

Working Paper
(Draft as of September 16, 2008)

Regulatory challenges of Next Generation Access Networks in telecommunications in Europe

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Abstract:

The global telecommunications industry is on the edge of its next technological transformation: Fiber-optical Next Generation Access Networks (NGAN) will enable internet access at presently unrivalled speeds and create an environment for new all-IP applications and services. Compared to preceding technology evolutions, NGAN will exhibit under-investment in the current market environment from a social planner perspective. This is caused by a low share of producer surplus appropriation, most likely high social externalities, and high regulatory uncertainty combined with a long investment horizon. These findings suggest that regulation needs to contain NGAN investment promotion to approximate social optimal investment levels. Regulatory tools for this investment promotion are investor-friendly regulatory decision-making around NGAN, regional rebalancing mechanisms and financial support by governments. A combination of these tools will be needed to reach socially desirable NGAN investment levels and this papers presents approaches that can guide regulators in selecting and balancing these tools.

JEL classification: K23; L22; L51; L52; L86; L96; O33

Keywords: Next generation access networks; regulation; broadband; competition; telecommunications

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The author gratefully acknowledges the helpful comments of Prof. Dr. Felix Höffler and Sarah Schuster. All remaining shortcomings are mine.

1 Introduction

In the past 40 years, the European telecommunications industry was characterized by strong growth, capturing an increasing share of GDP from 2.1% in 1985 to 3.4% in 2001 (OECD 2007). This growth was fueled by increasing service penetration as well as innovative new services like mobile telephony in the late 1990s and broadband starting in 2000. However, industry growth has stalled recently with saturating penetration growth of many important services and fierce price competition triggered by regulation that strives for welfare maximization in a historically uncompetitive market. In the past, this trend has therefore attracted research on the interaction of regulation and competition with telecommunication infrastructure investment and its social welfare implications (see Guthrie 2006).

At this point of time, the industry is looking at the next technological innovation that will most likely change the telecommunication service offering in the future, Next Generation Access Networks (NGAN), which offer broadband with virtually unlimited bandwidth beyond the currently feasible 10 to 25 MBit/s in ADSL 2+. This additional bandwidth could enable many new IP-based applications and services in the future.

Next Generation Access Networks are defined technically as the successive replacement of the current copper access network with optical fiber. Optical fiber hereby has superior properties to existing copper and coaxial cables, since the bandwidth that can be transmitted through the fiber is significantly higher and does not deteriorate with the length of the fiber cable. The roll-out of NGAN implies very high investments that range from 500 to 2,000 EUR per household passed¹ and amount to roughly 330 billion EUR for the 220 million households in Europe. Since this is more than 6 times the current annual European investment volume, it can be assumed that the interaction between regulation and NGAN investment will be an important topic in the regulatory debate going forward.

The interdependence of regulation and investments in telecommunications has been intensely discussed in scholarly literature so far (see Guthrie 2006 and Vogelsang 2003 for overviews). Whereas theoretical research mainly focused on describing the impact of regulation on the timing and return requirements of single, specific investments (see Blum et al. 2006, Evans and Guthrie 2005, Gans and King 2004 and Valletti 2003 as examples), empirical research yielded an ambiguous picture of interdependence of regulation and investment (see Chang et al. 2003, Dawson 2006 and Ros 2003 in contrast to Beardsley et al. 2006). These ambiguous results could be explained by insufficiently decomposing investment types between, e.g., redundant competitive investment, capacity investment and investment in new technologies. Therefore, this research has limited relevance for any given specific investment, e.g., NGAN, and the interaction between regulation and investment needs to be analyzed more closely in this particular case. Given the importance of NGAN investment for the telecommunications industry, this paper will focus on NGAN with its specific properties, discuss the interaction between regulation and investment and develop regulatory policy options that yield socially desirable industry outcomes.

After introducing NGAN technology and its capabilities in Chapter 2, Chapter 3 will show

¹ See Enders (2007), Heavy Reading (2008) and Wittig et al. (2006) for investment cost estimations. Total FTTH deployment cost will most likely range from 500 to 1,000 EUR per household passed for metropolitan areas to 1,500 to 2,000 EUR per household for a full NGAN roll-out. In the following, 1,500 EUR for a full roll-out are assumed for the European example.

that the current market environment will yield significant under-investment in NGAN from a social investment perspective and that regulators and policy makers are not well equipped to counter this insufficient investment. Thereafter, Chapter 4 then discusses options to promote investments through regulatory and political decision-making considering the effects on the competitive market for telecommunications services and derive policy implications.

2 Overview of Next Generation Access Networks

This section aims at introducing Next Generation Access Network technology, its capabilities and the technological challenges. This understanding will be required to later appreciate the regulatory policy implications for NGAN. This chapter is structured into two parts. Initially, the products and services feasible on NGAN and, thereafter, the underlying technology are presented.

2.1 Products and services on NGAN

NGAN will enable new broadband access products with a higher bandwidth, beyond the existing 10 to 25 MBit/s based on a current copper infrastructure in ADSL 2+. It has been shown that the capacity limitations in the access network will most likely be the biggest bottleneck for future growth of broadband speed (see Nemertes Research 2007). With NGAN, the broadband speed will only be limited by the capacity of the aggregation and core network in the medium term and it can be expected that the broadband speed available to residential consumers could grow to beyond 1.000 MBit/s before 2020.

In the current market environment, demand for connectivity beyond these limitations is small and limited to high-end applications as high-definition TV and other high-capacity streaming services. Nevertheless, demand for bandwidth constantly grew over the past years and is expected to continue growing exponentially in the future with about 40% (as suggested by Cisco 2008). This trend is enabled by various drivers with a few named below:

- **Better quality of existing applications** - Customers demand an improved user experiences of their current IP-based services and applications. Better quality coincides with a higher bandwidth requirements in data connectivity.
- **New IP-based applications** - Higher bandwidth enables users to receive former non-IP or new applications and services via their broadband access in better quality or with more choice (e.g., IPTV, voice and video communication).
- **Hardware substitution** - With lower bandwidth, users need considerable hardware in their premises to support IP-based applications (e.g., decoders, hard drives, computers). This hardware could be substituted with more efficient remote hardware in data centers that is accessible with high-speed broadband.

Thus, it can be assumed that there is a growing demand for high-bandwidth broadband access in the future and policy makers should ensure the availability of this technology up to a socially desirable level. Alternative access technologies will hardly be able to substitute the need for NGAN deployment in the medium and long term, since they

cannot address the access network bottleneck in the broadband infrastructure in the same way:

- **Cable TV networks** - With the new Docsis 3.0, cable TV networks may reach speeds of beyond 100 MBit/s that are able to cover demand development in the short and potentially medium term. Beyond these limitations, cable network operators would need to replicate investments in fiber optics equivalent to NGAN to provide higher bandwidths. Furthermore, cable networks for example in Europe only cover approximately 35.5% of the population (see IDATE 2007) and therefore will not be able to serve as the only solution for broadband access in the future.
- **Mobile networks** - Mobile access technologies lag behind fixed ones in bandwidth development since it is a shared medium among many users and available frequency bands are limited. Thus, they could not be an alternative to high-speed fixed broadband access enabled by NGAN in the future.

From a service perspective, NGAN will most likely play an crucial role in broadband access market and thus the telecommunications industry in the future. In order to avoid an enduring bottleneck for future service development in the access network, regulators and policy makers should engage in ensuring social desirable investment levels in NGAN in Europe.

2.2 Technology characteristics of NGAN

With the deployment of NGAN, the existing copper access network is replaced with fiber optical cables from the central offices in the network to the customer (see Illustration 1). The extend of copper replacement defines different roll-out types ranging from fiber-to-the-curb (FTTC) where only the copper to the street cabinet is replaced to fiber-to-the-home (FTTH), where the entire copper is replaced. The more copper cable is replaced, the higher is the possible broadband bandwidth that can be supported by the broadband access technology.

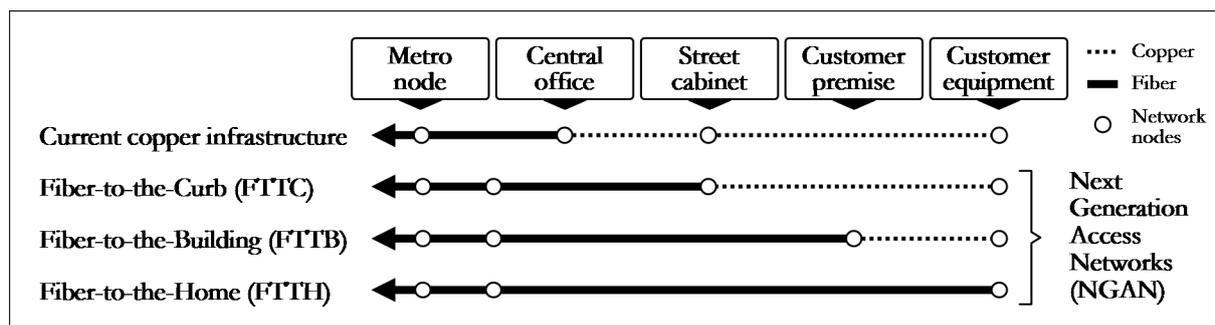


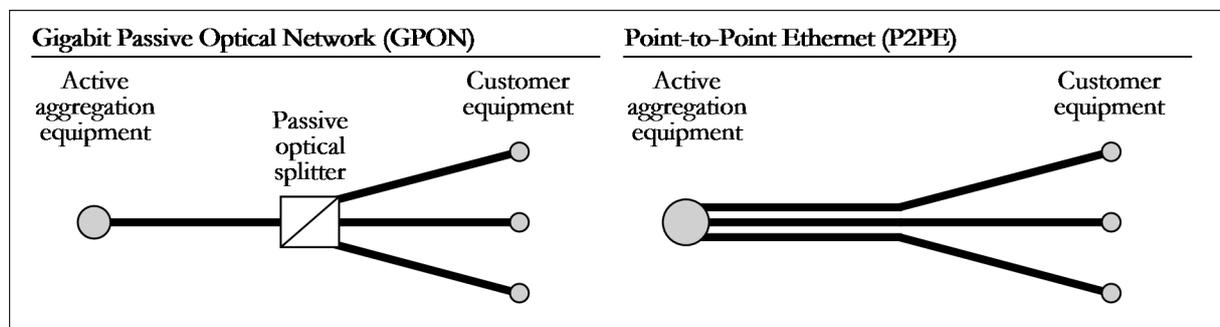
Illustration 1: NGAN investment types

The technical properties of NGAN also eliminate the mandated network hierarchy in the access network with its central offices and street cabinets and their required density in the network. A considerable share of the existing street cabinet and central office locations could be vacated, since the NGAN network could be supported by a less dense structure of locations for active switching equipment in the optical distribution frame. This could

result in operational synergies for the network owner in case he operates the copper access network as well.

However, these synergies will be difficult to realize, since central offices are shared with competitors that offer the current local loop unbundling wholesale products. These competitors incurred sunk investments in active switching equipment to attain regulatory-desired infrastructure competition in unbundling products. This equipment has an economic life beyond the likely introduction of NGAN. Vacating central offices and decommissioning street cabinets to realize synergies in a NGAN roll-out would result in a required write-off of competitive investments. Thus, regulators need to look at a balanced decision making in the migration to NGAN in order to make operational synergies available to the investor, but at the same time not to harm the existing competitors unduly.

NGAN investors engaging in the deployment of FTTH will have to make a technology choice between two deployment archetypes that are defined in Illustration 2. Gigabit passive optical networks (GPON) use a passive optical splitter in the last mile to split the broadband signal among multiple users. In comparison, Peer-to-peer ethernet (P2PE) contains a separate fiber-optical cable for each connected household.



*Illustration 2: Alternative NGAN network technologies
(See Fijnvandraat and Bouwman 2006)*

The technology choice is ambiguous from a technical perspective. Whereas GPON seems to be advantageous from a cost perspective, P2PE offers a higher flexibility in initial deployment and with subsequent product upgrades. Investors would have to decide on the most efficient deployment depending on the projected market share of the investing company and the expected service penetration, the assumed probability of upgrades and the deployment cost per operator and FTTH technology alternative.

Furthermore, both technologies have different properties as regards to feasible regulated wholesale products that will most likely influence the technology decision in the first place. With P2PE, an passive unbundling of the fiber cable at the active equipment location is possible, whereas with GPON only active bitstream wholesale products are supported, since passive unbundling is not feasible with the deployment of passive optical splitters servicing more than one customer. With passive unbundling, competitors only procure the cable to the customer and are independent to deploy any product and active switching equipment themselves. This gives competitors the chance to fully determine product differentiation of the broadband access. In active bitstream access, the broadband signal of customers is handed over to the competitor in the network backbone. Here product differentiation has already happened to a high extend by the incumbent network operator and the competitor only has limited further product differentiation opportunities.

Investors are likely to anticipate the feasibility of access products in their technology decision and assume that regulators will introduce wholesale products opportunistically, if they are technically feasible. Therefore, investors will have a bias towards GPON deployments to manifest a favorable regulation in the future, which could possibly prevent a socially optimal investment. Thus, it is important that the regulatory environment is credibly decided before the NGAN roll-out in order to enable the most efficient technology choice from a social perspective.

3 NGAN from a private and social investment perspective

Since liberalization and deregulation in the industry in the past 20 - 30 years, investments are believed to be even triggered in the current competitive environment and there is considerable evidence that this has been true so far for investments in, e.g., mobile networks, the digitalization of fixed networks and broadband. However, NGAN poses to be a different technology evolution that is more likely to result in under-investment from a social perspective. In this chapter, the investment incentive of a private investor is compared with the one of a social planner to evaluate the size of the potential investment volumes.

3.1 Decreasing producer surplus appropriation

In order to replicate socially desirable investment behavior, private investors would have to be able to appropriate the entire surplus generated by their investments. However, it can be observed that the NGAN investor will most likely only be able to appropriate a decreasing share of the surplus. A lower producer-appropriated surplus share results in a reduced investment incentive in the technology that enables this additional surplus, e.g., NGAN for high-speed broadband access. There are four reasons that support this hypothesis: Decreasing vertical product and price differentiation through (1) a trend towards one-part tariffs, (2) passive access products and (3) uniform pricing across regions as well as (4) a regulatory-driven price erosion through service and infrastructure competition.

Firstly, in the broadband access market, flat-rates are the most common price plans that can be observed today, diverging from the concept of two-part tariffs in voice telephony. This trend is mainly driven by customer preference that favors this simple pricing structure and its introduction has usually lead to a surge of broadband penetration. There are reasons to believe that broadband two-part tariffs will not be viable in the future, as shown for the most common forms of two-part tariffs in broadband:

- **Data volume based two-part tariffs** - Data volumes are difficult to observe for user in current broadband products resulting in an inherent price risk from a user perspective. In addition, the data volume is hardly linked to the value of a specific application or use case, e.g., data-intensive video streaming vs. simple static web pages, and this pricing would thus result in an adapted and from a customer perspective undesirable broadband usage behavior.
- **Usage time based two-part tariffs** - Usage time is difficult to establish as a driver for a two-part tariff, since it contradicts one core value proposition of broadband

as "always on" internet compared to previous dial-up connections. Furthermore, many devices engage in IP connectivity without the conscious intervention of the user, resulting in an additional price risk from a user perspective as well.

As two-part tariffs in broadband will hardly emerge again, it can be assumed that broadband access will in the future be based on a single access charge that does not allow for any form of usage-based price differentiation. However, given that a higher usage is usually correlated with a lower price sensitivity, this will necessarily result in lower overall profits from this product offering assuming that marginal cost are negligible. This declining producer surplus share is elevated by the increasing number of communications services delivered via these broadband access lines that applied two-part tariff structures in the past, e.g., voice over IP.

Secondly, the emergence of passive access products, i.e., unbundled local loop, with cost-based pricing has resulted in a Bertrand-undercutting competitive environment that discourages product and price differentiation based on divergent bandwidth. As cost differentials in access products with different bandwidths are negligible and are by far surpassed by the customers' willingness to pay for this additional bandwidth, competition is increasingly focused on the single product with the highest available bandwidth in ADSL 2+ to gain customer preference on the access market. This trend discourages any form of bandwidth-based product and price differentiation that could result in a higher share of producer surplus appropriation by all players.

Thirdly, product and price differentiation across regions and customer groups is very limited in the industry for political as well as commercial reasons. From a political perspective, equal pricing of infrastructure services across regions has been part of the political agenda for years to prevent accelerating urbanization and divergent living conditions across the country. From an commercial perspective, country-wide campaigning and sales propositions have advantages that oppose regional product and price differentiation. Thus, products and market pricing will in the future hardly be able to reflect divergent infrastructure cost levels as well as customer preferences across regions and cannot be used to increase producer surplus participation.

Lastly, regulatory-induced service competition at various levels of the telecommunications infrastructure has driven down prices and increased penetration of broadband services. Although this is socially desirable in the short term on an existing infrastructure, it has further lowered producer surplus appropriation and thus the proceeds that could finance investments in new surplus-generating technologies, e.g., NGAN.

Additionally, regulators have put in place a regulation that guarantees minimum price gaps between wholesale and retail products of bottleneck infrastructure owners in order to prevent margin squeeze of retail competitors on wholesale access products. Although this regulation protects competition in the broadband access market, it constrains the bundling of access with access-near services that require high-bandwidth broadband access, e.g., IPTV. Any form of cross-subsidization of services with access charges is regarded as anticompetitive for the access market and will be punished in this form of regulation.

Although these services require a NGAN access line and, thus, the access-near surplus is a direct consequence of the NGAN investment, their revenues and profits cannot be employed to finance NGAN investment, since any form of service-to-infrastructure subsidization of the infrastructure owner has to be assessed in light of market dominance exploitation or will be competed away by under-cutting access-near service providers.

Therefore, margin squeeze regulation prevents infrastructure owners from appropriating possible benefits in adjacent, access-near services markets enabled by new technology investments. Thus, the benefits of NGAN investment can only be appropriated in the actual broadband access market with its previously discussed, decreasing producer surplus share.

Hypothesis 1:

In the broadband access market, the share of producer surplus is decreasing in the current market environment. NGAN investors will thus only be able to extract a low share of benefits from their investments in the current market, product and regulatory environment. In addition, current regulatory practice prevents any form of benefit appropriation from adjacent, access-near service markets.

3.2 Social externalities of broadband

Beyond the broadband access market and its surplus, telecommunications infrastructure and investments in the past seem to have explained a considerable share of economic growth. As an example Röllner and Waverman (2001) showed this for traditional telecommunications infrastructure and Gillett et al. (2006) for the specific case of broadband infrastructure in the United States. From this research, economic externalities of telecommunication investment can be assumed to include productivity growth in other industries, human capital development, economic output growth as well as avoided social cost through, e.g., unemployment. The latter research furthermore underlines that these economic effects are observable on a regional level pointing towards arising regional economic development differentials, if the infrastructure is only deployed selectively across a country's footprint. In summary, these economic externalities will increase the desirability of NGAN investment from a social perspective beyond the surplus in the broadband access market and, thus, beyond the investment incentives of any private investor in the market.

NGAN is an investment deep into the technology stack of the existing telecommunication infrastructure, where a large share of the existing telecommunications asset base is replaced that forms the foundation of today's network, i.e., the access network. This investment will prepare the telecommunications network to cater for the upcoming service innovations within the next 20 to 30 years as the copper infrastructure has done for the past 30 years. Thus, its social value is not limited to a single service innovation in the short term, but many innovations with increasing importance to the customer in the medium and long term. Thus, we can assume that the social value of NGAN will increase in the future. This social value is likely to be higher than for preceding technology evolutions since it refers to many future service innovations, but more opaque from a current point of view due to its long time horizon of applicability.

Hypothesis 2:

NGAN investment will most likely have a high social value in the future that has considerable externalities beyond the broadband access market and the remnants of private investment incentives. Its social value can be expected to grow in the future along with an increasing number of service innovations relying on NGAN broadband bandwidths.

3.3 Uncertainty of demand and regulation

NGAN investors face a high level of uncertainty as regards to the benefits associated with their investments. This uncertainty is very important for investment decision-making since a larger share of the benefits is bound to emerge only in the medium and long term. The main categories of uncertainty associated to NGAN are as follows:

- **Demand for bandwidth beyond 10-25 MBit/s in ADSL 2+** - It is uncertain that demand for higher bandwidth will emerge or not only cover a small share of the customer base. Furthermore, there is uncertainty about the actual amount customers are willing to pay for the higher bandwidth offered through NGAN.
- **Regional infrastructure competition** - Under required uniform pricing across the footprint, regional infrastructure competition in one part of the country will change the market dynamics across the entire footprint and has implications on price levels, product differentiation, regional competitiveness and thus NGAN investment incentives across the country.
- **Regulatory-induced service competition** - Type and pricing of wholesale access regulation is uncertain and will thus determine price levels and benefit participation of the NGAN investor. Furthermore, even if decided beforehand, investors may expect changing regulatory conditions in the case of a favorable industry development. This can be interpreted as the cutting upside benefits of the investment and reducing the expected proceeds from the investment (Gans and King 2004).

These uncertainties will reduce NGAN investment incentives for the risk-averse private investor that needs to finance itself on the capital market. It is safe to assume that for this reason private investors are more risk-averse than the social investors and the existence of these uncertainties is therefore curbing private investment incentives to a larger extent. In addition, the latter two risks are associated to the regulatory-induced market environment and competition, which only apply to the private investment incentive. Therefore, existence of uncertainties will lead to an even stronger deviation of private investment incentives from the social investment incentive as argued before in this paper.

Hypothesis 3:

NGAN is facing a high level of market and regulatory uncertainty. The higher private risk-averseness and the existence of regulatory uncertainty leads to an even stronger deviation of the private and the social investment incentive. The medium to long term investment character of NGAN further elevates the importance of these uncertainties for the private investment decision.

3.4 NGAN technology deployment cost

The preceding three sections underlined the difference of the social and private investment incentive for NGAN. This, however, would only be relevant, if the private investment incentive does not result in a complete investment across the footprint. In previous technology deployments, private investment incentives seemed to be sufficient for a broad roll-out of telecommunications infrastructure, e.g., as for mobile and ADSL, but there

are reasons to believe that this will not happen again in NGAN. The deployment cost of NGAN have two notable differences: The cost are considerably higher compared to preceding investments after liberalization, and they are characterized by high cost differences across the country's footprint. Firstly, historic technology deployments in the telecommunications industry since its liberalization were characterized by comparably lower investment requirements. Any earlier technology could be deployed for less than 100 EUR per household compared to the necessary 1,500 EUR for NGAN (see Enders 2007). Although, this does not affect the economic evaluation of the actual investment, it needs to be considered that investors as well as capital markets will exert higher scrutiny on the investment decisions and the associated uncertainties. Investors could potentially risk their commercial future on the NGAN endeavor, which plays an important role in the existing risk-averse market environment.

Secondly, the major cost driver for NGAN is the length of the local loop that drives about 75% of the total deployment cost (see Wittig et al. 2006). Since the length of the local loop differs significantly across the regions within a country, these cost can be seen as the driver for high differences in average deployment cost projections ranging from 500 to 2,500 EUR per household for NGAN. Therefore, it is suggested that deployments are initially focused on and restricted to areas with lower deployment cost in densely populated areas up until the private investment incentive reaches its limits. Currently announced investments in metropolitan areas are an indication of that the private investment incentive is viable in the most favorable areas, but the contained roll-out underlines the fact that the private investment incentives are not sufficient to enable a full or even broader NGAN roll-out. Thus, we can observe that the decision around NGAN is not whether NGAN investment happens, but how far into the population footprint it will happen. This makes the gap between the private and the social investment incentive relevant for the economic assessment.

Hypothesis 4:

NGAN is characterized by high investment cost and significant cost differences between regions depending on the respective length of the local loop. Investment seem to be feasible in the most favorable areas, but the breadth of the investment will depend on the level of the private investment incentive.

3.5 Wholesale access and price regulation

European regulation in the past decade was guided by promoting infrastructure competition to avoid *ex-ante* regulation in the long run and the principles of the ladder of investment (Cave and Vogelsang 2003) to grow competition in a formerly uncompetitive market. These paradigms fit the past fixed voice telephony and broadband network technologies with its topology and feasible wholesale access products. Illustration 3 shows that the selection of possible access products in NGAN has changed to an extent that the underlying rationales for the regulatory paradigms should be revisited.

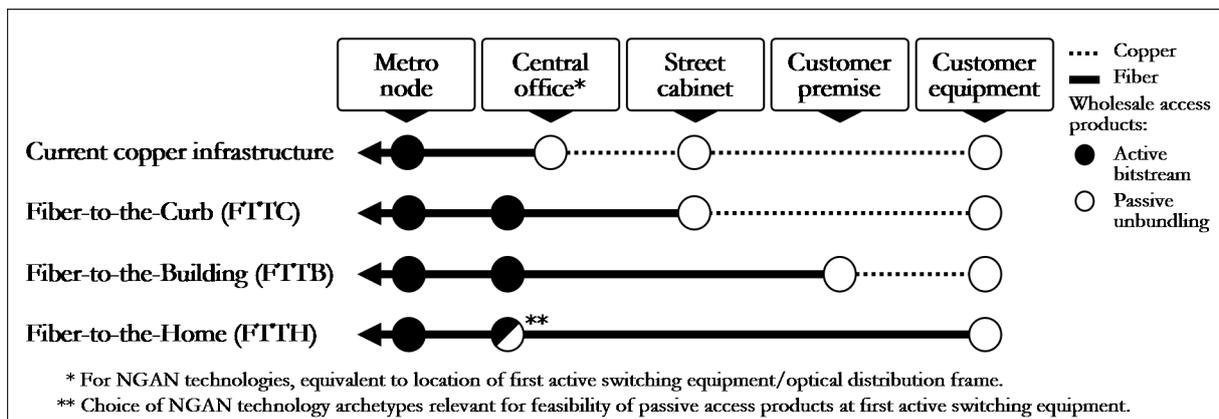


Illustration 3: NGAN investment types and possible wholesale access products

As discussed earlier, full infrastructure competition in NGAN will only be possible in selected metropolitan areas, where the cost of the NGAN roll-out is comparatively low. In these areas, the local competition model could most likely be characterized as a Bertrand under-cutting competition that will drive down prices with both competitors trying to recover the high upfront sunk investments. Although this competition is desirable for consumers in the local market, it can become detrimental, if it has negative externalities to other regions. These externalities can have two forms. Firstly, price interdependencies mandated by political as well as commercial reasons will impact price levels across the country, reducing the level of NGAN benefit appropriation and therefore NGAN investment incentives in other regions. Secondly, lower prices and investment cost of redundant investments consume profits that could otherwise be earned in the favorable investment areas. In case these profits could be applied to foster investments beyond the favorable areas via transfers or any form of rebalancing, infrastructure competition will have negative effects on NGAN investments across the country. For these reasons, the promotion of infrastructure competition in NGAN should be reviewed as an aim of regulatory policy-making due to its likely negative NGAN investment effects.

The ladder of investment principle, on the other hand, encourages regulators to mandate wholesale access products that allow competitors to successively invest in infrastructure to become an independent infrastructure competitor. After having shown that the desirability of infrastructure competition in NGAN is ambiguous, it will now be the focus to discuss the favorability of even pushing for wholesale access products that are situated deeper in the network, i.e., passive unbundling products, as suggested by the ladder of investment principle and currently done in the ADSL environment.

With passive unbundling wholesale products, product differentiation with different broadband speed categories would happen in the competitive retail market. This will lead to a competitive cost-oriented product and price differentiation and will most likely result in competition limited to the access product with the highest possible speed as observable in the current ADSL environment. This would prevent a competitive market environment in which broadband speed upgrades are priced according to Ramsey/Boitieux principles that would maximize the proceeds from the NGAN investment. Since these proceeds are required for the private investment incentive, it can be concluded that with passive wholesale access products mandated to NGAN investors, the investment incentive and thus the breadth of the investment across the country will be lower.

With NGAN, a technology that relies on high private investment incentives and product and price differentiation for its investment incentive, the ladder of investment paradigm with its preference of passive unbundling wholesale products could be detrimental. Furthermore, the feasibility of passive unbundling products is determined by the technology choice for the FTTH deployment. In a GPON network, only active bitstream access products are possible, since the application of passive optical splitters prevents an unbundling of the physical fiber-optic cable to the customer. With P2PE, this passive unbundling is feasible, because a separate fiber cable connects each household. Since passive unbundling is less favorable for any investor, it can be assumed that the threat of its imposition by regulators will influence efficient technology choice in the first place. Thus, the threat of a continued focus on the ladder of investment principle by regulators can yield inefficient technology choices to avoid wholesale access products that are eventually socially undesirable anyway.

Hypothesis 5:

The past regulatory paradigm of the ladder of investment and continued focus on promoting infrastructure competition can have negative effects on private investment incentives and might not be socially desirable in a NGAN environment. A review of regulatory principles for NGAN is therefore necessary.

3.6 Summary of requirements of NGAN investment

The analysis revealed that private NGAN investments are most likely not going to be made to the socially desirable level. This is caused by a different technology and market environment compared to preceding technology deployments since the liberalization of the telecommunication industry. Over the past years, the share of producer surplus of total surplus has been decreasing and is not likely increase for future broadband products. This renders the private investment incentive to be necessarily lower than the investment incentive from the perspective of a social planner.

Additionally, private investors are not able to appropriate the social externalities of the market that have been shown for telecommunication services, further widening the gap between the social and private investment incentive. With its very long pay-off horizon, NGAN investment decisions are taken in the context of a high level of uncertainty. This uncertainty with the private investor's risk averseness as well as the additional regulatory uncertainty further reduce the private investment incentive in comparison to the social one. In summary, for the NGAN investment it can be observed that the market is characterized by a sizable gap between the private and the social investment incentive, resulting in a potentially high level of under-investment in NGAN infrastructure.

This threat of under-investment, however, will only materialize, if required investment volumes are high enough that private investors do not have an incentive to invest the socially desired investment level. It has been shown that NGAN will require an unprecedented level of investments that will most likely not be made with the existing private investment incentive, leaving potentially large parts of the country without NGAN investments.

Observing the regulatory policy environment in Europe at the moment, long established regulatory paradigms like the ladder of investment and the promotion of infrastructure

competition have the potential to even lower existing private investment incentives. This leaves regulators with the challenge to review their existing regulatory decision criteria in light of NGAN to comply with the objective to ensure socially desirable investment levels in future telecommunications infrastructure. In order to achieve this aim, policy makers should engage in investment promotion measures to counter the gap between the private and the social investment incentives. Possible investment promotion measures are analyzed and discussed in the next chapter.

Hypothesis 6:

NGAN investments in the current market environment will significantly fall short on socially desirable investment levels. Regulators need to engage in NGAN investment promotion measures to ensure a socially optimal NGAN infrastructure deployment.

4 NGAN investment perspective on regulation

It has been shown that under the current market and regulatory environment, under-investment in NGAN will most likely happen. This chapter aims at discussing industrial policy and regulatory strategies to counter this NGAN under-investment problem without surrendering the benefits of a competitive market. It starts with an analysis of the private NGAN investment incentive and its dependence on regulatory decision-making. Thereafter, the insights are combined in an economic model that allows the evaluation of various regulatory tools to promote NGAN investment and counter the under-investment challenge. In the end, policy implications for regulatory decision-making around NGAN are discussed.

4.1 Private NGAN investment perspective

In order to understand the economic environment of NGAN investments for private investors, an analysis of the most important investment benefit components is used to evaluate the sensitivity of regulatory decision-making on these benefits. The NGAN investor has investment benefits that can be structured in three categories:

- **Additional, appropriated willingness to pay** - The amount of consumer willingness to pay for higher bandwidth products that an investor can appropriate given the limitations to product and price differentiation in the market.
- **Market share gains along the value chain** - Gaining market shares from competition on various steps of the telecommunication value chain serves as an incentive for NGAN investments as well.
- **Operational synergies** - NGAN networks can have lower operational cost and a fast migration with limited migration cost can add to the benefits of a NGAN investment for an existing copper network owner.

All three benefit components are highly sensitive to regulatory decision-making on NGAN. Table 3 summarizes the most important interdependencies between the investor's benefits and regulatory decisions. It can be seen that investment benefits are to a large extent

Table 1: Interdependence of regulation and NGAN investment benefits

		Effect on private investment incentive	
Regulatory decisions in NGAN	Customers' additional willingness to pay	Market share gains along the value chain	Operational synergies
Wholesale access type			
<ul style="list-style-type: none"> • Passive unbundling products • Active bitstream products • Regulatory forbearance, holidays 	<p>High. Influence on share of willingness to pay that can be appropriated by investors due to its influence on retail market product and price differentiation.</p>	<p>High. Avoidance of retail market competition through forbearance and influence on market share in crucial value chain steps that are commanded by the investor.</p>	<p>None.</p>
Wholesale access pricing			
<ul style="list-style-type: none"> • Cost-based access pricing • Wholesale/retail price caps • Wholesale pricing freedom 	<p>High. Access pricing determines the level to what product and price differentiation can be employed to raise investor surplus participation.</p>	<p>Medium. Access pricing defines the importance of margin squeeze regulation for maintaining competition. This regulation usually results in market share shifts.</p>	<p>None.</p>
Interconnection requirements			
<ul style="list-style-type: none"> • Number of interconnections • Conditions for access provision 	<p>None.</p>	<p>Low. Number of interconnection points defines depth of feasible competition in NGAN environment.</p>	<p>High. Interconnection rules could affect efficient NGAN network design, i.e., if redundant interconnection points are retained.</p>
Migration rules to NGAN			
<ul style="list-style-type: none"> • Timing (forced or consensus) • Cost of migration 	<p>None.</p>	<p>Low. Fast and inexpensive migration would reduce competition from ADSL 2+ products, leaving competitors with sunk investments and financial restraint.</p>	<p>High. Influences timing and cost of realizing operational benefits through decommissioning of the existing network infrastructure.</p>

driven by regulatory decision-making around NGAN. These dependencies allow regulators to influence the NGAN investment benefits of the private investor and thus foster or inhibit private NGAN investments. A very conducive environment for NGAN investment would thus entail a limitation to active access products, wholesale pricing freedom, considerable market share gains through any form of regulatory forbearance and high operational synergies through a rapid migration to the new NGAN network. The current undecided regulatory environment in Europe puts a high risk on any NGAN investor as regards to his investment benefits and explains their reluctant investment behavior so far.

Nevertheless, it has to be noted that improvements of the NGAN private investment benefits can have side effects on the overall social welfare in the market through limiting competition, allowing super-normal profits and inefficient technology choice. These effects are usually connected to benefits through market share gains. It will be important that regulators balance the positive NGAN investment effects with the potential negative side effects on competition in the market. This would entail focussing their NGAN investment promotion on supporting a higher appropriation of willingness to pay and the realization of operational synergies.

Hypothesis 7:

Regulatory decision-making is the single most important determinant of NGAN investment levels in a country. Regulators need to engage in proactive investment promotion to replicate socially desirable investment levels, while refraining from allowing investors to obtain anti-competitive market share gains.

4.2 Economic environment of NGAN investment

The NGAN investment situation from a national economy perspective is now summarized in an economic model that is able to evaluate tools for promoting investments in NGAN technology in order to attain socially desirable investment levels. The following inputs have been considered in the model and are shown in Illustration 4:

- **NGAN investment requirements** ($I(H)$) - Increasing NGAN deployment cost across the footprint along with the length of the local loop for each household.
- **Private investment incentive** (B_0, B_1) - Discounted investment-related cash flows that a private NGAN investor can appropriate in a given regulatory environment.
- **Social investment incentive** (B^*) - Discounted value of NGAN from a social planner perspective, whereby the social value significantly exceeds the private investor benefits as shown in the previous chapter.

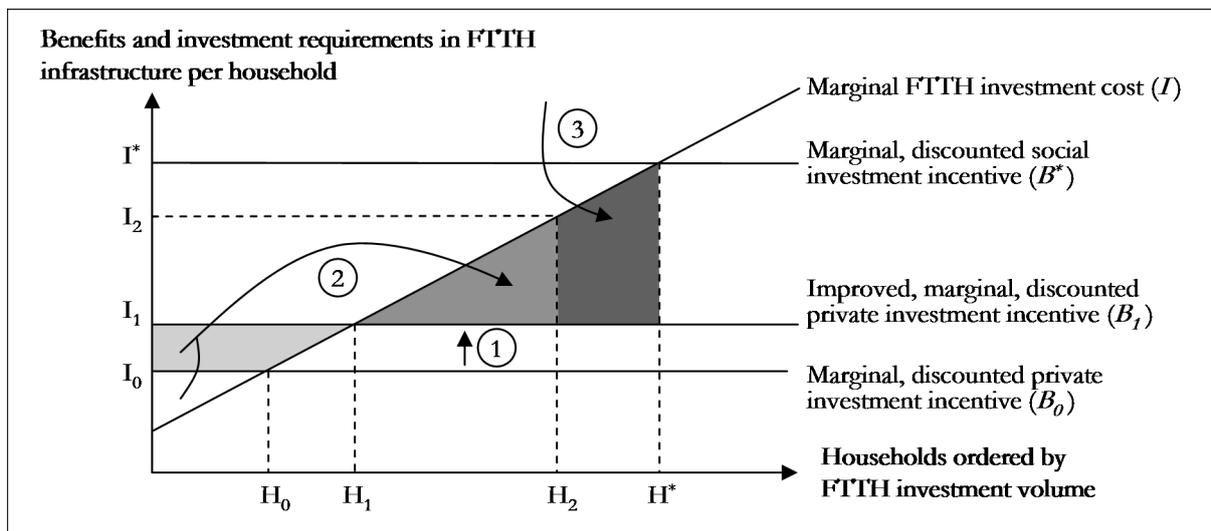


Illustration 4: Effect of regulatory measures on NGAN investment

It can be observed that equilibrium NGAN investments (H_0) falls short on the socially desirable investment level (H^*), since the social investment incentives (B^*) exceed private ones (B_0). This under-investment in NGAN ($\int_{H_0}^{H^*} I dH$), however, occurs at the same time as a excess profit ($H_0 \cdot B_0 - \int_0^{H_0} I dH$) is earned by the investor in favorable investment areas, where a return beyond the risk-adjusted cost of capital can be achieved. In order to address the NGAN under-investment challenge, regulators and governments have three generic tools at hand that can be applied in this context:

(1) Improvement of the marginal, private investment incentive

As discussed in the preceding section, regulators can improve the marginal investment incentive (B_1) through their decision-making. Resulting positive investment effect ($H_0 \rightarrow H_1$), however, occur at the same time as additional excess profits ($B_1 \cdot H_1 - B_0 \cdot H_0 - \int_{H_0}^{H_1} I dH$) that an investor can generate from this favorable regulation. Nevertheless, even with the furthest reaching improvements of the investment incentive, private investments are still unlikely to reach socially desirable investment volumes, if regulatory-induced market share shifts are avoided. This form of investment promotion is observable in the United States with its forbearance regulation that was imposed in 2004 (FCC 2004 as an example).

These improvements are desirable from a private investor perspective, since they create high, additional excess profits that can be appropriated by the investor. However, the effectiveness of these concessions from a social perspective need to be assessed in light of possible side effects on competition as well as the social desirability of the granted excess profits. Concessions need to be carefully selected to avoid negative welfare effects arising from opportunities to prevent competition and competitive pricing as well as exert anticompetitive behavior. This is mainly associated to investment benefit improvements arising from market share gains and regulators should be particularly careful in granting concessions in this area. In addition, excess profits from these concessions are granted without yielding social benefits. Their existence will attract infrastructure competition that will reduce excess profits for the initial investor and might lower the overall investment benefit even beyond these favorable areas, if regional price interdependencies are considered. Thus, the existence of excess profits is hardly desirable from a social point of view and will require conscious trade-offs within every country of its application.

(2) Regional rebalancing of excess profitability

Excess profits are in this tool applied to finance NGAN investments ($H_1 \rightarrow H_2$) beyond the viable private, marginal investment incentive. Since these investments are not profitable for the private investor *per se*, regulators need to create an environment, in which regional rebalancing becomes commercially viable for investors. This can be achieved through two types of imposed regulation: either a rebalancing that is administered by the regulator or the government or by creating an incentive system for the private investor that allows for an internal rebalancing within the investing company. Many forms of regional rebalancing have been previously analyzed in the universal service literature in the context of the initial deployment of the copper access network (see, e.g., Riordan 2002 for a summary), however, should be adapted for the specific case of NGAN due to its high investment requirements and the different product market environment. The UK, Singapore and Australia are countries already employing regional rebalancing mechanisms for NGAN.

A regulatory-administered rebalancing can either be done by licensing NGAN investments or by a setting up a NGAN investment fund. With NGAN licensing, industry players are awarded roll-out licenses for NGAN investments in a specified regional area that entail favorable regulatory conditions. The license conditions define the regulatory rules of the NGAN investment and, thus, determine the investor's benefits. The regulator redistributes the proceeds of granting licenses in favorable areas to support licenses in areas, which would not find a licensee under these terms and conditions. Assuming optimal pricing of licenses, this would result in an efficient regional rebalancing mechanism, applying excess profits to drive NGAN investment in less favorable areas. However, from a practical perspective, this form a redistribution will leave regulators with a high administrative burden and the risk of conducting an inefficient auction (Sorana 2000). On the other hand, rebalancing can be done by setting up a fund that will support NGAN investments in less favorable areas and will be fueled by taxing industry revenues. This tool was largely applied to cover the gaps in the existing copper network, however, would most likely be not viable for NGAN investment due to its high required investment volumes.

Alternatively, investors can as well be equipped with an internal incentive to rebalance excess returns to less favorable investment areas. This can be done by applying a rate-of-return cap regulation. Here, the regulator credibly accepts an unregulated average rate of return on NGAN investment that covers the cost of capital and an adequate risk premium. Investors in this regulatory regime will not only consider the return on every marginal investment, but the entire NGAN investment portfolio, consisting of investments with a higher and a lower return than the granted average rate of return. This regulatory incentive mechanism would result in an efficient rebalancing conducted by the investor, if regulators can credibly commit to these regulatory principles in the long run. In this regulatory regime, NGAN investments could be induced far beyond the improved marginal business case with a possible long-term perspective of returning to a regulation that fosters efficient competition after the NGAN investments earned a sufficiently high return. Nevertheless, rate-of-return regulation runs the risk of 'gold-plating' investment, if it is not sufficiently scrutinized by regulators. Thus, it would have to be accompanied by measures that prevent this form of exploitation of the regulatory regime by NGAN investors.

(3) Financial support from government

Remaining NGAN investment gaps can be closed by government intervention. This intervention could include supply and demand side intervention ranging from direct investment

contribution to indirect fiscal transfers as tax breaks for consumers on NGAN broadband products. As with any fiscal transfer, they incur opportunity cost that need to be considered from a social perspective. Since the telecommunications industry is generating very high cash flows and regulators are equipped with a broad toolkit to influence industry development, fiscal transfers should only be considered, if all other potential tools were exhausted beforehand. Financial transfers are used in Korea, Malaysia, Australia, Denmark and Sweden to drive broadband penetration and investment.

Optimal investment promotion strategy

A combination of these three tools could help to improve NGAN investment levels and ensure a private investment behavior that approximates socially desirable investment volumes. Furthermore, it has to be considered that these tools interact with each other. An improved private investment incentive can generate excess profits that in a second step would yield an regional rebalancing mechanism more effective. Thus, all three tools should be discussed to envision a consistent and effective regulatory investment promotion strategy in every country. It is up for future research to develop these tools and policy mixes for NGAN in more detail to define a range of effective regulatory strategies and their requirements.

This model provides guidance on regulatory tools and remedies that foster NGAN investments. However, it can only be applied while considering some shortcomings in the presented model. Firstly, it is a static model and with growing private and social benefits, the equation shifts over time and might alter recommendations and optimal policy mixes. Secondly, the model assumes that full population coverage of NGAN cannot be attained and thus any improvement of the benefits has a positive investment effect. Thirdly, for simplicity reasons private investors are assumed to face the same benefits, although in reality the benefit and cost scenarios for each player group could differ significantly. Lastly, a uniform competition environment across the whole country is assumed. With regionally different intensities of competition, this model could imply inaccurate NGAN investment effects. However, despite these shortcomings, it can serve as a helpful tool to structure the current debate about a feasible regulatory NGAN investment promotion strategy.

Hypothesis 8:

Regulatory NGAN investment promotion should employ a mix of three tools: improvements of the marginal private investment incentive, regional rebalancing mechanisms and government intervention. Since these tools are interdependent, optimal policy mixes need to be determined jointly to be most effective.

4.3 Policy implications for NGAN

In many countries as well as in the European Commission, the regulatory policy for NGAN is currently being developed and this section is dedicated to deriving policy implications that should be considered in its development. Without commanding governmental funds, regulators are at liberty to engage either in an improvement of the NGAN investment benefits as well as introducing regional rebalancing mechanisms to foster NGAN investments. With the described interaction of these measures, it is recommendable for regulators to first evaluate regional rebalancing options, since it constitutes the more effective measure

for NGAN investment promotion and is more difficult to implement starting with existing regulatory paradigms.

In case regional rebalancing of excess profits is established as part of the regulatory regime, this rebalancing mechanism can be fueled by improvements of the NGAN investor's benefits that besides fostering NGAN investments also generate more excess profits that can be used for regional rebalancing. Hereby, the choice of the remedies that improve the benefits for the NGAN investor should be guided by least interfering with retail market competition to ensure that effective, socially desirable competition still takes place on NGAN. Both measures complement each other in this context and jointly drive socially desirable NGAN investment effectively. Direct and indirect governmental support measures should within this logic focus on filling the gap to the desired NGAN investment level that could not be addressed with the former two levers.

This paper refrains from suggesting concrete regulatory measures, since all countries and their characteristics differ significantly. NGAN cost, its social desirability, the legacy of regulatory decisions and the player landscape make it virtually impossible to recommend a uniform regulatory approach for balancing the measures for NGAN investment promotion. Thus, any form of rigid harmonization of regulatory remedies apart from the described over-arching economic principles of NGAN investment promotion runs the risk of being detrimental for effective NGAN regulation within a specific country. In the following, two prominent proposals for features of NGAN regulation are discussed to evaluate their effect on NGAN deployment within the presented model.

The strife for infrastructure competition in NGAN

In many countries, regulators are guided by the long-term aim of transforming the telecommunication industry in a competitive industry that requires no further *ex-ante* regulation in the future. This can only be achieved, if infrastructure competition can credibly prevent any form of anti-competitive behavior of infrastructure owners. With increasing NGAN deployment cost, infrastructure competition will most likely only emerge in the favorable investment areas, where a single investor would earn high excess profits that attract infrastructure competition. With this infrastructure competition, excess profits are consumed by duplicate investment as well as regional price competition. Furthermore, the benefits for NGAN investments and its reach across the country are reduced, if price interdependencies exist across regions, which is the case in the current market environment that largely focusses on national product marketing.

Thus, any form of tolerated or fostered infrastructure competition will result in a negative investment effect in NGAN infrastructure in other parts of the country. Furthermore, excess profits in favorable investment areas are reduced and are no longer available for any form of regional rebalancing. Regulators willing to conduct regional rebalancing should discourage direct infrastructure competition in favor of service competition, since it would complicate this effective form of NGAN investment promotion.

Sub-national markets and its effect on NGAN investment

The idea of sub-national markets for the assessment of a market's competitiveness has been proposed to adapt the regulatory remedies to the local competitive environment and enjoys broad support within the industry. In its application, this can have two forms that are currently broached in the discussion: Firstly, regulatory relief on mandatory wholesale access regulation in case of infrastructure competition and, secondly, regula-

tory concessions in unfavorable NGAN investment areas to create investment incentives. Although both measures are beneficial in creating a fair and effective regional competition environment, they have a significant negative impact on excess profits generated through NGAN investment in favorable areas that are required for any form of regional rebalancing. Thus, if regional rebalancing is approached as a measure to foster NGAN investment, regulators might be careful in the application of sub-national markets, since it might endanger effective NGAN investment promotion.

Hypothesis 9:

Effective investment promotion strategies will be based on a regional rebalancing mechanism enabled by an investment-friendly regulatory decision-making around NGAN. A focus on infrastructure competition in NGAN as well as sub-national markets should be reassessed in light of any NGAN investment promotion strategy.

5 Conclusion on social optimal Next Generation Access Network regulation

Next Generation Access Networks (NGAN) will be the fundament of telecommunication infrastructure in the coming decades, enabling high speed broadband access and a myriad of new applications and services. However, the deployment of NGAN across a country will require unprecedented investments, which will hardly be feasible or profitable for private investors in the current regulatory environment.

There are many reasons, why NGAN investment will be insufficient from a social point of view in the current competitive markets. Low levels of product and price differentiation and a passive access product competition environment prevent NGAN investors from sufficiently appropriating surplus generated from their own investment. High market uncertainties and regulatory risk combined with NGAN's long investment horizon, further reduce private incentives for NGAN investment. In addition to this insufficient investment incentive in the broadband access market, externalities of telecommunications infrastructure are not considered, leaving the industry with considerable under-investment in NGAN from a social planner perspective on infrastructure investment.

In NGAN, regulators and market players will face a situation with under-investment and they should consider investment promotion opportunities around NGAN. It has been shown that this investment promotion could be based on three measures to reach the socially desirable investment levels. Firstly, regional rebalancing of excess returns in favorable investment areas should be employed to finance investments in less favorable investment areas. Secondly, regulatory decisions should further ensure that these excess returns are generated through an investment-friendly regulatory decision-making around access products, pricing and network migration to NGAN without endangering existing retail market competition. Lastly, remaining investment gaps can be approached by direct or indirect governmental support of the industry focused on NGAN investments.

A mix of these three measures will constitute the most effective NGAN investment promotion strategy for a country and should be assessed as part of the current regulatory discussion of NGAN. European harmonization beyond the principles of investment pro-

motion would be the most likely ineffective for most countries. Furthermore, a continued focus on infrastructure competition in NGAN and the introduction of sub-national markets as currently been proposed in the regulatory discussion could be detrimental for NGAN investment promotion, since regional rebalancing will be made ineffective as a measure to spur NGAN investments.

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