in the CODE. The market consolidation in wireline and mobile sectors in recent years implies even narrower oligopolies. Nevertheless, oligopolistic access regulation as suggested by BEREC (2015b) would not only be at odds with the essential facility doctrine and the EU interpretation of the essential facilities doctrine based on market dominance, it would also most likely induce a further extension of access regulations and hence be detrimental to the CODE´s core goal of promoting investment in new communications infrastructure. In view of this, it is encouraging that the CODE apparently did not adopt the concept of oligopolistic dominance as another source of unilateral market power, which would have enabled far-reaching tight oligopoly regulation.

5 The relevance of co-investments and risk sharing co-operation models

As discussed in Section 4.4.2, competitive intensity may vary significantly across regions. In competitive (black) areas there is by definition no longer a need for sector-specific ex ante access regulations on the basis of the essential facility doctrine or the concept of market dominance. In white areas, where network deployment would not be profitable even for a monopolist, it is not possible to incentivize network deployment through sector-specific access regulation. Public policies based on subsidies would be a considerably more effective instrument in these circumstances. In grey areas, where only one infrastructure provider is active, it is much more difficult to determine the best policy, since there is a range of trade-offs that need to be taken into account. In grey (or otherwise white) areas co-operation (or: co-investment) models and the authorization of these seems to be an effective measure for sharing market risks, market exposure and deployment costs and thus for generating additional investment incentives. This also ensures that inefficient investment such as the duplication of infrastructures can be avoided in grey areas (Briglauer et al. 2015b). Support

for co-operation models in the form of market-driven collaboration solutions has already been mentioned in the EC´s NGA recommendation (European Commission, 2010b, recitals 12, 15, 19, 27 and Art. 13, 16) and in its framework directive (Art. 8 (5) lit d), wherein collaborations and other risk-sharing models are explicitly intended as a means of supporting investment.

An example from Germany is the "Kontingentmodell" launched by Deutsche Telekom, which was authorized in 2012 by both the sector-specific regulatory authority and the EC. This volume-discount based co-operation model requests that competitors must book and pay for a specific quota in advance, whereby they can secure lower monthly payments compared to basic bitstream access for a fixed fee ("upfront payment"). This model ensures that risks are shared, since access seekers are also effectively assuming some of the demand risk. All things being equal, this model can generate higher investment incentives due to this risk sharing mechanism. What is crucial about this co-operation model is that it is not an access obligation imposed asymmetrically as part of sector-specific ex ante regulation nor is it imposed at costs directly set by the NRA. It is instead a quasi-market solution albeit one that requires ex ante authorization from NRAs and has to be offered on the market on a non-discriminatory basis. In this specific case, agreements have already been made under this model between Deutsche Telekom and alternative competitors (Godlovitch et al., 2015a, p. 56). In general, co-investment models with "open-access" are based on the voluntary commitment of an infrastructure provider subject to the regulatory constraint that potential access seekers are to be offered a means of gaining that access on a non-discriminatory basis. Both the aspect of risk-sharing (framework directive, Art. 8 (5) d)) and the primacy of voluntary market solutions (framework directive, Art. 8 (5) f)) correspond with the current European regulatory framework in this respect. The latter appears to be the more advantageous alternative with regard to substantial investment risk, particularly in view of current market uncertainties: *"There may be a case for the primacy of negotiated solutions – as is already set out in the TKG [=German telecommunications act]. Given the uncertainties relating to demand and the willingness to pay for new NGA services, commercial, negotiated solutions are to be given preference when it comes to access prices, as these are more likely to permit market-based pricing of the underlying investment risk than remuneration which has been set by authorities"* (Nett & Stumpf, 2011, p. 12). Consequently, sharing risks related to future demand and market exposure on the one hand, as well as capital formation in case of capital market imperfections on the other, are the dominant features of effective co-investment models. Investment sharing might also come hand in hand with cost reductions, e.g. in case of traditional and non-traditional telecommunications operators, such as utilities, (ITU, 2015, p. 5) share skills, capabilities and different infrastructure elements in the network hierarchy. It is important to note, however, that the reasons why co-investment agreements might be successful do not imply that market risk disappears altogether with such agreements. Risk and uncertainty clearly remain; the existence of a co-investment agreement simply shares the *exposure* to these risks to all investors that commit to invest ex ante (i.e. before the investment is made), but they clearly affect the decision to invest. Note

also that co-investment models shall not be subjected to certain restrictions a priori as regards the organizational design of how firms co-operate, which is ideally left to the market. Co-investment agreements can thus involve several operators investing jointly in different infrastructure components ("co-build", based on joint ventures if applicable) and then giving each other (or third parties) access as well as a different version of volume-discount models with only one firm deploying the infrastructure. Further alternative sharing agreements are geographic agreements (ITU, 2015, p. 14) where one operator deploys a network in a certain region and requests access in an area covered by another co-investing party (and vice versa). Geographical co-investment, however, does not represent a typical network sharing scenario – which might also be under close scrutiny of competition authorities.

When comparing network sharing in mobile and fixed networks, the question arises as to why co-investment occurs relatively infrequently in fixed networks (ITU, 2015, p. 6-8).[23] One reason could be that such co-investment activities – geographic sharing in particular, but also co-investment in general – could interfere with competition law and therefore may require ex ante authorization. Note that sharing agreements not only involve physical infrastructure elements but inevitably also sharing of commercial information among co-investing parties. Such concerns appear to be more serious ahead of time in fixed networks where there is typically already less competition than in mobile markets (Section 4.1). Ex ante access conditions imposed on the co-investing SMP operator represent another obstacle which is not present in the case of mobile-network sharing. Finally, co-ordination costs in fixed networks might be higher due to comparatively higher heterogeneity in terms of business models, network elements and size distribution of involved operators (ITU, 2015, p. 9-10).

5.1 EECC: Intended measures and critical appraisal

Art. 74 envisages an exemption from regulation for networks with very high capacity, insofar as the following conditions are met on a cumulative basis (Art. 74 (1)): "*i) the deployment of the new network elements is open to co-investment offers according to a transparent process and on terms which favor sustainable competition in the long term including inter alia fair, reasonable and non-discriminatory terms offered to potential co-investors; 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 after the deployment of the co-invested infrastructure; ii) the deployment of the new network elements contributes significantly to the deployment of very high capacity networks; iii) access seekers not participating in the co-investment can benefit from the same quality, speed, conditions and end-user reach as was available before the deployment, either through commercial agreements based on fair and reasonable terms or by means of regulated access maintained or adapted by the national regulatory authority.*" According to this, the CODE´s

[23] Whereas the term "network sharing" is typically used for co-operation models in the mobile industry, the term "co-investment" is typically used with respect to co-investing fixed-network operators.

proposed exemption from regulation is tied in with a range of additional conditions. For example, the co-investment package must not be offered to interested parties at one time only, but rather over the entire service life of a network and on a non-discriminatory basis. The content and procedures involved in the package must also be transparent for all market participants and the package must safeguard sustainable competition for the long term (Annex IV lit. a – lit. d). On the one hand, this approach still represents a rather strong regulatory component, with the result that co-investment models such as these differ substantially from purely voluntary market solutions and their associated ex ante investment incentives. On the other hand, the inherent concept of ensuring that all involved parties effectively share risk should be viewed positively as an effect that encourages investment. However, co-investment models will only induce additional infrastructure investment if the regulatory conditions which are imposed ex ante on co-investing parties are not too restrictive in terms of accruing future investment rewards and in view of the actual extent of risk-/cost-sharing. The sharing effect increases the longer participating parties have to co-operate, the more commercially negotiated terms prevail and the lower the scope of regulatory gaming is. In case (an) infrastructure operator(s) reach(es) a commercially negotiated long-term agreement with other market participants, NRAs might even consider fully withdrawing from ex ante regulations / side conditions and switching to ex post market monitoring (HSBC, 2016, p. 29) subject to other competition factors inside and outside the market.

In Annex IV lit. a the CODE pushes for imposing open co-investment agreement on the SMP operator which enables access for later entrants to join the co-investment agreement. In some sense, letting the co-investment agreement remain open over its entire period of validity on a non-discriminatory basis is in accordance with standard wholesale access regulation. The option for late entrants to pay an access fee that includes a fraction of those risks would work if, and only if, the regulator is able to precisely assess those risks and monetize them through the access fee, but it is extremely complex and difficult to implement in practice. Yet, the CODE (Annex IV lit. c) provides for a dynamic adjustment of access prices reflecting the timing of commitments made at later stages. Hence, imposing such open co-investment specifications increases regulatory uncertainties and transaction costs and further reduces the incentives to co-invest because it negatively affects the incentives to pre-commit on investment. Also, the risk of imposing investment-diminishing access regulations is of particular concern in view of the aforementioned co-investment obstacles in fixed-network industries. To induce co-investment regulatory obstacles should thus be minimized.

6 The role of symmetric non-SMP access regulation

Besides voluntary forms of co-operation, the joint usage of infrastructures can also take shape based on symmetrical regulatory obligations. In contrast to asymmetric regulation, symmetric forms of regulation concern measures that must be imposed on all providers,

irrespective of market power. However, the essential facility doctrine is a common starting point for both forms of regulation (Nett & Stumpf, 2011, p. 8-9). Against this background, general examples of symmetric obligations for all network operators would include rights of joint installation and shared use in the case of physical network infrastructure elements that are essential to NGA deployment. According to Art. 12 (1)-(2) framework directive NRAs may impose co-location and facility sharing on all firms: "*Where an undertaking providing electronic communications networks has the right under national legislation to install facilities on, over or under public or private property, or may take advantage of a procedure for the expropriation or use of property, national regulatory authorities shall encourage the sharing of such facilities or property. In particular where undertakings are deprived of access to viable alternatives because of the need to protect the environment, public health, public security or to meet town and country planning objectives, Member States may impose the sharing of facilities or property (including physical co-location) on an undertaking operating an electronic communications network or take measures to facilitate the co-ordination of public works only after an appropriate period of public consultation during which all interested parties must be given an opportunity to express their views. Such sharing or co-ordination arrangements may include rules for apportioning the costs of facility or property sharing*." In short, both wireline and wireless infrastructures are covered, as are infrastructures not owned by telecommunications companies, such as routes used by power supply networks, pylons and existing cable duct capacities, as well as empty conduits and overhead power cables on traffic routes (Nett & Stumpf, 2011, p. 7).

Insofar as symmetrical obligations are suitable for delivering synergy potentials and lowering total investment costs such as the comparatively high installation costs in Europe (where underground deployment is the norm), they will increase the profitability of NGA projects and, all other things being equal, overall investment activity. Accordingly, in its cost reduction directive the EC envisages shared use obligations on a large scale for public communications network operators and firms that own rights of use, primarily due to cost aspects (European Commission, 2014c, recital 13): "*It can be significantly more efficient for electronic communications network operators, in particular new entrants, to re-use existing physical infrastructures, including those of other utilities, in order to roll out electronic communications networks, in particular in areas where no suitable electronic communications network is available or where it may not be economically feasible to build up a new physical infrastructure. Moreover, synergies across sectors may significantly reduce the need for civil works due to the deployment of electronic communications networks and therefore also the social and environmental costs linked to them, such as pollution, nuisances and traffic congestion. Therefore this Directive should apply not only to public communications network providers but to any owner or holder of rights to use, in the latter case without prejudice to any third party's property rights, extensive and ubiquitous physical infrastructures suitable to host electronic communications network elements, such as physical networks for the provision of electricity, gas, water and sewage and drainage systems, heating and transport services*." It is important to note, however, that in order to

increase investment, symmetric regulations must not ultimately result in extending asymmetric access regulations to a variety of infrastructure elements and all infrastructure operators regardless of actual market power (SMP). This would run contrary to deregulation steps that have already been put in place and the central goal of promoting investment. Accordingly, mandatory non-SMP access obligations imposed on "passive" infrastructure elements[24] must not discourage ex ante investment incentives to avoid counteracting the positive effect associated with lowering deployment costs due to synergies. However, assuming that costs are reasonably distributed between operators,[25] that opportunity costs for the infrastructure owners (Held et al., 2015, p. 13) are factored in, and that proportionality is strictly observed, shared use and joint installation obligations – where appropriate combined with voluntary forms of co-operation – should offer considerable potential for reducing total deployment costs.[26] In this case, symmetric regulatory measures would also be suitable for boosting the deployment of optical fiber networks both in terms of geographical spread and investment-intensive FTTP deployments.

In this context, a similar situation arises in view of investment incentives and possible future shared use obligations as regards the connection of 4G/LTE antennae with optical fiber infrastructures (backhaul segment). The latter are needed to carry the high data traffic generated over the air interface to backbone networks. This applies even more to the upcoming mobile successor technology (5G). This technology should – following standardization at the World Radio Conference 2019 – be market ready by 2020 and achieve data rates of up to 1 GBit/s. This will have substantial implications for digitization applications in both the private consumer (entertainment, connected house, smart car) and industry sectors (Industry 4.0, machine-to-machine, smart grids) (Henseler-Unger, 2016, p. 74). Furthermore, 5G will unify a large part of the fixed-line and mobile infrastructure resulting in generic all-IP transport networks. This kind of technology driven fixed-mobile convergence might also exert significant impact on fixed-mobile substitution patterns on the demand side. As regards the relation between regulation and investment, 5G infrastructure operators are confronted with massive investment requirements. Consequently, ex ante investment incentives will be significantly impacted by expected (a-)symmetric access regulations (such as access to fixed-line backhaul capacity) imposed ex post. Investment diminishing effects can be mitigated through credible regulatory commitments to impose only soft or no access obligations once the infrastructure is installed.

[24] While the passive infrastructure relates to physical infrastructure elements such as trenches, poles, ducts and optical fiber, optical distribution frames, patch panels etc., the "active" elements relate *"to the electronic network equipment needed to bring the passive infrastructure alive, as well as the operational support systems required to commercialize the fiber connectivity"* (FTTH Council Europe, 2012, p. 18-19).

[25] See Held et al. (2015) for standards used to determine prices for the shared use of infrastructures.

[26] For illustrative purposes, the reader is referred to substantial cost reductions that can be achieved for optical fiber connection networks solely by installing them in conjunction with power networks (Jay & Plückebaum, 2014).

6.1 EECC: Intended measures and critical appraisal

To achieve the investment objectives, the CODE envisages a promotion of symmetric market regulation – which does not take account of SMP – in order to reduce deployment costs and thus ultimately support investment incentives as well. Art. 44 of the CODE provides for symmetric regulations on co-location and sharing of network elements and associated facilities for providers of electronic communications networks. In particular, "[*c*]*ompetent authorities shall be able to impose the sharing of such facilities or property, including land, buildings, entries to buildings, building wiring, masts, antennae, towers and other supporting constructions, ducts, conduits, manholes, cabinets or measures facilitating the co-ordination of public works. Where necessary, national regulatory authorities shall provide rules for apportioning the costs of facility or property sharing and of civil works co-ordination*." In the last sentence of the cited paragraph, the CODE refers to the role of NRAs in determining charges for infrastructure sharing, which creates room for regulatory gaming and impacts market arrangements. Furthermore, co-existing specifications in Art. 3 of the cost reduction directive (European Commission, 2014c) create some legal uncertainties as regards the scope and application of symmetric access regulations. Art. 59 further standardizes access regulations that apply to all firms irrespective of whether they have SMP. Art. 59 (1) lit. a.) and lit. b.) update the pre-existing regulations for ensuring end-to-end connectivity, which can be used to impose obligations on all firms that control access to end-users (usually subscriber network operators), thus requiring them to provide competitors with physical access to the network and/or safeguard the interoperability of their services. The rule in Art. 59 (2), however, is new. This rule stipulates that, regardless of the necessity of safeguarding end-to-end connectivity, NRAs can also impose on firms without SMP the obligation to ensure network access to existing in-house cabling or up to the first concentration or distribution point. According to Art. 59(2), an access obligation such as this can even be extended on a case-by-case basis to network components beyond the first distribution point.

A central element of justification for these far-reaching symmetric access obligations would be that such a right of shared use over the existing access infrastructure can lower total deployment costs substantially. However, this incentivizing effect for investment has to be weighed up against the investment-lowering effect of potentially expanding ex ante regulation to all infrastructure operators and owners and to a broad range of physical access infrastructure elements. While the first effect is dependent on country-specific cost factors, the latter is determined centrally by the specific implementation of symmetric regulation regarding access types and the way regulated access charges are calculated. Planned symmetric access regulations might also raise a legal problem insofar as the essential facility doctrine is extended to a wide variety of infrastructure elements without reference to the concept of the relevant market. In addition, symmetric regulations might in practice give rise to a substantial expansion of industry regulation as these regulations are readily available without conduction of extensive market definition and SMP analyses (HSBC, 2016, p. 3).

7 The role of asymmetric SMP access regulation

The question as to what extent existing broadband access regulations hamper or encourage investment in new networks and what influence they have on end-customer prices and the quality of services has been the subject of debate for years. At a European level, regulated infrastructure providers argue that mandatory access obligations with regulated fees would diminish incentives to invest in the deployment and improvement of access infrastructure. By contrast, many NRAs and alternative (service-based) providers believe that the deployment of new broadband infrastructures also presents a risk of new and potentially more pronounced monopoly areas and therefore requires appropriate ex ante regulation.

When it comes to the effects of regulating broadband infrastructures, proponents of regulation also argue that this approach does not necessarily have to lead to a decline in investment (Godlovitch et al., 2015a, p. 74-78). In this regard, Vogelsang (2014, p. 13) points on the one hand to the partial initial success of both the deployment of FTTH networks by Verizon during the first few years after deregulation in the US and the primarily FTTC/VDSL-based deployment by AT&T. On the other hand, there has over recent years been a clear slow-down in FTTH deployment in the US (using the "FIOS" (Verizon) and "GigaPower" (AT&T) products). Outlining the reasons for this, Vogelsang (2014, p. 13) refers to the focus on profitable, densely populated areas ("low-hanging fruits first") and the rising marginal costs (in rural areas) and comparative cost benefits of DOCSIS 3.0 in other areas. Nonetheless, the comparative EU-US study by Yoo (2014) concludes that the US exhibits better results than the European average in 2011 and 2012 for most of the relevant parameters of the broadband infrastructure. In its price comparisons, the study finds that the US has lower average prices for connections below 12 Mbit/s and that US pricing levels are higher only in the case of connections with higher bandwidth levels. However, on the same subject, Yoo also points out the much higher intensity of use. Once adjusted accordingly to take utilized capacities into account, the prices for fast connections barely differ at all. As HSBC (2016, p. 19) argues unit price metrics should indeed be the preferable measure when comparing market outcomes, as unit prices also capture customer preferences on quality parameters (whereas monthly bills do not). Other studies have, by contrast, found a relative increase in the US pricing level (e.g. Mariniello & Salemi, 2015, for a comparison of EU-US mobile markets). Generally, a trade-off between static and dynamic efficiency – i.e. between regulation and short-term price effects on the one hand and investment and long-term market results on the other – is well documented in telecommunications-specific literature (Krämer & Schnurr, 2014).

7.1 Literature on the impact of access regulation on NGA investment

Briglauer et al. (2015b, p. 231-246) provide an overview of the existing academic literature and a detailed discussion of the theoretical and empirical findings. The theoretical literature – most prominent here features Bourreau et al. (2012) – suggests that a higher access charge for the old broadband technology (unbundling price in particular) is encouraging NGA

investment on the part of entrant firms. However, there are countervailing effects for incumbent firms suggesting ambiguity as to whether a higher or lower access charge imposed on old broadband networks is more likely to induce NGA investment from incumbents and hence enhance aggregate NGA investment. Not addressed by Bourreau et al. (2012) is the case of competitive areas where both an entrant and the incumbent company invest in NGA infrastructure. This case is taken up by Inderst and Peitz (2012a), who find that this can lead to a prisoners' dilemma, where both firms would be better off not investing. Based on Inderst and Peitz (2012a/b), Vogelsang (2016) comes to the conclusion that NGA infrastructure should not be regulated if NGA investment is the objective. The main mechanism here is a Schumpeter effect, because not regulating the new infrastructure increases the profitability of the investment. The Schumpeter effect is larger here than for a firm that was not regulated to begin with. For an in-depth examination of the relevant theoretical literature on the impact of various regulatory schemes, the reader is referred to Part II of this study.

As regards the empirical evidence, Table 4 first summarizes the findings as well as the data employed in the literature. From the empirical literature, we can infer that all studies that use data from European countries find a negative impact of ex ante access regulations or related service-based competition on NGA deployment in terms of investment or adoption. Only one study that uses OECD and ITU data for NGA adoption finds insignificant results (Samanta et al., 2012). Whereas all these studies use aggregate country level data, one study makes use of Japanese data (Minamihashi, 2012) at the municipal level and also finds that unbundling regulations have a negative impact on entrants' incentive to invest in NGA infrastructure (the incumbents´ investment is not affected). Overall, the empirical literature indicates a negative impact of ex ante access regulations on NGA investment incentives. These results seem to favor deregulatory approaches, which appears to be largely in line with the older broadband-related literature as surveyed in Cambini and Jiang (2009) and the subsequent empirical analysis on regulation and broadband investment,[27] which largely confirm the results in Cambini and Jiang (2009). Although there are only few NGA related empirical contributions available, the studies reviewed in Table 4 suggest that the findings of the older broadband-related literature is also applicable – apparently even more strongly – to NGA infrastructure.

Secondly, the empirical evidence is confirmed by independent assessments of financial market analysts. It seems appropriate to also consider the independent viewpoint of investors and contrast this with the view of policy makers. Firstly, reference is made to the survey that Credit Suisse (2016) conducted among financial investors about selected questions from the EC´s public consultation on reviewing the European regulatory framework, and particularly about the questions regarding how different types of regulation impact investment incentives (Credit Suisse, 2016, p. 8-10). Credit Suisse (2016, p. 1) summarizes the investors believes as follows: "*Policies that would boost NGA investment in*

[27] See inter alia Bouckaert et al. (2010), Grajek and Röller (2012) or Crandall et al. (2013).

the view of the investors sampled include evolving from ex ante to ex post regulation, extending FTTC investment incentives, lengthening the period between market reviews, longer spectrum licenses, considering whether fixed and mobiles are substitutes, reflecting regional variations in wholesale prices and centralizing market power over regulation and spectrum at the EC." Secondly, a study by HSBSC (2016) analyzes the impact of regulatory schemes as set out in the CODE on investment incentives. In view of fixed-line market and incumbent-related regulation, the study concludes: "*Europe needs to create a telecoms market where competition is based on capex, rather than the ersatz competition that wholesale and unbundled products represent. In the practice, for the fixed-line market, this would mean establishing a clear roadmap for incumbents, setting out their obligations, in return for which they would enjoy the benefits of a more deregulated (though not unregulated) environment*" (HSBC, 2016, p. 14). From an investor´s point of view a more deregulatory approach thus increases the investment incentives for incumbent operators. Furthermore, there is an indirect investment-diminishing effect on rival infrastructure operators if regulation is targeted at static efficiency and lowering bills for customers (HSBC, 2016, p. 21). As regards the mobile industry, the study identifies a similar need for a more pronounced focus on dynamic efficiency. Particularly in the course of merger control analysis and spectrum management, the duration of licenses should be extended and spectrum trading made easier (p. 15).

Thirdly, in more recent years the EC has also gradually begun to acknowledge that strict cost-based access regulation is at odds with the goal of promoting investment in new infrastructures. At this point, reference is made to the EC's recommendation for standardized non-discrimination obligations (European Commission, 2013). In terms of the stipulations in European Commission (2013), efficiency-oriented NRAs would fully deregulate NGA and legacy infrastructure in black areas and apply legacy regulation with comparatively high prices plus NGA regulation with only softer regulation obligations in grey areas. Softer regulations refrain from cost-oriented access regulations which largely eliminate pricing flexibility and instead impose forms of (a-)symmetric regulations targeted at increased pricing flexibility. However, in trying to factor in the interdependent correlation between regulation, competition and investment as well as giving regulated firms more flexibility on pricing (Vogelsang, 2014, p. 12), this recommendation also introduces several new definitions and criteria for NGA infrastructure regulation and thus brings up questions regarding implementation issues and corresponding uncertainties. In its 2014 market recommendation, the EC further expresses concerns about negative effects of regulation on investment (European Commission, 2014b, explanatory note): "*Regulation must be targeted and balanced in a way that addresses the true obstacles to effective competition in the sector: an excessive regulatory burden on operators would stifle investment and innovation*." Overall, it appears that the EC increasingly adjusted its policy on regulation and investment in light of industry experience and empirical evidence. A similar adjustment process can be observed in view of the ladder of investment hypothesis that initially represented one of the EC´s core justifications for promoting investment via asymmetric access obligations.

Table 4: Overview of empirical studies on the impact of regulation on investment[*)]

Author(s)	Data	Main results
		Studies examining the impact on NGA investment
Minamih-ashi (2012)	Japan 2005-2009 Municipal level	• Unbundling regulations hinder cable entrants from investing in own NGA infrastructure
Briglauer et al. (2013)	EU27 countries 2005-2011 National level	• The more effective service-based competition is, the more negative the impact on NGA investment • Infrastructure competition from cable and mobile networks affects NGA investment non-linearly
Yoo (2014)	US and European countries National level	• Service-based competition and NGA investment are negatively correlated • Infrastructure competition from cable networks is positively correlated with NGA investment
Bacache et al. (2014)	15 European countries 17 semesters 2002-2010 National level	• Ladder of investment hypothesis supported at lower rungs • Presence of multi-layer access regulation does not increase NGA investment
Briglauer (2015)	EU27 countries 2005-2011 National level	• A higher unbundling price positively impacts NGA investment and the effect is stronger the more effective the unbundling regime is • The more effective service-based competition is, the more negative the impact on NGA investment • The replacement effect from legacy infrastructure exerts a negative impact on NGA investment
Briglauer et al. (2017)	EU27 countries 2005-2011 Firm level 2003-2014	• A higher unbundling price positively impacts NGA investment from incumbent operators but it has no impact on cable and other operators • Stronger NGA access regulations diminish NGA investment from incumbent operators but it has no impact on cable and other operators
		Studies examining the impact on NGA adoption
Wallsten & Hausladen (2009)	EU countries, Japan and Korea 2002-2007 National level	• The more effective unbundled local loops or bitstream unbundling is, the lower the rate of NGA adoption • Infrastructure-based competition has a positive impact on NGA adoption
Samanta et al. (2012)	ITU/OECD 25 countries 1999-2009 National level	• Unbundling regulation has no significant impact on NGA adoption
Jeanjean (2013)	15 European countries 2007-2012 National level	• Tight copper access regulation decreases speed of NGA adoption
Briglauer (2014a)	EU27 countries 2004-2012 National level	• Wholesale broadband regulation lowers the rate of NGA adoption • Infrastructure-based competition from first-generation broadband and mobile networks affects NGA adoption non-linearly • Network effects lead to an endogenous NGA adoption process
Briglauer & Cambini (2016)	EU25 countries 2003-2014	• An increase in the unbundling price positively effects NGA adoption; effect is stronger the more effective the unbundling regime is

*) Table 4 constitutes a modified and updated version of the table in Briglauer et al. (2015, p. 19-20).

7.2 Ladder of investment

Regulatory instruments at the wholesale level are generally always to be viewed in the form of "access prices" and "access products". The ideal type of interaction and dynamics for these instruments has been popularized in the EU as the "ladder of investment" hypothesis.[28] Given the situation in the fixed-network sector at the outset of regulation, the legacy infrastructure that had been built decades ago had to be transformed into competitive structures, a process that happened gradually at first, by means of service-based competition. Regulation-induced service-based competition relies on various wholesale access products, which differ according to price and quality. The previous broadband wholesale obligations implemented in the European regulatory framework were primarily: i) full local loop unbundling, ii) shared access, iii) bitstream and iv) DSL-Resale. With regard to the investment ladder, all the access products reflect the basic relation that access seekers have to make bigger investments if they also want to obtain more options in terms of shaping the quality of retail products. It was only when the full unbundling model was introduced that alternative competitors were able to also technically differentiate products at end-customer level (Neumann et al., 2013, p. 12).

Figure 11 depicts the hierarchy of broadband wholesale access products as it was intended by the EC. Initially, according to the ladder principle, the first rungs – i.e. the forms of access with rather low investment requirements – should facilitate a rapid entry to the market. Over the course of liberalization/regulation, wholesale service seekers should reach the higher and more investment-intensive rungs. This process should ultimately help provide competition in the field of local loop networks that is sustainable because it would be based on access infrastructures ("own infrastructure level"). The latter is thus the highest rung on the investment ladder and the first that would enable complete exemption from asymmetrically imposed access obligations (with some complementary symmetric obligations such as "duct access" in place). Combined with optimum dynamic access prices, such an approach could finally resolve the persistent underlying trade-off between the short-term market effects of regulation-induced service-based competition and the long-term effects of infrastructure-based competition: „*Proponents of the ladder of investment approach claim that such regulatory measures would make service-based entry and facility-based entry complements – albeit they have been traditionally viewed as substitutes – in promoting competition*" (Bourreau et al., 2010, p. 683). It is against this background that Bauer (2010, p. 69) cites the ladder principle alongside the essential facility doctrine as a core justification for the imposition of asymmetric access obligations (for the same reasoning see also Renda, 2016, p. 8-9).

[28] This approach was initially developed by Cave et al. (2001), Cave & Vogelsang (2003) prepared for the EC and the Dutch regulator OPTA and later modified in Cave (2006). In the US, the approach is known as the "stepping-stone hypothesis" and was introduced in the 1996 Telecommunications Act.

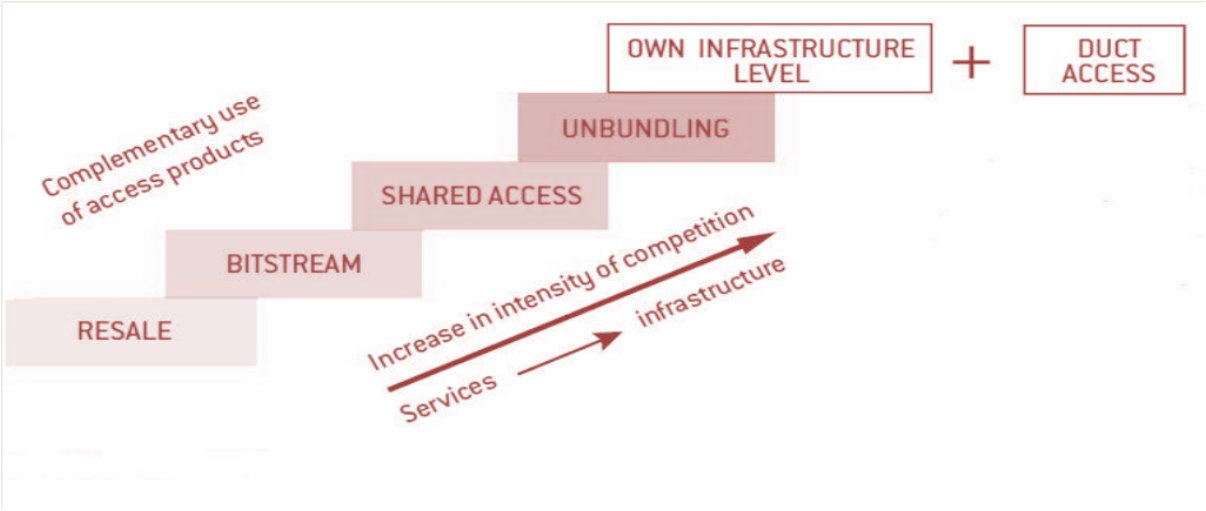

Figure 11: Hierarchy of broadband access obligations (source: European Commission, 2010b)

Figure 12 shows the actual development in broadband wholesale access products in the EU member states between 2005 and 2015. It is clear that service-based competition has only become well established under full unbundling; according to Figure 13, "LLU access" accounts for more than 78% of all DSL connections based on access regulations in 2015. The rise in unbundling saw a simultaneous drop in other access variants, which is even clearer when viewed over the entire regulation period starting in 2000 (European Commission, 2000). This can be seen as partial confirmation of the ladder principle and there is also corresponding evidence for this in the academic literature (Bacache et al., 2014). However, it is equally clear that the last rung of the ladder, which represents infrastructure competition in the local loop ("Own infrastructure level" in Figure 11 and "Own network" in Figure 12) and the long-term goal of the ladder of investment approach (Renda, 2016, p. 21), could not be realized on the basis of access regulations.[29] Referencing the specific market structure for local loops and the underlying "economies of density", Vogelsang points out that the investment ladder has been unsuccessful in ultimately delivering infrastructure-based competition within a timeframe of more than a decade as a "*natural outcome of the economics of fixed broadband access*" (Vogelsang, 2013, p. 212). Another reason for the failure of the ladder of investment hypothesis in inducing infrastructure-based competition is the fact that it was never implemented by NRAs as initially suggested by Cave and Vogelsang. The authors made the very important point that NRAs must be able and willing to "burn down" the lower rungs of the ladder over time to induce further investment on the part of entrant firms seeking access. NRAs, however, have appeared to be reluctant to eliminate existing access regulations over the course of liberalization and have instead established a complex system of multiple access regulations, which gave rise to strong regulatory dependencies instead of infrastructure-based independence. Similarly, HSBC

[29] A few notable exceptions are e.g.: NetCologne (Germany), Iliad (France) or Optimus/Sonaecom (Portugal), where former service-based operators started to deploy their own FTTH/B access infrastructure (Godlovitch et al. 2015a, p. 21; company information on NetCologne available at https://www.netcologne.de/ueber-uns/unternehmen/geschichte).

(2016, p. 21) concludes "*the ladder of investment must (however well intentioned) now be judged in retrospect a failure – a conclusion upon which the academic community has now reached broad agreement. Academic studies have also revealed the negative impact that regulation in general (and unbundling in particular) can have on network investment.*" In fact, the types of NGA infrastructure providers identified in section 5.1 already had cost advantages in the form of their physical infrastructure elements, which were not established as the result of any inducement from sector-specific regulation. Accordingly, Vogelsang, who along with Cave established the ladder of investment hypothesis in the European debate on regulation, summarized as follows: "*Besides incumbents, only firms with prior access investments (either in other networks, such as cable TV, or in ducts, such as municipal electric utilities) have successfully invested in such networks*" (Vogelsang, 2013, p. 212).

These empirical findings on the ladder of investment hypothesis can also be applied directly to the migration to new fiber-optic based infrastructures and the DOCSIS 3.0 and Vectoring/VDSL migration technologies, since these will exhibit even greater economies of density. This is to be expected because the relevant distribution points in the access network are closer to the end customer. This is why profitable replicability in the case of the aforementioned hybrid NGA networks declines further and why regulatory forms of access can indeed deliver service-based competition, but are unlikely to result in infrastructure-based competition. Neumann et al. summarized this effect as follows (2013, p. 36): "*We (and others) have shown in various studies that this competition model is based on the illusion of the replicability of NGA networks. However, economies of scale and economies of density mean that NGA networks require market shares of 50 percent and more before they can be operated on a profitable basis. […] A lack of replicability implies that NGA networks, along with the existing cable networks, can only be deployed efficiently by one additional operator*." Hybrid NGA networks in the same area are therefore also limited in terms of their suitability for duplication.

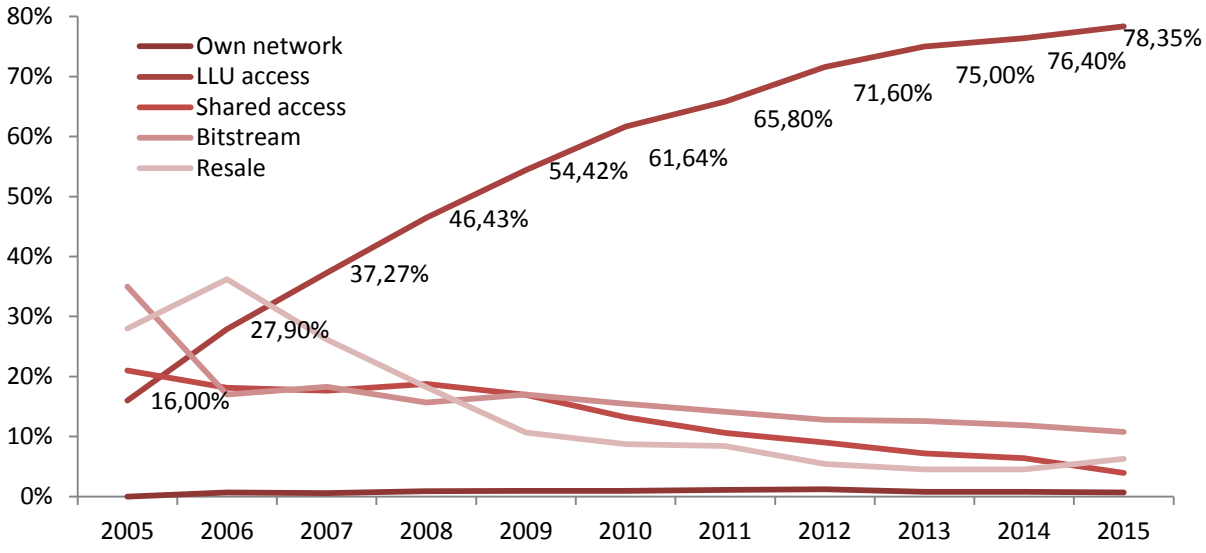

Figure 12: Relevance (%) of old broadband access regulations in the EU

Nonetheless, the EC also adopted the ladder principle into its "NGA recommendation" as a guiding principle: "*The appropriate array of remedies imposed by an NRA should reflect a proportionate application of the ladder of investment principle*" (European Commission, 2010a, recital (3)). However, when taking the above statements into account, the potential for applying this principle in the future should be qualified accordingly: "*Thus, while the ladder of investment is intended as a Stage 2 policy approach, in practice it stops short and remains anchored in Stage 1*" (Vogelsang, 2013, p. 194).[30] In addition, the most broadly established form of access regulation in the past – full physical unbundling – encounters substantial implementation problems when it comes to migration to NGA networks and thus its importance as a central wholesale product will be limited and at a lower rung of the new ladder. Furthermore, there is also a risk in the migration process that access regulation will become more complex due to the old investment ladder, path dependence and access products that need to be redefined: „*[A] regulatory transition to deregulation entails propensities to micromanage the process to generate preferred outcomes, visible competitors, and expedient price reductions*" (Hausmann & Taylor, 2013, p. 206). Thus, besides the additional costs of regulation, there would primarily be additional uncertainty over the types of regulation to be implemented in the future. One specific additional form of complexity associated with new access regulation and new access products is the use of vectoring technology. Although this technology can be used to reduce the disadvantages of VDSL2 (such as crosstalk), it is also associated with a negative technical external factor. In particular, when using this technology, providers must have at their disposal the entire cable branch. This can be countered through "virtual unbundled local access" (VULA) products, whereby the network operator guarantees competitors bitstream-like access at a lower level of the ladder. Furthermore, only this type of virtual access is possible on "point-to-multipoint" FTTP network architectures. In principle, "point-to-point" FTTP network architectures would also enable physical unbundling obligations, but subject to much higher FTTP deployment costs.

In accordance with the above discussion, any remaining mandatory access products serve as a mechanism for safeguarding competition in otherwise non-competitive areas but not for inducing self-sustainable infrastructure-based competition.

7.3 The role of regulatory (un-)certainty

Investment incentives are hampered by a range of investment risks. In general, the higher the anticipated risk of generating revenue surplus in the future, the lower the expected profitability of an investment and thus ex ante investment incentives is. In fact, the investment-intensive deployment of new communications infrastructures comes up against considerable technological and market structural dynamics and uncertainties. "*Market*

[30] The definitions of regulatory periods are as follows: "*Stage 1 represents settled policies that are currently applied, while the transition Stage 2 represents policies dealing with changes associated with reaching the future Stage 3, which we associate with full IP convergence and ultra-fast broadband access of fixed and mobile broadband networks*" (Vogelsang, 2013, p. 194).

outcomes in industries that experience rapid technical change embodied in extremely expensive facilities whose costs are largely sunk are inherently unpredictable" (Hausman & Taylor, 2013, p. 228). Added to those uncertainties are risks relating to (future) sector-specific regulatory measures, which also have corresponding impacts on investment uncertainties and incentives. Sector-specific regulatory obligations that are to be imposed in the future also bring additional complexity, as there is interdependency between the wholesale regulations applied to existing infrastructures and any future wholesale regulations that are to be applied to new infrastructures. In addition, existing regulations may give rise to expectations regarding the form of future regulations and may thus impact investment in new infrastructure accordingly. Against these uncertainties and the complexity in applying regulations to both old and new access products, remaining access regulations, including their technical annex regulations, should be designed to be as simple and predictable as possible, so as to minimize the associated investment uncertainty. In addition, it is important to ensure that regulations are binding in terms of credible commitments set out in advance (framework directive, Art. 8 (5) a); European Commission, 2013, recital 4). However, under the auspices of regular market analysis procedures, this is only ever possible under certain circumstances, as future decisions often involve having to trade-off regulatory commitment against necessary regulatory flexibility. Added to this, there are often incentives for NRAs to indulge in (ex post) opportunistic behavior once investments have been made ("regulatory opportunism", "hold-up problem"). This refers to regulatory (ex post) decisions – such as access regulation after the deployment of infrastructure – that would prevent a full reward for the risks associated with the investment project.

7.4 EECC: Intended measures and critical appraisal

With regard to the residual relevance of asymmetric access regulation, the CODE envisages a logical sequence of steps (Art. 71 (1)), according to which this form of regulatory intervention – the strongest from a conceptual point of view – is only to be applied as a last resort (Art. 71 (2)). Accordingly, prior to its application, the potential forms of competition in grey areas are to be considered first, if necessary, complementary to instruments of symmetric regulation. For example, an NRA must first check whether symmetric access to civil engineering assets is already sufficient to safeguard competition in corresponding end-customer markets. In areas that are classed as black from a competitive perspective and where there are two infrastructures in the access network, the measures pursuant to Art. 70 along with competition law ought to be adequate. In areas with three independent infrastructures, the application of competition law on its own ought to suffice. Limiting asymmetric wholesale regulation in this way is to be welcomed in principle. However, there is the question of an economic justification for differentiating between two and three infrastructures within black areas and whether this can be justified against the background of the basic facility doctrine and competition policy. Furthermore, Art. 70 is in parts redundant in light of existing symmetric regulation pursuant to the cost-reduction directive (European Commission, 2014c) and Art. 70 (2) extends asymmetric access regulations beyond the scope of Art. 71 to include infrastructure elements outside the bounds of the

relevant market definition: "*National regulatory authorities may impose obligations on an operator to provide access in accordance with this Article, irrespective of whether the assets that are affected by the obligation are part of the relevant market in accordance with the market analysis*." Accordingly, this specification not only implies an extension of the scope of asymmetric regulation but it also runs contrary to the logical structure of the market analysis procedure under the EU regulatory framework (Section 3) which aligns asymmetric access regulations to specified access products within relevant markets.

In Art. 66 (4), the CODE envisages that the NRA will have to carry out a cost-benefit analysis. This is reasonable in view of the costs related to the complexity of (new) wholesale access products and their regulation. Naturally, potential efficiency gains from imposed regulations must not be overshadowed by the additional transaction and implementation costs. Another development that is to be welcomed in terms of reducing regulatory complexity for access products in this regard is the proposed reduction of the number of access instruments (removal of pure resale obligation as the lowest rung of the ladder). In this context, it is interesting to note as another positive step that the CODE does not make any more reference to the "ladder of investment" hypothesis even though this has been considered as a guiding principle since the introduction of the 2002 regulatory framework.

The CODE also envisages an extension of the regulation period from three years at present to five years (Art. 65 (5)). By extending the regulation period to five years, the EC hopes to increase planning certainty for regulated firms in order to increase, where possible, their willingness to invest (recital 162). Insofar as NRAs can credibly commit ex ante to not intervene during the regulatory period, extending this period should increase planning capabilities on the part of infrastructure operators and might therefore increase investment incentives at the margin given that it aligns the regulatory review period more closely with the NGA investment cycle.

8 Interim conclusions on policy trade-offs and future regulations

Building on the discussion in the previous sections, this section provides a compilation of the most prevalent trade-offs associated with various market structures, regulatory regimes, investment incentives and the extent of externalities. To illustrate the resulting trade-offs, Table 5 provides a synopsis, which maps the different competitive areas to expected investment and externalities. Table 5 also suggests an alternative policy roadmap for the design of future regulatory policies.

Note that the categorization of white, grey and black areas (column 1) is endogenously determined by the chosen policy options and the targets of policy makers. Firstly, a white area might not be covered because potential operators expect that a monopolistic infrastructure will become subject to some form of access regulation under the EU framework; being confronted with access regulation might turn some otherwise grey areas into white ones. Secondly, the number and size of white areas is endogenously determined

by public targets and their specific definition of desired bandwidth levels and other quality parameters. Public targets might furthermore generate regulatory games on side of infrastructure operators. The latter might wait and postpone investment in otherwise profitable grey areas, if they expect public funding in the case that politicians commit to fulfill target criteria and no pre-emption from other infrastructure operators (Valletti, 2016, p. 15).

The available policy options are based on respective market structures (column 2). Obviously, the assessment of these alternatives will depend on the competitive intensity in relevant markets and regions in terms of subnational markets as well as on the effectiveness of competition law, 4G/LTE and the uniform pricing constraint as the main relevant outside options. Similarly, basic wireline broadband products represent relevant substitutes for some consumer segments and thus exert competitive constraints for NGA pricing.

Column 3 reports the effect of policy options on expected investment where we assign ordinal values (“Low”; “Medium”; “High”) based the related empirical evidence as discussed in section 7.1, which shows quite unambiguously that stronger access regulation implies lower NGA investment incentives. In the case of white areas we assume for the purpose of the presentation in Table 5 that the extent of the public subsidy is exogenous and hence expected investment is dependent only on the degree of ex ante regulations. Note, however, that public subsidies will most likely be endogenously determined by policies and expectations, which shape the extent of white areas.

The final column 4 presents a ranking of policy combinations based on expected externalities. As there is no conclusive evidence available so far that NGA deployment also involves high externalities, let alone on the differential effect of individual NGA technologies, we simply distinguish two broad cases in column 4 (“Low”; “High”). A further complexity would arise from the fact that externalities will be a function of NGA coverage/adoption. If expected externalities are high, policy makers should focus on dynamic efficiency and incentivize investment. If expected externalities are low, then policies should be primarily based on static efficiency.

Based on Briglauer et al. (2015b, p. 262-264), the discussion below presents the main trade-offs in deriving investment enhancing policy options in the categorized competitive areas:

i) If the competitive intensity is deemed sufficient (black areas), then this alternative becomes the gold standard. This may not fully hold for the US experience, but it shows that an almost nation-wide duopoly infrastructure could be sufficient to ensure competition and trigger investment. This would apply even more so if NGA deployment attracted new market players who focus particularly on FTTH/B deployments, such as forward-integrating municipalities or energy utilities in some European states or backward-integrating Internet content providers like Google in the US. Furthermore, duopoly infrastructure or narrow oligopolies do not have to be established on a full nation-wide scale, if infrastructure operators are e.g. subject to a uniform pricing constraint (UPC) that arises from retail

demand or if they face strong pricing constraints from mobile broadband operators (LTE) which can typically cover areas where no parallel CATV infrastructure exists. The empirical literature as well as the theoretical models have considered duplication of NGA infrastructure resulting in NGA duopolies or narrow NGA oligopolies. One would expect that NGA oligopolies induce higher NGA investment in general, which is preferable in the case of high externalities arising from the NGA deployment. In turn, NGA duopolies would be preferable over wider oligopolies in the case of low NGA externalities or when costs of additional infrastructure duplication are higher than welfare gains from product differentiation.

ii) The number of investing operators is also crucial for assessing the role of co-investment models in grey areas. Whereas co-investment largely avoids fixed-cost duplication in the case of several independent NGA deployments, it also involves the danger of collusion among co-investing operators. A higher number of co-investors makes collusion less likely but also imposes a negative externality on the other members of the co-investment in terms of lower individual market shares and hence higher costs per user (Rendon & Xiong, 2013). Assessment of the overall impact of co-investment as an alternative in an unregulated setting has so far been limited to experimental and anecdotal evidence. This alternative becomes more attractive if the above-mentioned intra- and intermodal competitive safe-guards are present and if the co-investing parties have comparative cost advantages; the latter might be due to prior ownership of passive infrastructure elements on the part of municipalities or utilities. In the absence of these conditions and if ex post collusion is likely, then ex ante NGA access obligations (or geographically differentiated access regulations in subnational markets) are still necessary and justified.

iii) Provided strong enough externalities or spill-over effects exist, there is justification to use public subsidies to cover white areas where private network deployment is not profitable, even if there is a monopoly and no danger of crowding out private investment. Although access regulations typically include white areas at least formally, they are in practice ineffective in those regions in terms of inducing NGA investment. Hence, public subsidies represent a relevant and complementary alternative, which might, though not necessarily should, be accompanied by further third party access obligations.

An extreme case is the governmental involvement in Australia and New Zealand (Given, 2010) where government either has chosen to build NGA networks themselves (Australia) and/or NGA operators are subjected to vertical separation obligations which both imply long-term ex ante access regulations. Whereas the New Zealand model is one of subsidized FTTH providers (the largest of which is Chorus) which were chosen through some competitive bidding, the Australian experience with overly ambitious coverage targets was quite unsatisfactory (Cave and Feasey, 2017, p. 68). In case of vertical integration the regulator is also confronted with a wholesale monopoly but the operator might be subject to retail pricing constraints or compete at the retail level (anchor tenant) with substitute products in the mid-term. Also from the UK experience with functional separation

("Openreach") introduced in 2005, after having "invested more time and energy than anyone in trying to deter and police non-price discrimination by BT" (Cave and Feasey, 2017, p. 18) this option appears to be less favorable and likely has reduced incentives for infrastructure-based competition in the UK (HSBC, 2016, p. 11). In fact, structural separation would result in a new natural monopoly-like regulated wholesale infrastructure operator with well-known problems related to dynamic efficiency. In fact, the debates between the incumbent British Telecom (BT) and the British regulator about alternative modes of separation have been going on for years. Recently BT has reached a settlement with the British Regulatory Authority on the legal separation of BT's infrastructure division Openreach transforming it into a legally separate but fully BT owned subsidiary.[31]

Ideally, policy combinations specifically oriented for white, grey and black areas present even stronger alternatives to the current status quo of NGA access regulations. In particular, deregulatory approaches in grey and white areas in combination with public policy measures in white areas (e.g. state aid, cohesion funds, Juncker plans or other funds provided by the EC and the European investment bank) will be needed if rapid and broad-scale deployment – including rural areas – with high-end fiber infrastructures is to be the main policy target. At this point, it is necessary to note that the academic literature so far provides no guidance on the role of this counterfactual policy mix.

[31] BT`s press release is available at: https://www.mynewsdesk.com/uk/bt/pressreleases/bt-and-ofcom-reach-agreement-on-future-governance-of-openreach-1851139.

Table 5: Synopsis of regulatory schemes, competition and investment

Area	Policies based on market structures and safeguarding competition factors	Expected invest.	Ranking of policy decisions based on expected externalities and investment as objective function
White	Subsidized monopoly*) is vertically integrated (VI) => – access regulation: competition law and/or UPC are weak – soft regulation***): competition law and UPC is strong Subsidized monopoly*) is vertically separated (VS) => – access regulation: irrespective of competition law and UPC	Low Medium Low	Expected externalities are high => 1) VI and soft regulation 2) VI and access regulation**) 3) VS and access regulation Expected externalities are low => No public subsidies: only low cost NGA/LTE funding based on universal service doctrine
Grey	Monopoly wireline operator (M) => – access regulation: LTE and UPC and competition law are weak – soft regulation: LTE or UPC and competition law is strong – no regulation: UPC and LTE and competition law are strong Co-investing wireline operat. (CI) ****) => – access regulation: LTE or UPC and competition law are weak and collusion expected – soft regulation: LTE or UPC and competition law are weak but no collusion expected – no regulation: LTE or UPC and competition law are strong and no collusion expected	Low Medium High Low Medium High	Expected externalities are high => 1) CI and no or soft regulation 2) M and no or soft regulation 3) CI and access regulation 4) M and access regulation**) Expected externalities are low => Trade-off: avoidance of inefficient infrastructure duplication from co-investors vs. comparative cost advantage for co-investors
Black	Duopoly (D) => – soft regulation: LTE or UPC and competition law are weak and collusion expected – no regulation: LTE or UPC or competition law is strong Oligopoly (O) => – no regulation: irrespective of LTE and UPC and competition law	Medium High High	Expected externalities are high => 1) O and no regulation 2) D and no regulation 3) D and soft regulation***) Expected externalities are low => 1) D and soft regulation***) 2) D and no regulation 3) O and no regulation

Source: Table 5 represents a modified version of the table in Briglauer et al. (2015b, p. 265). *) Subsidized monopoly might also be LTE operator. **) Since these options are based on weak competition law/LTE, better options may not be available for those regions/countries. ***) Soft regulation includes symmetric access regulations, asymmetric non-discrimination rules or regulatory holidays and assumes that investment enhancing effects due to cost/risk reductions and/or increases in pricing flexibility dominate investment diminishing effects due to symmetric regulations and/or ex ante side conditions. ****) Co-investment models include various forms of infrastructure-based co-operation ("co-build") as well as volume discount agreements and assume that investment enhancing effects due to risk sharing and/or cost reduction dominate investment diminishing effects due to ex ante side regulations.

Part II:
Implications from recent theoretical results

The goal of Part II is to present some recent theoretical analyses that deal with the impact of different forms of copper and fiber access regulation on the incentives to invest in NGA by both incumbents and alternative operators. We first briefly review the theoretical literature on migration to ultra-fast broadband networks and the role of regulation imposed on the old (copper-based) infrastructures (Section 9). Then, building on this, we present new results that specifically consider the following new features relevant to public policy as addressed at several instances in Part I of the study:

i) the introduction of NGA regulation and the impact of asymmetric remedies;
ii) the role of cost advantages in NGA investment;
iii) the presence of geographical regulation, i.e. access charges that differ according to the varying degree of infrastructure competition prevailing in different areas of a country;
iv) the influence of co-investment on NGA investment.

In Sections 10 to 12, we present the main results of selected recent analyses on the topics listed above in a non-technical manner. For a complete technical analysis, the reader can directly refer to the abstracts of the cited papers in the Appendix A2. Section 13 draws some interim conclusions from the reviewed theory models.

9 The basic economics of migration to ultra-fast broadband networks

During the transition phase from standard copper-based to (ultra-)fast networks, the incentives to invest in fiber infrastructures is inevitably influenced by the terms of access set for the legacy copper networks. The recent economic literature has therefore focused on how access regulations on the existing old network affect infrastructure investment in new fiber-based networks.

The first systematic analysis of migration is provided by Bourreau, Cambini and Dogan (2012 and 2014).[32] The authors consider a model where regulated access to the legacy copper network (in the form of local loop unbundling) is available everywhere in a country. Competition is simplified and considers the presence of an incumbent and a service-based entrant operator that compete for the provision of retail broadband services to consumers.

[32] These papers were used and cited by Charles River Associates in 2012 for its report on, "Costing methodologies and incentives to invest in fibre," prepared for DG Information Society and Media. See Haydock et al. (2012).

In the next section, we will present more recent studies that consider a more complex competitive setting.

The model consists of developing a coverage game, i.e. a game in which firms compete in covering a portion of a country made by a continuum of areas with their own investments in a new technology and then in offering retail services based on (ultra-)fast broadband networks. To ensure as much realism as possible, the fixed cost of rolling out the NGA network is assumed to vary in different areas of the country, and the areas (denoted by *z*) are ordered in such a way that the ranking reflects the order of the magnitude of NGA investment costs (from high densely populated/urban areas to low densely populated/suburban and rural areas). A graphical representation of investment cost is reported in Figure 13.

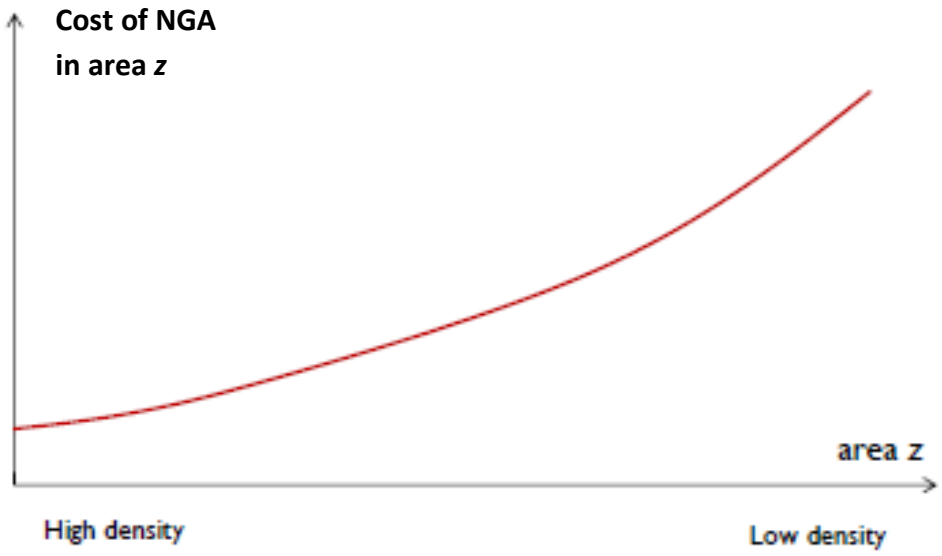

Figure 13: Investment cost assumed in the theoretical models (source: author´s own graph)

The model assumes that there is a copper-based technology network (the legacy network) and that mandatory access to this network is available throughout an entire country. The entrant operator could thus ask for mandatory access to the legacy network in the form of unbundling, i.e. instead of investing it could act as a service-based operator by using the "legacy" infrastructure.

Firms decide sequentially on their investments in fiber technology in the different regional markets. In that paper the sequential game[33] is justified because of the incumbent's control over the legacy network and other facilities.

[33] As we will see later, in more recent analysis this assumption has been modified to introduce simultaneous moves.

The goal of each firm is to maximize its own profit through the following sources: i) the profit obtained in the area where the incumbent and the entrant both deploy their own fiber network (hence, in the duopolistic ("black") infrastructure areas); ii) the profit obtained in areas where only one firm deploys a fiber network (hence, where either the incumbent or the entrant has a monopolistic position in fiber ("grey areas")); iii) the profit obtained in all areas where nobody invests in fiber ("white areas") and therefore all firms provide basic broadband services by using the existing copper network.

By solving the above described problem, the competitive game leads to three conflicting effects:

i) the *replacement effect* that hinders infrastructure investment by alternative operators when the access price is low;
ii) the *wholesale revenue effect* that discourages the incumbent from investing in a higher quality network when the access price is high so as not to jeopardize its wholesale profits in case the entrant then invests in its own network;
iii) the *retail-level business migration effect*: when the access price to the copper network is low, the retail prices of the services which rely on the copper network are also low. Therefore, in order to encourage customers to switch from copper to fiber, operators should also offer low prices for fiber services. This effect reduces the profitability of the NGA infrastructure, and hence, the incentive to invest in it.

The coexistence of these multiple effects creates a non-monotonic relation between the access price for copper and investment in the new access technology (i.e., the coverage of the fiber networks).[34]

From a social point of view, there can be conflicts between different potential objectives:

i) a higher access charge on the legacy network stimulates investment from entrants (if alternative operators are expected to invest in fiber) and sometimes from incumbents, enhancing dynamic efficiency;
ii) however, a higher access charge has a negative effect on static efficiency due to higher retail prices in areas without coverage and duplication of fixed costs.

[34] Note that recent empirical analysis (Briglauer and Cambini, 2016) finds evidences of the presence of the *business migration effect* at play in EU27 countries. Results show that in countries where the unbundling regime is highly diffused, the unbundling access price imposed on the old legacy-based technology exerts a positive and significant impact on fiber adoption. Estimates point out the presence of a cross-price effect between the adoption of NGA connections and the increase of the LLU access price in the range of magnitude of 0.15-0.23; that is, a 10% increase in the LLU access price leads to increases in NGA adoption (i.e. the number of households connected to NGA networks) of around 1.5-2.3%. This implies that a policy measure that increases the cost of accessing the old broadband network, though affecting competition, could exert a positive effect on the adoption of (ultra-)fast broadband technology. Briglauer (2015) has examined the impact of broadband regulations, including the unbundling price, on NGA investment, utilizing EU27 panel data and found that, as the unbundling price increased, so too did the average incentive for NGN investment. This result points to a positive net impact of the unbundling price on NGA investment.

In a companion paper the same authors (Bourreau et al., 2014) extend the analysis to the presence of symmetric fiber access regulation, whereas the access regulation of copper only applies to the incumbent operator that owns the network (and is thus asymmetric). The paper studies the interplay between access regulation to copper and NGA infrastructures. The authors find that the regulation of NGA infrastructure dilutes the incentive to invest in that technology. Moreover, they also show that the correlation between access prices depends on which firm – the incumbent or the entrant – is expected to build the larger NGA network. If the incumbent dominates NGA investments, the two prices should be positively correlated in order to incentivize both firms to invest in the new infrastructures and hence encourage migration to the new technology. In the case where the entrant is expected to invest more, the correlation between the two prices is the opposite, with a low copper access price in areas without coverage (to level the playing field) and a high fiber access price to sustain new investments.

The impact of old network (copper) access regulation on fiber investment was also recently analyzed by Vogelsang (2016). The author concludes that a low regulated price for the old copper-based access services can preclude the adoption of new services (migration argument) and eliminates the incentive for both incumbents and entrants to invest in (ultra-) fast networks. This implies that it may be good for the NRA to commit to *not* lowering the price of the regulated legacy product in response to the launch of the new fiber-based product. Relatively high prices for the old service will thus increase the rate of adoption of the new (ultra-)fast broadband services and be more profitable both for the investing firm and the entrant firms.

10 The impact of NGA regulation: symmetric vs. asymmetric remedies

The above papers assume that entrants use the copper network managed by the incumbent to compete on basic broadband services and eventually invest in fiber infrastructure, at least in parts of a country. However, they do not consider the case in which the entrant is a cable operator that does not need access to the existing copper infrastructure to provide broadband services. They also do not consider the case in which only the fixed telecom incumbent is subject to ex ante regulation while the cable operators investing in fiber or in updating their access technology are not subject to any ex ante restriction. This latter case implies the presence of an asymmetric regulation that has characterized the previous and current EU regulatory frameworks (Section 3). Though somewhat peculiar, these simple extensions are important for fine-tuning the theory to apply to actual regulatory and market conditions, considering that in most European countries the main category of entrants in NGA markets are indeed cable TV operators using an alternative legacy infrastructure to the incumbent´s copper access infrastructure (Section 4.1).

This analysis was recently developed in the paper by Briglauer, Cambini and Grajek (2017). The authors develop a model of investment competition in fiber deployment that builds on and extends the Bourreau et al. (2012) model in multiple ways. The aim of these extensions

is to account for a number of stylized facts about the European NGA infrastructure investment patterns, as well as dominant regulatory approaches, and derive testable hypotheses, which yield direct policy implications. Most importantly, they account for heterogeneous entrants to the NGA market, which are present in many European markets. To this end, they consider the presence of three (rather than two) different competitors: an incumbent telecom firm that owns a legacy copper-based telephone network; a cable firm that owns a legacy cable-TV network and does not have access to the existing copper network to provide its final services; and a service-based entrant that does not own any legacy infrastructure. The first two firms provide broadband services using their respective legacy networks; the third relies on mandated access to the incumbent firm's legacy network. However, only the telecom incumbent is regulated ex ante on both the copper and fiber infrastructure; the model thus explicitly considers the effect of an asymmetric SMP regulation regime imposed on old and new access infrastructures.

As before, the authors use a coverage game where they assume a country composed of a continuum of areas with a total size of *z* and the fixed cost of deploying the fiber network varies across different areas, as reported in Figure 13. The goal of each firm is to determine the fraction of the territory to cover for maximum profit. Firms' profit – as before – is given by three different streams: i) the profit in areas where both the cable operator and the incumbent deploy a fiber network (duopoly case);[35] ii) the profit in areas where only one firm deploys the fiber network due to the higher cost of deployment; iii) the profit in areas where nobody invests and all firms only compete over standard copper broadband services.

In a first model without NGA regulation, the authors extend the Bourreau et al. (2012) model by pointing out the *indirect* impact that the copper access price has on the cable operator's incentive to invest in NGA: an increase in the price of the LLU reduces the competitive pressure of the (service-based) telecom entrant by inflating its costs and this in turn raises the rival cable firm's profit and thus boosts its incentive to invest in fiber. This effect is indeed similar to the *retail migration effect* previously described. However, investment in fiber comes at an opportunity cost resulting from the retail profit lost through its legacy cable services. While the telecom entrant faces a cost disadvantage due to a higher access price, the retail prices for legacy cable-based services are higher and so is the opportunity cost of investing in fiber network for the cable firm. This effect, which the authors label *business stealing effect*, counterbalances the previous one. Thus, the overall effect of increased access prices on the cable firm's incentive to invest is ambiguous and depends on the balance between these two countervailing effects. The other effects remain the same as the one previously described.

In sum, this implies that the impact of LLU prices on the incentive to invest is not limited to the incumbent and telecom-based entrants but also applies to cable operators who could

[35] The authors develop several different scenarios where the (service-based) telecom entrant is first passive, i.e. does not invest in fiber, and then active, i.e. it also invests in its own fiber infrastructure. Results remain qualitatively the same as the one described in the main text.

benefit indirectly from copper-based access regulation through the degree of market competition.

This framework was then extended Briglauer, Cambini and Grajek (2017) to account for the presence of NGA regulation and the impact of cost asymmetry on investment.

The results show that, when the incumbent is expected to be the leader in NGA investment, the presence of ex ante regulation imposed on fiber access infrastructure lowers the incumbent firm's incentive to expand NGA coverage. This result complements the one in Bourreau et al. (2014), who also highlight the detrimental effect of fiber regulation on the incentive to invest. This happens because introducing regulation on fiber networks limits the incumbent's options to exploit revenues from its investment and this in turn decreases the incentive to invest. However, when a cable firm is the leader, the decision to invest in fiber is not at all affected by the presence of fiber access regulation. Similarly, Vogelsang (2016) also finds that NGA regulation either should not be imposed or it should be soft (hence, above the LRIC of the services) in order to incorporate the additional risk of investment and to avoid mitigating investment incentives for entrants and incumbents. More generally, he states that new services should not be regulated at all, but if this solution is not feasible, a regulatory holiday regime could be an option: regulation is thus delayed until a set of necessary requirements have been met.

In sum, the results show that the role of the fiber access price on investment incentives is unambiguously relevant. A less stringent form of fiber access regulation (i.e. a higher access price or lack of the regulation) incentivizes all firms to invest more in NGA networks. This is also true for cable firms in all cases in which they are at the forefront of NGA deployment. When cable firms are instead the investment leader, their incentive to invest is unaffected by access regulation. Thus, a less stringent form of fiber access regulation (i.e. a higher access price or lack of the regulation) incentivizes the cable firm to invest more only when it is a follower in NGA deployment and therefore must invest in order to compete with the incumbent; otherwise, when cable operators are the leader in fiber deployment strict fiber regulation has no effect on a cable operator's investment decision and is only detrimental to the incumbent. In a nutshell, results show that soft regulation of fiber access, or even lifting regulatory burdens, has an overall positive effect on market investment from all operators.

The model by Briglauer, Cambini and Grajek (2017) points out not only that NGA regulation, if severe, is detrimental to fiber investment, but, on top of this negative effect, the implementation of a regime of asymmetric regulation between incumbents and cable operators would only have further negative effects by favoring the latter but not the former. Hence, from a policy perspective, the model shows that, should the NRA want to impose NGA regulation, regulation should at least be symmetric and involve all firms investing in NGA, not only the incumbent ones. This is even more relevant considering the current data from the EU: EU data – as cited by the authors – shows that, in the period 2004-2014, in about 68% of EU countries cable operators are the leader in NGA investment, while the incumbents dominate NGA deployment only in about 32% of cases. Service-based entrants

never play a leading role in NGA deployment. They have been active only in a few countries (like in Greece and Italy) and are typically the smallest operators in terms of NGA coverage. This does not imply, however, that the imposition of symmetric access remedies, i.e. the extension of SMP remedies to all investing companies, is the best solution. Indeed, the theoretical results previously described (Bourreau et al, 2012 and 2014; Inderst and Peitz, 2012a and 2012b; Vogelsang, 2016) all show that too strict regulation of fiber access negatively affects aggregate (i.e. market level) investment and hence leads to a reduction in total fiber deployment. This implies that, from a policy perspective, should some degree of regulation have to be imposed; regulatory interventions should be symmetric and soft regulation e.g. limited to passive and not active elements of the fiber network in order to partially mitigate the adverse effect of extensive ex ante interventions in fiber deployment.

The significance of a symmetric regulation (Section 6) is also emphasized when differences in investment costs are taken into consideration. Indeed, engineering reports show that the investment costs for cable operators to upgrade their DOCSIS infrastructures are much lower than the investment costs for fiber upgrades faced by incumbent operators (Section 2.1). In this scenario, Briglauer, Cambini and Grajek (2017) show that the cost advantages for cable operators increases their probability of becoming the leader in the new market in terms of NGA deployment: the larger this difference in cost, the lower the probability that a telecom incumbent will become a leading investor in fiber. Indeed, this result is confirmed by the EU data cited above.

In conclusion, in the face of investment cost asymmetries, the implementation of asymmetric NGA access regulation that affects only the “second mover” (i.e. incumbents) not only has a vicious effect on incumbent firms by depriving them of incentives to invest in fiber, but also unbalances the playing field in favor of the unregulated cable operators and thus perpetuates existing regulatory-induced market asymmetries (Section 4.3). Obviously, a symmetric regime would level market competition, but at the expense of a reduction in total NGA investment.

11 The implementation of geographical access remedies

As reported in Part I (Section 4.4.2), one complication of NGA deployment is that competition among high-speed broadband networks is likely to emerge only in specific regions of a country, mostly in dense metropolitan (black) areas, while in the rest of the country infrastructure competition will probably not materialize. For the least densely populated (white) areas, private investment will only be viable with the help of government subsidies. However, even within the areas that will be covered without the need for subsidies, the number of operators rolling out their network will vary. Large swathes of the country will most likely be left with only one high-speed network (grey areas), while urban areas might be covered by two or more.

From a regulatory point of view, this calls for ex ante access rules to differ across areas according to these differing degrees of infrastructure competition. Indeed, regulatory practice has changed and a transition from country-wide uniform measures to more locally tailored regulation is taking place. As a result, alternative operators and incumbents may have more incentives to invest in NGA networks. Hence, geographical remedies may be a new regulatory intervention to help encourage investment and to speed up the process of convergence towards the targets set by the EC in its Digital Agenda for Europe (DAE) and the gigabit society connectivity goals.

Building on a similar coverage game as the one adopted in Bourreau et al. (2012, 2014), Bourreau, Cambini and Hoernig (2015) focus on the implementation of geographically-differentiated regulation imposed on fiber infrastructure as a potential regulatory tool to improve the trade-off between more intense retail competition and more infrastructure investment. The authors analyze whether this potential can be realized, and how it depends on the type of geographical regulation that is implemented. The model considers two firms, an incumbent and an entrant, that both either invest in fiber access infrastructure or not. In all areas access regulation is mandated but the price can differ according to the degree of market competition, i.e. the presence of only one or more than one networks.

Two different access regimes have been studied. Firstly, in the "duplication-based" regulatory regime, the NRA maintains an access obligation everywhere, but sets different access prices in the areas with a single infrastructure and in the areas with multiple competing infrastructures. A first clear result is that setting two different access prices not only enhances the incentive to invest but also improves welfare compared to a uniform access price regime. The authors also discuss the relevant trade-offs, and show that the optimal access charge is higher where only one infrastructure is present than where multiple infrastructures exist. The intuitions are two-fold: Firstly, a higher access charge in areas with only one infrastructure provides a stronger incentive to cover more of the most expensive marginal areas, i.e. to expand total coverage. Secondly, when mandatory access is an alternative to infrastructure duplication, the latter is optimal only in the most densely populated areas. Thus, to avoid duplication, access charges in competitive areas should then be set at a lower level than in monopolistic areas.

In the second scenario, named "competition-based" regulatory regime, the NRA sets the access price in the areas where only one infrastructure is present, but leaves it to the market everywhere else. The idea is that in the presence of multiple infrastructures, competition at the wholesale level arises. Contrary to what one might expect, though, the authors find that market outcomes turn out to be neither easily predictable nor efficient. Firstly, the wholesale game between access providers has a natural tendency towards multiple equilibria. Secondly, resulting equilibria might not lead to efficiency. In particular, if strong wholesale competition is expected to arise ex post, then ex ante incentives for network duplication are eliminated. If ex post wholesale competition is weak, equilibrium retail prices may remain too high since competition is less intense.

The main finding of this analysis is that partial deregulation of access in competitive areas tends to be suboptimal: duplication-based regulation creates more certainty both for firms and NRAs and leads to greater welfare. However, the superiority of duplication-based regulation over competition-based regulation depends on the implicit assumption that the NRA is fully informed and can fully commit to setting two (or more) prices. This assumption establishes the right benchmark for measuring how good competition-based regulation can be. However, the NRA may suffer from large information asymmetry and commitment problems. In this case, competition-based regulation – though imperfect – may turn out to be the only feasible alternative to uniform prices, which is always superior from a welfare perspective.

In conclusion, though complicated to implement and to assess, the adoption of geographically-differentiated regimes could be a new regulatory tool that can encourage the deployment of NGA networks and speed up the process of convergence towards the EC's high-speed broadband connectivity targets.

12 Co-investment as an alternative to access remedies

Since the principal barrier to entry in network markets is the cost of constructing the physical access network, a logical way to increase NGA coverage seems to be to invite operators to invest jointly rather than individually. This approach is gaining support at the European level (Section 5). A main NGA-specific twist is that co-investing operators can lay multiple fiber lines instead of just one, so that operators engage in full facility-based competition while sharing the cost of digging as well as other lump-sum costs. Even when no multiple fibers are laid, co-investment agreements can involve operators investing in different areas and then giving each other access on a preferential basis (via unbundling or bitstream access). Both approaches split the investment cost and the associated risk and represent variants of the co-build investment scenario.

Cost and/or risk-sharing rules can be viewed as a relevant alternative instrument to access price regulation, potentially enhancing dynamic efficiency (by expanding fiber network coverage), consumer surplus and social welfare. Nitsche and Wiethaus (2011) and Cambini and Silvestri (2011, 2013) show under different modelling assumptions that risk-sharing does indeed lead to higher welfare in comparison to alternative modes of regulation, such as partial regulation (where ex ante intervention applies only to the legacy network, while the NGA network is left unregulated) or full regulation (where access to NGA networks is also regulated), especially in the presence of demand uncertainty.

Standard access obligations were introduced in Europe during the first phase of broadband roll-out, in order to allow for retail competition over the monopoly copper network. In terms of retail market outcomes, this policy has been largely successful;[36] it is considered less

[36] According to the discussion in Section 3, the EC has deregulated all – formerly relevant – retail markets since the EC´s 2014 market recommendation.

propitious, though, for creating incentives to invest in NGA networks. For this reason, the recent EECC proposal specifically invites NRAs to consider co-investment as an alternative to standard access obligations (Section 5.1).

Bourreau et al. (2016) focus on co-investment as an *alternative* regulatory obligation to standard access regimes to spur market competition and investment incentives. With co-investment, an entrant can request access to an incumbent's infrastructure by sharing the investment cost of the infrastructure after an investment plan have been announced by the incumbent.

The first question the authors address is whether co-investment can stimulate infrastructure investments and enhance social welfare in comparison to a standard access pricing regime. They thus compare different regulatory regimes in terms of infrastructure coverage and social welfare. A second relevant issue addressed in the paper is the role of demand uncertainty. It is often hard to predict the level of demand before new infrastructures are constructed and implemented. This implies that an investor must invest before final demand is known, while an access seeker can wait until enough information is available to decide whether to enter. Thus, access provides entrants with a cream-skimming option that is exercised exactly when market outcomes are good, whereas the network investor bears all the downside risk, while the returns on the upside are shared. The authors study how demand uncertainty affects the relative effectiveness of co-investment, where commitments must be made before uncertainty is resolved, and the trade-off between the different regulatory regimes.

The model builds again on Bourreau et al. (2012): in a country composed of a continuum of areas and with investment costs as reported in Figure 13, an incumbent firm rolls out a new infrastructure and an entrant can decide where and how to enter in all different areas. The model has the following structure: first, the incumbent decides on the areas where it will invest; then, the entrant decides where it will co-invest (sharing the investment cost of the infrastructure) or ask for access, depending on one of the three different regimes considered, i.e. i) access only, ii) pure co-investment, or iii) co-investment with access.

The three regulatory regimes are the following: the "pure access" regime corresponds to the standard (“service-based”) access regime, i.e. the entrant can ask for access in all the areas where the incumbent has deployed its network; it then pays a linear access tariff fixed by the regulator. In the "pure co-investment" regime, the entrant can ask the incumbent to share its infrastructure in covered areas by taking on half of the investment cost, but access is not available outside the areas covered with fiber. Finally, the "co-investment with access" regime allows the entrant to decide whether to ask for access or to co-invest in each covered area. In this perspective, co-investment mimics a sort of discount model where the entrant operator pays before demand reveals a share of the investment cost for the right to use the fiber infrastructure, bearing the corresponding risk of low demand. From a technical point of view, the type of co-investment also accounts for the co-building case where the incumbent and the entrant invest together in the fiber infrastructure. The model assumes, however,

that the incumbent decides first where to invest and then the entrant decides to start co-operating with it.

The incumbent and the entrant then compete at the retail level in every area where they operate.[37] The degree of competition may vary according to the kind of regulatory regime in question. In the "pure access" regime, duopoly competition emerges only in those areas where the entrant decides to enter and ask for access; under the "pure co-investment" regime, duopoly competition emerges in all areas in which the two firms co-invest, while – given the absence of access obligations – in those areas where only the incumbent invests, the incumbent has a monopoly position. Finally, under the "co-investment with access" regime, the entrant can choose in which areas to co-invest while in the rest of the country where the incumbent only invests, the entrant can ask for access and compete with the incumbent.

The implementation of a standard wholesale access obligation on new infrastructures involves the classic trade-off between static efficiency and investment in coverage. The authors find that compared to the pure access regime, the pure co-investment regime leads to more intense competition in the areas where the firms operate a shared network and to larger coverage. On the downside, it involves a monopoly area where retail prices are higher (but a large part of this region would not be covered at all under the access regime). Adding an access obligation on top of co-investment ("co-investment with access") reduces the incumbent's profit in marginal areas, therefore total coverage is lower in this regime than under pure co-investment. In addition, co-investment coverage is also lower. This is because the access option offered to the entrant constitutes an opportunity cost of co-investment, reducing co-investment incentives compared to the pure co-investment regime. In terms of social welfare, results show that if the access price is low, social welfare is higher in case no access is granted, because a low access charge both reduces the incentive for the entrant to co-invest and the incumbent's incentive to cover costly areas.

The role of demand uncertainty largely affects the equilibrium coverage. In the face of demand uncertainty, the entrant can wait for the true state of demand to become apparent before asking for access. Hence, the entrant has the option to wait while the incumbent has to invest before demand is apparent and thus assuming the entire risk. In this scenario, the authors show that the existence of this "access option" for the entrant reduces investment incentives: larger uncertainty leads to lower total coverage. The pure co-investment regime involves a pre-commitment and does not suffer from this problem, and would therefore appear to be the preferred regulatory regime not only in terms of investment incentive but also from a social perspective.

From a policy side, the model developed by Bourreau et al. (2016) considers a general model of co-investment that is valid whatever kind of co-investment agreement can be

[37] This assumption makes this paper different from other studies that specifically look at the "collusive" effect of a co-investment agreement; see Inderst and Peitz (2013).

implemented. This also implies that the organizational mode of the co-investment agreement is not important but rather the impact that they have on extending NGA coverage. In turn, it also implies that the decision on the kind of agreement can be left to the market in order to reduce the administrative burdens on co-investors.

From a competition policy point of view, then, other interesting insights could be derived from the discussed model. The CODE pushes for imposing open co-investment agreements; that is, to give later entrants the chance to enter the co-investment agreement. Though not directly addressed in this paper, the results could clearly be applied to this case: granting late entrants the possibility to "wait and see" whether market demand expands and only committing to invest when this eventually happens and the opportunity cost of joining the agreement ex ante increases. At the same time, this takes away the incentive for early investors who assume the entire risk and uncertainty of the investment. In some sense, allowing the co-investment agreement to always remain open is equivalent to the "access option" in the model. The option for late entrants to pay an access fee that includes a fraction of those risks would only work if the regulator is able to assess those risks precisely and monetize them through the fiber access charge, but this would be extremely complex and difficult to implement in practice. Hence, imposing open co-investment may reduce the incentive to co-invest because it has a negative impact on the incentive to pre-commit on investment.

A second issue related to co-investment is the risk of collusion. Krämer and Vogelsang (2016) performed a laboratory experiment to study the effect of co-operation in broadband markets, with an underlying model where non-cooperation would be the optimal choice for the individual. They found that co-operation still arises due to communication between players, and that it facilitates collusion while not stimulating further investment. Whether this increased chance of collusion materializes in actual markets is still an open question however; antitrust authorities in many EU countries have not detected cases of collusive agreements and co-investment has indeed led to higher roll-out (see the French and Portugal cases). Nevertheless, different regulatory models can have a differing impact on the risk of collusion: a "pure co-investment" agreement without access in monopolistic areas may indeed lead to more risk of collusion compared to the "co-investment with access" mode. Indeed, in areas where access is available, firms are more likely to compete and this reduces the risk of collusion between the same firms in the co-invested areas. Therefore, adding collusion into the framework may rebalance the benefits of co-investment without access, though this would negatively affect NGA coverage.

13 Interim conclusions from the theory

Merging all the results from previous studies to create an ideal ranking of regulatory options as regards to both investment incentives and social welfare is rather difficult. Indeed, each of the analyses previously described considers a specific problem, but there does not exist any comprehensive analysis that incorporates all previous features (i.e. asymmetric and

symmetric NGA regulation, cost asymmetry, various co-investment models, and geographical remedies) into a single framework.

Nonetheless, some results are clear-cut. In order to compare the below statements we assume as a benchmark the case of full asymmetric cost-based access regulation of incumbents as regards both the old and new infrastructure: this solution is clearly the optimal one in terms of static efficiency, but not in terms of dynamic efficiency. With respect to this regime, the main results of the theoretical analyses are as follows:

1) *Stricter (cost-based) fiber access regulation reduces investment incentives for telecommunications operators (incumbents and alternative operators).*

Relaxing regulation on fiber access is essential to encouraging NGA investment. Ideally, full deregulation of the economic fiber access conditions incentivizes both alternative operators and incumbents to invest in fiber. Should full deregulation not be feasible, a softer regulatory approach has to be imposed: cost-based access prices might not work in this scenario and can reduce investments; on the contrary, access prices above the LRAIC, i.e. access prices that incorporate a premium for demand risk and uncertainty, limit the "opportunity costs" for entrants to wait and demand access to the incumbents' investments.

An intermediate regime representing softer regulation would be the implementation of obligations to share passive elements of the network, i.e. duct access obligation, the right to use ducts, and so on, only. This regulatory remedy appears to be a pre-condition to avoid the duplication of fixed costs. However, stricter regulatory conditions on active infrastructures may only limit the investment incentives for both the incumbents and the telecom-based entrants while favoring companies that already have their own infrastructure, which only has to be upgraded.

2) *In cases where regulators introduce fiber regulation, symmetric remedies perform better than asymmetric ones.*

Ex-ante intervention on fiber is detrimental to NGA investments. However, if a deregulation regime is not feasible, regulation should be *at least* symmetric, i.e. applied to all operators – incumbents, cable operators and telecom entrants. Asymmetric regulation of SMP operators (typically incumbents) further reduces the incumbents' incentive to invest and does not necessarily incentivize cable firms to invest further. The obligation for a symmetric regime, if needed, is even more relevant if some firms (such as cable operators) have substantial advantages in terms of costs when it comes to deploying an (ultra-)fast broadband network. The potential of cost synergies when using passive infrastructures further calls for obligations (on passive elements) to be imposed on all network-based operators.

3) *Partial "geographic" deregulation of fiber access increases both the incentive to invest and welfare*

The level of infrastructure competition surrounding fiber networks will largely differ between urban, suburban and rural areas, with two or even more networks in densely populated areas and no more than one in the rest of a country. In this scenario, a partial deregulation on fiber access may enhance the incentive to invest in fiber and increase social welfare. Therefore, when the degree of infrastructure competition is more intense, leaving the determination of access charges for active elements to the market may generate a positive effect, though wholesale competition could also be too intense and eliminate the incentives to invest. However, results clearly show that this scenario provides better results both in terms of coverage and welfare than the implementation of a regulated uniform access regime, the access regime usually adopted in most of the EU countries.

4) *Co-investment without access stimulates investment and is socially preferable when demand uncertainty is high*

Co-investment performs better in terms of total coverage than the standard access regime. Offering access to the entrant as well leads to both lower total coverage and lower co-investment coverage because the access option constitutes an opportunity cost that makes co-investment less attractive. On the one hand, starting from a standard access regime, thus, welfare is strictly increased if a co-investment obligation is added; on the other hand, adding access to co-investment reduces welfare if the access price is relatively low. Thus unless the NRA is willing to set a potentially very high access price, pure co-investment leads to higher welfare. Hence, from a policy perspective, co-investment obligations without access should be preferred over a pure access regime or a regime with co-investment and access, in particular when demand uncertainty is high.

14 Final conclusions and policy recommendations

Part I of the study examined broadband market structures in terms of relevant market developments, competition factors inside and outside the market and underlying access regulations and identified relevant policy trade-offs and recommendations. We furthermore identified dynamic efficiency as a main regulatory goal and found that softer regulatory approaches enhance investment incentives. Similar effects can be derived from a deeper focus on co-operation models for risk-sharing and on symmetric forms of regulation designed to reduce total deployment costs. The first conclusion is primarily based on the empirical evidence, which points to a negative relationship between access regulation and investment. The second conclusion is based on the premise that the extent and design of symmetric regulations do not lead to investment-diminishing incentives, which outweigh any positive effects related to the reduction of overall deployment costs. Only in this sense do symmetric regulations fall within the category of "soft" regulations. Vogelsang concludes his survey (2014, p. 2015) in a similar vein: "*The emphasis on investment results in a more deregulatory frontier involving softer regulation, cooperative investment, and deregulation or regulatory holidays*". A series of such deregulatory approaches has already been implemented by NRAs to varying degrees with the primary intention of increasing pricing flexibility in order to adapt to changing market conditions. On the same subject, it is also worth noting the risk-sharing co-investment models that have already been introduced by some operators and approved by NRAs. In grey (or otherwise white) areas symmetric regulations and co-operation models seem to be an effective measure for sharing market risks, deployment costs, and market exposure and thus generating additional investment incentives. Whether symmetric regulations and co-investment models subject to ex-ante approval are in fact suitable instruments for promoting NGA investment depends largely on the exact implementation in individual member states. The more extensive the list of conditions as regards co-investment approvals and the more extensive the definitions of symmetric access products are, the smaller the investment-promoting effect.

As has already been discussed, asymmetric types of access regulation are based on the dominant market positions of firms (SMP) on the relevant market. Consequently, when addressing the transition to new communications infrastructures and services, it is important to highlight the significance of the preceding analysis stage of market definition. Besides defining product/service markets, particular importance should be attached to a methodically sound definition of geographic markets in terms of the considerable variation in competition conditions between (sub-)urban and rural areas in most countries. If no sufficient substitution patterns are identified which define a common market, one still has to consider the pressure from competition factors (or imperfect substitutes) which are outside the relevant and regulated market; naturally, the stronger the competition-safeguarding functions related to those factors (and products), the stronger the case for favoring deregulation steps. Only in cases of persistent monopoly-like bottleneck market structures should asymmetric access obligations still be imposed to safeguard competition. The

existence of an essential facility implies that neither sufficiently active nor potential substitutes would be provided in (unregulated) competition (Knieps, 2001, p. 102-103; Nett & Stumpf, 2011, p. 9). For example, the move towards deregulation in the US was justified largely on the basis of an almost nation-wide duopoly and thus the absence of an essential-facility characteristic and with a focus on dynamic efficiency: „*The deregulation of broadband networks in the US in the 2002/05 period was based on the view that two major competitors are now deemed to be enough (because it means that access is not an essential facility) to avoid wholesale access regulation if infrastructure investment is a major concern*" (Vogelsang, 2014, p. 13). Comparing the US and EU regulatory frameworks, a certain convergence can be noted, since measures of deregulation have been promoted both by the EC (European Commission, 2013; 2014) and NRAs over recent years, in particular against the background of fostering dynamic efficiency. Furthermore, intermodal competition and competition from OTTs are becoming more intense in both jurisdictions due to the massive uptake of mobile broadband communications (4G/LTE) and the increasing popularity of OTT services provided over wireline and wireless infrastructures.

Below we cite in detail from the final conclusions from the HSBC study (2016, p. 24) on investment promoting regulatory policies: "*In general, the measures that would most incentivize additional infrastructure-based competition are simply those that would support incumbent infrastructure investment: i.e., pricing flexibility, the retention of technology neutrality, longer market review periods (so providing greater predictability and visibility), fewer remedies (one wholesale product per market to minimize expense, not to mention the complexities of potential margin squeeze tests), a preference for commercial agreements (i.e., actively reflecting the presence of such interventions when deciding on regulatory interventions), NRAs explicitly pursuing the goal of long-term customer welfare and the use of broader market definitions.*" Apparently, the investors´ view as independently expressed by the HSBC study experts is largely in line with our conclusions as regards the role and relevance of investment-promoting regulatory policies.

There are still substantial differences between most EU member states as regards market conditions. One particular relevant source of heterogeneity refers to the geographic coverage of CATV networks and the associated intramodal competition pressures (Vogelsang, 2014, p. 17). Within Europe, CATV networks are predominantly relevant in urban regions.[38] More generally, heterogeneity is also evidenced in the various market shares of European incumbent operators. Further research might thus also call into question the EC's ambitions to harmonize regulatory approaches between member states as far as possible. In the EC's view, the superiority of a consistent regulatory approach had been proven to be beneficial and effective over many years. However, persistent country-specific differences between EU member states as regards costs of NGA deployment as well as demand

[38] 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.

characteristics (Briglauer & Gugler, 2013, p. 823) provide clear arguments against an EU-wide harmonized approach.

Since policy choices greatly depend on the expectations of the relevant decision makers, the underlying information should be based on empirical evidence and rigorous analysis (Mayo, 2013). A fundamental question as regards future regulatory policies concerns the counterfactual outcomes and the type of errors associated with incomplete competition combined with types of deregulation and competition law on the one hand, against competitive distortions such as suboptimal investment due to overregulation on the other (Hausman & Taylor, 2013, p. 206). At the very beginning of market liberalization and sector-specific access regulation in the late 1990s, the more severe error would have clearly been incomplete competition, since the counterfactual situation in the absence of (access) regulation would have been most likely persistent monopolies with low innovation and high price levels. However, market structures in communications have changed substantially due to sector-specific regulations and high competition intensity, which have turned communications into one of the most innovative industries with favorable outcomes for consumers. Consequently, the counterfactual to the current regulatory regime is much less obvious to identify, but rather depends on various trade-offs related to market structures, competitive intensity within and outside the relevant markets and infrastructure related externalities.

Part II of the study presented the results of some recent and related theoretical analyses that deal with the impact of different forms of access regulations on incentives for both incumbents and alternative operators to invest in NGA. The conclusions drawn from the reviewed theory models largely reaffirm the hypotheses drawn from the policy discussion in Part I:

Firstly, the theory shows that relaxing regulation on new fiber-based networks is essential to induce investment, which applies to asymmetric and symmetric access regulations. The extent of deregulation depends on the competitive intensity and includes full deregulation as well as types of softer regulation such as symmetric access regulations. The latter become more relevant if certain operators (e.g. cable-TV operators) have substantial cost advantages in upgrading NGA networks compared to regulated incumbent operators.

Secondly, as the level of infrastructure-based competition in NGA markets will differ largely between urban, suburban and rural areas, with two or even more networks in densely populated areas and no more than one in the rest of a country, a partial geographical deregulation on fiber access may enhance the incentive to invest in NGA networks and increase social welfare. Results clearly show that geographical deregulation provides better results both in terms of coverage and welfare than the implementation of a regulated uniform access regime, which is the access regime usually implemented in most EU countries.

Thirdly, co-investment performs better in terms of total coverage than the standard wholesale access regime. Offering access to the entrant as well leads to both lower total coverage and lower co-investment coverage because the access option constitutes an opportunity cost that makes co-investment less attractive. On the one hand, starting from a standard access regime, thus, welfare is strictly increased if a co-investment obligation is added; on the other hand, adding access to co-investment reduces welfare if the access price is relatively low. Thus, unless the NRA is willing to set a potentially very high access price, pure co-investment leads to higher welfare. Hence, from a policy perspective, co-investment obligations without access obligations should be preferred over a pure access regime or a regime with co-investment and access, in particular when demand uncertainty is high.

The CODE´s proposed measures point in parts in similar policy directions but also raise some serious concerns in view of our analysis in Part I and Part II. Firstly, the following measures to foster NGA investment certainly represent a positive development and are largely in line with the main conclusions and recommendations of this study: i) measures to provide more pricing flexibility to regulated firms; ii) enhancing the role of co-investment models; iii) intensive interventions in terms of asymmetric access regulations only as a ultima ratio policy in case all other regulatory policies are deemed insufficient; iv) providing for deregulatory policies in the case of sufficient competitive safeguards; v) measures to reduce regulatory uncertainties such as extending the regulation period; vi) measures to ensure equal baseline conditions for all market participants; and vi) refocusing on competition problems at the retail level which implies that no wholesale access regulation will be imposed even where there is a lack of competition in the wholesale market. In particular, we agree with the CODE´s basic focus on dynamic efficiency in terms of encouraging investment in new communications infrastructures and infrastructure-based competition as the ultimate policy goal.

Acknowledging these proposed measures we contend, however, that the goal of encouraging NGA investment is in fact under serious threat when one examines details of implementation and the complexity of regulatory conditions embedded in the CODE more closely.

Firstly, the CODE´s regulations for co-investment models constitute a strong regulatory component, with the result that such co-investment models differ substantially from pure voluntary market solutions and their associated ex-ante investment incentives. However, co-investment models will only induce additional infrastructure investment if the regulatory conditions which are foreseen ex ante by co-investing parties are not too restrictive in terms of accruing future investment rewards and in view of the actual extent of risk-sharing and cost reduction. Sharing risks as regards future demand and market exposure, capital formation in case of capital market imperfections and the primacy of voluntary agreements are the dominant features of effective co-investment models. The risk sharing effect increases the longer participating parties have to co-operate, the more commercially

negotiated terms prevail and the lower the scope of regulatory gaming is. The organizational mode in which firms cooperate should not be subject to certain ex-ante restrictions. Co-investment agreements can thus involve several operators investing jointly in different infrastructure components ("co-building") and then giving each other (or third parties) access as well as different version of volume-discount models with only one firm deploying the infrastructure. In the case of co-investment with obligatory open access, entrants enjoy a cream-skimming option that is exercised when market outcomes are good, whereas the network investor bears all the downside risk, while the returns on the upside are shared. Adding an access obligation on top of co-investment reduces the incumbent's profit and therefore total coverage is lower in this regime than under pure co-investment. In the presence of demand uncertainty, the entrant can wait for the true state of demand to be realized before asking for access. In this scenario, the existence of an access option for the entrant further reduces investment incentives: larger uncertainty leads to lower total coverage. The risk of imposing investment-diminishing access regulations is of particular concern in view of incentivizing new investment and the existing co-investment obstacles in fixed-network industries.

In Annex IV lit. a. the CODE pushes for imposing open co-investment agreements on the SMP operator, which enables access for later entrants to join the co-investment agreement. In some sense, allowing the co-investment agreement to remain open over the entire period of the agreement on a non-discriminatory basis corresponds to the standard access regulation scenario. The option for the late entrants to pay an access fee that includes a fraction of those risks would only work if the regulator is able to assess those risks precisely and monetize them through the fiber access charge, but this would be extremely complex and difficult to implement in practice. Yet, the CODE provides for (Annex IV lit. c) such a dynamic adjustment of access prices to reflect the timing of commitments made at later stages. Hence, imposing such open co-investment specifications increases regulatory uncertainty and transaction costs and further reduces the incentive to co-invest because it negatively affects the incentive to pre-commit on investment.

Secondly, although the CODE´s proposed regulations on symmetric access obligations are supposed to allow operators to withdraw from more restrictive asymmetric access obligations, and thus to reduce the overall intensity of regulation, the proposed symmetric access regulations actually entail the potential to significantly expand the current regulations to a apply to a large number of operators and access infrastructure elements. Moreover, symmetric regulation might de facto give rise to a substantial extension of regulation, as they are readily available to NRAs without the need to conduct extensive market definition and SMP analyses. These circumstances and lack of clarity as regards the scope and implementation of symmetric regulations raises serious concerns with respect to investment incentives. Of similar concern is the CODE´s aim to extend asymmetric access regulations to infrastructure elements outside the scope of the relevant market concept. Accordingly, this specification not only implies an extension of the scope of asymmetric regulation but it also runs contrary to the logical structure of the market analysis procedure under the EU

regulatory framework which aligns asymmetric access regulations to specified access products within relevant markets.

Thirdly, the CODE emphasizes the importance of infrastructure-based competition in incentivizing investment in high-speed broadband networks, which is greatly appreciated. Moreover, 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 options for achieving the policy goals of substantial infrastructure investment in new communications infrastructure. Hence, pursuing these targets should not lead to distortions of market outcomes by engaging in "winner-picking" by explicitly favoring certain NGA technologies. Deviating from the principle of technological neutrality should instead only occur based on sound empirical evidence on the differential welfare effects of available NGA technologies – evidence that is currently not available. Existing and future "second-life copper/coax technologies" 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. The market-driven speed of migration will inter alia depend on country-specific characteristics such as the availability of ducts (favoring ceteris paribus FTTP deployment) or the number of street cabinets (favoring ceteris paribus FTTC deployment). Another fundamental technological change will be brought about by 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. In fact, 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 more efficient investment subject to the imperfect information available on future demand for high-bandwidth and technological progress.

Appendix A1

List of Figures

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List of abbreviations

Art.	Article
BEREC	Body of European Regulators for Electronic Communications
BMWi	Federal Ministry for Economic Affairs and Energy
CATV	Cable Television
DAE	Digital Agenda for Europe
DOCSIS	Data Over Cable Service Interface Specification
DSL	Digital Subscriber Line
DT	Deutsche Telekom
EC	European Commission
ECS	Electronic Communications Service
EECC	European Communications Code
EU	European Union
FTTB	Fiber to the Building
FTTC	Fiber to the Cabinet
FTTDp	Fiber to the Distribution Point
FTTH	Fiber to the Home
FTTLA	Fiber to the Last Amplifier
FTTN	Fiber to the Node
FTTP	Fiber to the Premises
FTTx	Fiber to the x(=Home/Building/Cabinet/Node)
Gbit/s	Gigabit per second
ICT	Information and Communications Technology
IP	Internet Protocol
IT	Information Technology
ITU	International Telecommunication Union
LLU	Local-Loop Unbundling
ECJ	European Court of Justice
LR(A)IC	Long-run-(average)-incremental costs
LTE	Long Term Evolution
M&A	Mergers & Acquisitions
Mbit/s	Megabit per second
NGA	Next Generation Access
No	Number
NRA	National Regulatory Authority

OECD	Organization for Economic Co-Operation and Development
ONP	Open-Network-Provision
OTT	Over-the-Top
SIM	Subscriber Identity Module
SMP	Significant Market Power
TFEU	Treaty on the Functioning of the European Union
TKG	Telekommunikationsgesetz (German Telecommunications Act)
UK	United Kingdom
US	United States of America
VATM	Verband der Anbieter von Telekommunikations- und Mehrwertdiensten e. V. (Association of Telecommunications and Value-Added Service Providers)
VDSL(2)	Very High Speed Digital Subscriber Line (2)
VULA	Virtual Unbundled Local Access
XGfast	Fast Access to Subscriber Terminals
ZEW	Centre for European Economic Research
4G	4th generation mobile networks
5G	5th generation mobile networks

Appendix A2

1) Bourreau M., Cambini C. & Dogan P. (2012), “Access Pricing, Competition, and Incentives to Migrate From “Old” to “New” Technology.” *International Journal of Industrial Organization*, 30, 713-723.

In this paper, the authors analyze the incentives for an incumbent and an entrant to migrate from an "old" technology to a "new" technology, and discuss how the terms of wholesale access affect this migration. They show that the coverage of the new technology varies non-monotonically with the access price of the old technology: a higher access charge on the legacy network pushes the entrant firm to invest more, but has an ambiguous effect on the incumbent's investments, due to two conflicting effects: the wholesale revenue effect, and the retail-level migration effect. When the new technology is also subject to access provision, they find that migration from the old to the new generation network at the wholesale level can be incentivized if a positive correlation between the access prices (to the two old and new generation networks) is maintained.

2) Bourreau, M., Cambini C., & P. Dogan (2014). Access regulation and the transition from copper to fiber networks in telecoms. *Journal of Regulatory Economics*, 45(3), 233-258.

In this paper, the authors study the impact of different forms of access obligations on firms' incentives to migrate from the legacy copper network to next generation broadband infrastructures. They analyze geographically differential access prices of copper (that depend on whether or not an alternative fiber network has been deployed in the area) and ex-ante access obligations for fiber networks. They also discuss how these regulatory schemes fare in addressing the tension among different objectives, such as the promotion of static efficiency, encouraging investment in new infrastructures, and avoiding unnecessary duplication of (fiber) networks.

3) Bourreau, M., Cambini C., & Hoernig S. (2015). Geographical Access Markets and Investment. *Information Economics and Policy*, 31, 13-21.

In this paper, the authors analyze the adoption of access regimes that differ according to the prevailing degree of infrastructure competition in different geographical areas of a country. Their results show that, compared to a uniform access price, geographically differentiated access prices improve welfare and incentivize investment. However, when access provision

in areas with infrastructure competition is deregulated, welfare might decrease, because multiple inefficient equilibria at the wholesale level emerge, with either too little or too much investment.

4) Bourreau, M., Cambini C., & Hoernig S. (2016). Cooperative Investment, Access, and Uncertainty. Unpublished manuscript available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2879319

This paper compares the impacts of traditional one-way access obligations and the new regulatory scheme of co-investment on the roll-out of network infrastructures. The authors show that compulsory access leads to more limited roll-out, firstly because it reduces the returns from investment, and secondly because in the presence of uncertainty it provides access seekers with an option whose exercise hurts investors. Co-investment without access obligations leads to risk sharing and eliminates the access option, implying the highest network coverage. Allowing for access on top of co-investment actually decreases welfare if the access price is low.

5) Briglauer, W, Cambini, C. & Grajek, M. (2017). Regulation and Investment in European High-Speed Broadband Infrastructure. Unpublished manuscript.

In this paper, the authors study how the coexistence of the access regulations of the legacy (copper) and fiber networks shape the incentives to invest in the network infrastructure. To this end, they first develop a theoretical model explaining investment incentives by incumbent firms, cable operators and telecom-based entrants and test its main prediction using panel data from 27 EU member states over the last decade. The theoretical model adds to the existing literature by considering the heterogeneity of entrants in broadband markets. By allowing cable and telecom entrants to differ in the way they access incumbent firms' infrastructure, the authors are able to derive testable hypotheses with more direct policy implications. In the empirical part of the study, they use a novel data set including information on physical fiber network investments, legacy network access regulation and recently imposed fiber access regulations. Their main finding is that more stringent access regulations to both the legacy and the fiber networks harm investments from incumbent telecom firms, but do not affect cable firms.

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