A Unified Framework for Open Access Regulation of Telecommunications Infrastructure: Review of the Economic Literature and Policy Guidelines

Jan Krämer[a], Daniel Schnurr[a,*]

[a]*Karlsruhe Institute of Technology, Institute of Information Systems and Marketing, Englerstr. 14, 76131 Karlsruhe, Germany*

Abstract

The concept of Open Access (OA) plays a central role in the ongoing academic and political debate on the appropriate regulatory framework for next-generation access networks in Europe. However, clear policy conclusions on the effect of OA regulation were usually precluded by a fundamental lack in common understanding what actually defines an OA policy and along which dimensions OA regulation can be structured. This paper attempts to reconcile these diverse views by offering a definition and a conceptual framework by which OA endeavors can be identified and uniquely classified. The framework encompasses, among others, mandated OA regulation of vertically integrated firms, public-sector participation, co-investments, and OA in the context of vertical separation. Along this framework, the extant economic literature is surveyed with regard to aspects of competition and social welfare, investment and innovation, as well as practical and legal issues. Based on these insights, a policy guideline is developed that shall assist policy makers in identifying the appropriate OA scenario for the regulation of telecommunications infrastructure.

Keywords: Next Generation Access Networks, Open Access Regulation, Non-Discrimination, Co-investment, Vertical Separation, Public-Sector Participation

1. Introduction

With the Digital Agenda 2020 the European Commission has set ambitious targets for its member states and the European telecommunications industry. The requirements stipulate that until 2020 every household in the EU should be covered by a broadband connection offering at least 30 Mbit/s of bandwidth. Moreover, a penetration rate of above 50% is envisioned for 100 Mbit/s connections. In contrast to the ambitious political goals, the current implementation status is far behind schedule. For instance, by mid 2013 only 2% of European households have already subscribed to a connection offering 100 Mbit/s or more (European Commission, 2013b). Thus, large investments are needed to

*Corresponding author. Tel: +49-721-6084-8373, Fax: +49-721-6084-8399
Email addresses: kraemer@kit.edu (Jan Krämer), daniel.schnurr@kit.edu (Daniel Schnurr)

upgrade the existing broadband networks to the desired level. Especially, the deployment of next-generation access networks (NGAN) represents the most substantial share of these investments.

At the same time, European network operators experience declining revenues and profits facing strong competition by alternative infrastructures and IP-based services. In particular, former incumbent operators have criticized the current regulatory regime as heavy-handed and hostile to any investment strategy, portraying the European regulatory framework as the underlying root cause for the industry's bad performance (ETNO, 2013).

In July 2012, Commissioner Neelie Kroes announced her plan to enhance the broadband investment environment signaling her willingness to lighten the regulatory burden. The industry and various analysts have viewed this promise as a paradigm shift of the European Commission's stance towards access regulation. While it will likely not lead to a complete withdrawal of the regulatory framework, the balance between static and dynamic efficiency goals is going to be readjusted. Addressing the slow uptake of next-generation networks in Europe compared to Asian countries and the US, Kroes declared establishing an investment-friendly environment as the primary goal. While only a year before, the Commission postulated strict unbundling rules based on cost-based pricing, Kroes now advocated in favor of an approach based on non-discrimination rules. In addition, she promised to abstain from further price cuts of wholesale access charges to legacy copper networks and to establish a harmonized stable price floor across Europe (Kroes, 2012).

The first action of the European Commission in light of this announcement is the recommendation on non-discrimination and costing methodologies, which was published in September 2013. The recommendation outlines the conditions that would allow European regulators to replace cost-based price regulation with non-discrimination obligations, even in the presence of significant market power (European Commission, 2013a). During the consultation process that followed the draft recommendation, discussions have evolved around the implementation of non-discrimination. Most of all, contrary views have been stated on what actually defines a level playing field between the incumbent's subsidiary and competitors, besides a uniform wholesale price. In particular, network operators oppose an *equivalence of input* regime, that prescribes equality in terms of the used infrastructure and processes. Instead they argue in favor of *equivalence of output* that abstracts from the actual infrastructure and is concerned with equal functionality. Thus, the debate illustrates the difficulties and conflicts that are hidden behind the intuitive notion of non-discrimination.

Previously, in Europe the idea of non-discriminatory access has been discussed under the notion of Open Access (OA) and in the context of public-sector participation (European Commission, 2009). It has frequently been stated that OA could provide a balance between static and dynamic efficiency (e.g., OECD, 2013; Klumpp & Su, 2010). Yet, OA has been used to describe a very diverse set of access concepts. While there is no explicit definition given by regulators or legislators, the term has been used in various contexts of access regulation, state aid and voluntary provision of wholesale access provision. Despite the widespread use, there is no common understanding of the term among scholars, regulators and industry practitioners. Therefore a clarification of the actual OA notion and the related concept of non-discrimination is needed. In particular, a structured evaluation of the diverse applications is required in order to allow for precise

policy conclusions that can guide the search for a new European regulatory framework.

With regard to this ongoing discussion, this article is concerned with the application of OA at the network infrastructure level as well as with current regulatory issues and use cases that have influenced the European debate. At the same time, the history of OA as a regulatory remedy goes back for several decades and encompasses applications in telecommunications, but also in other industries such as the media sector. Policy debates about appropriate access provisions within the US have coined and significantly shaped the understanding of the OA principle. While covering the details of these historic applications is beyond the scope of this work, information drawn from the US is included when it can be applied to and interpreted in the European NGAN context. Moreover, the article does not explicitly address the current Net Neutrality controversy (which is, e.g., surveyed by Krämer et al., 2013) nor a comparison of both concepts (which is, e.g., discussed by Hogendorn, 2007). However, the proposed framework may serve as the basis for further refinements and extensions that focus particularly on quality of service (QoS) characteristics and requirements in access relationships among network operators as well as between network operators and application services providers. On top of the telecommunications network infrastructure, digital convergence is likely to raise new questions whether traditional network concepts should be applied to higher layers of the value chain. Therefore, the conclusion of this article points to potential applications of OA at the services level of the Internet value chain.

Along these lines, the remainder of this paper is structured as follows: In Section 2 the various notions of OA that were proposed by different stakeholders are presented and subsequently reconciled into a unified definition. Moreover, a conceptual framework is developed that allows for the classification of the diverse OA application scenarios. Based on this classification, in Section 3 the extant economic literature is reviewed and policy implications are derived for each OA application scenario. Section 4 relates the various OA applications to each other and presents an overreaching policy guideline for the OA regulation of NGAN. Finally, Section 5 concludes by summarizing the main results and identifying possible limitations and extensions.

2. The Concept of Open Access

There is a fundamental lack in common understanding what actually defines an OA policy and along which dimensions OA regulation can be structured. For example, while OA has been used to describe access obligations including price regulation in the US (Speta, 2000; Farrell & Weiser, 2003), the European Commission's understanding of OA refers to mandated access in the case of state aid (European Commission, 2013c), and on the other end network operators have put emphasis on voluntary access (Deutsche Telekom, 2011).

In the following, the definitions of OA proposed by the European Commission, the German telecommunications industry, and proponents of the open access network model are presented. The definitions indicate that there is common ground in referring to non-discrimination as the central criterion, but they also illustrate that stakeholders highlight different additional aspects. As mentioned above, these aspects differ with respect to how open access terms shall be reached (mandated or voluntary), but also with respect to which access levels of the value chain are concerned and whether the notion of OA requires

a specific organizational form of the access provider (vertical separation, public-sector participation).

2.1. Open Access in the Context of Public-Sector Participation

The emphasis on the European context is founded in the European Commission's use of the actual term in the State Aid Guidelines in 2009, thus introducing OA as a legal criterion that European network operators have to fulfill when they receive state aid (European Commission, 2009). Since the European Commission has refrained from giving an explicit legal definition, various stakeholders have subsequently engaged in interpretations and new definitions of the term, in particular in the context of public-sector participation, but also with regard to a potentially larger application scope.

The implicit definition that can be derived from the State Aid Guidelines is summarized by the Body of European Regulators for Electronic Communications (BEREC, 2011, p. 8):

> "The term open access [...] refers to mandated wholesale access whereby operators are offered effective, transparent and non-discriminatory wholesale-access to the subsidized network(s)."

The notion of non-discrimination is defined in Article 10 of the European Access Directive and requires equality between the integrated downstream subsidiary and an independent retailer as well as between two independent retailers (European Commission, 2002). However, this does not prohibit differentiated access offers in general. In particular, different prices can be charged if this differentiation is based on objectively justifiable reasons. The recommendation on non-discrimination explicitly mentions that volume discounts and/or long-term access pricing can be compatible with the non-discrimination criterion (European Commission, 2013a). In order to safeguard effective implementation in the context of such volume discounts, the recommendation stipulates that favorable conditions to the subsidiary are not allowed to exceed the highest discount offered to independent downstream firms.

In the US context, OA has been mentioned, on the one hand, in association with state-owned municipal networks (Lehr et al., 2004), where OA was seen as an instrument to ensure non-discriminatory access and may be adopted voluntarily or mandated. On the other hand, OA has frequently been used interchangeably with mandated price-regulation (Speta, 2000).

2.2. Voluntary Open Access

In Germany, OA has played a prominent role in the debate about potential regulatory regimes governing NGAN. In the context of regional deployment of NGA networks and in the advent of new business models, OA has been seen as a solution to drive rapid construction, fast penetration and interoperability. The Federal Network Agency, Germany's national regulatory authority (NRA), established the "NGA-Forum" with the goal to promote the standardization of access products which it views as a prerequisite for symmetric OA. In contrast to the European Commission, which has characterized OA as mandated wholesale access, network operators here have tried to establish OA as a concept that relies on the voluntary decision by the particular access provider. A definition representing the consensus among network operators was presented at the German IT-Summit (2010, p. 4):

> "Open Access in FTTB/FTTH-Networks refers to the voluntary, non-discriminatory access at different levels of the value chain."

2.3. The Open Access Network Model

Already prior to the State Aid Guidelines, a strand of literature emerged based on a notion of OA which not only requires non-discrimination, but also functional separation between network operators and the services companies. The OA network model is hereby characterized by the separation of roles between the service provider and the network owner. Battiti et al. (2005) stipulate the belief that vertical integration of communication networks is the main reason for "high costs of services and barriers of competition" (p.1). While a further economic analysis or elaborated reasoning to back the hypothesis of hindered innovation due to vertical integration is often neglected, proponents instead often point to public infrastructure such as roads in the case of transportation as a proven benchmark. In their view, a concept relying on mutual control and shared usage of physical access networks is able to lower costs for deployment and usage of access networks, while providing users with a greater choice and service providers with more freedom (Battiti et al., 2005). This line of argument focuses rather on aspects of static efficiency of network operations, e.g., fair competition among service providers, than aspects of dynamic efficiency as actual investment for building networks is believed to be facilitated by technological innovation, e.g., wireless networks (Bogliolo, 2009). A summarizing definition of OA as viewed by this strand of the literature is given by Forzati et al. (2010, p. 1):

> "In the open access network model, the roles of the service provider and the network owner are separated, and the service providers get access to network and the end customers on fair and non-discriminatory conditions."

As can be seen by the manifold definitions, the criterion of non-discrimination is central to the concept of OA. However, there is a diverse understanding among stakeholders of how the goal of non-discriminatory access is effectively and efficiently achieved. Therefore, the definitions differ according to the requirements they postulate and whether OA should be established as a voluntary or regulated regime.

Based on these insights the following unifying definition is proposed:

Definition 1 (Open Access Regulation). *Open Access regulation refers to the mandated or voluntary provision of access to an upstream resource which must be based on the principle of non-discrimination. The concept may apply to publicly or privately owned access providers that are vertically separated, integrated or represent a cooperative of multiple entities. Open Access regulation usually refers to the network layer, but may also be applied to other layers of the telecommunications value chain.*

Considering this definition, it becomes clear that non-discrimination may be achieved by various approaches. In fact, even price-regulation can be included as a specific version of mandated OA that attempts to implement non-discrimination by setting a regulated access charge. In the narrow sense, however, open access refers to *mandated non-discrimination*, where the upstream provider may freely set the terms of access, but is forced to provide access on a non-discriminatory basis. Thus, following the previous discussion, the proposed definition also reconciles the different meanings of OA in Europe

and the US. As a consquence, scholars analyzing OA have to be aware of the large scope that the concept actually comprises and derived implications need to be explicitly related to a particular application of OA.

2.4. A Conceptual Open Access Framework

In order to allow for the classification of results obtained by the extant economic literature and in order to be able to derive coherent policy conclusions, a conceptual framework is offered that structures the further analysis of particular OA relationships and allows for a subsequent comparison of different OA models. The OA classification framework (Figure 1) is based on three dimensions that are deduced from the key characteristics of the presented definitions and represent the major determinants of access relationships in the NGAN context.

The *vertical structure* denotes how ownership in the access network (the upstream market) and activities in the services market (the downstream market) are related. Of course, the actual degree of integration may not only be defined by common ownership, but also by additional dimensions such as task integration, knowledge integration and coordination integration (Jaspers & van den Ende, 2006). While being aware of the fine-granular spectrum of vertical organization models, the subsequent analysis is structured by referring to the most relevant cases, i.e., i) an integrated firm that is also active in the downstream market, ii) a separated wholesaler, or iii) a cooperative undertaking between several downstream competitors (co-investment).

Ownership denotes the ownership structure and the goals of the access provider that vary with the influence of the public sector. The access provider may be entirely state-owned, as in the case of municipal public utilities or public access networks (e.g., the Australian National Broadband Network), represent a Public-Private-Partnership (PPP) or a private-sector, profit-oriented corporation. PPP models again can be differentiated according to the allocation of responsibilities concerning financing, design, construction and operation of the access network (European Commission, 2011). The goals of the organization according to its ownership structure may range from pure profit-maximization to non-profit pursuit of public interests. A further differentiation may be needed in the case of a private network operator specifying whether the firm is subject to price-regulation or whether it is unconstrained in setting its wholesale prices.

The *access level*, finally, indicates at which level of the value chain access is given to downstream competitors. In this vein, the concept is readily applicable to a wide and diverse set of access relationships. Since the emphasis of this article is on NGAN, the following analysis is particularly concerned with access levels to "Internet infrastructure services", i.e., OSI layers one through three, according to the terminology introduced by Jordan (2009). While most incentive-based arguments concerning vertical integration and public ownership apply equally to higher levels of the Internet value chain, specific characteristics of "Internet application services" (Jordan, 2009) need to be considered in addition.[1] The set of feasible access options to network facilities may differ across access technologies (e.g., coaxial, copper, fiber networks) and depend as well on the network architecture (e.g., point-to-point and point-to-multipoint). Access may also be granted at

[1] In the conclusion of this article it is discussed how the framework can also be applied to higher access levels.

different geographical locations. Moreover, the introduction of QoS and respective traffic classes may increase the technical and commercial possibilities of further differentiation in access agreements between network operators. Eventually, the access level defines the degree of control and the potential quality differentiation that the access seeker can achieve. Therefore, this dimension reflects also a well-known concept in telecommunications regulation: the *Ladder of Investment* (Cave & Vogelsang, 2003; Cave, 2006a). Figure 1 illustrates potential access levels in the case of a fixed NGAN. A more elaborate discussion of the Internet layers as well as architectural principles can be found in Van Schewick (2010). Claffy & Clark (2013) point to a further important differentiation when considering access to (infrastructure) platforms in convergent networks, namely the distinction of the platform's intended use (closed vs. open to complementors) and its construction (single- vs. multi-firm formation). Thus, their framework is especially suited to guide consistent regulation of emerging "spezialized" or "managed services" and coexisting open systems like the Internet that are based on identical physical networks.

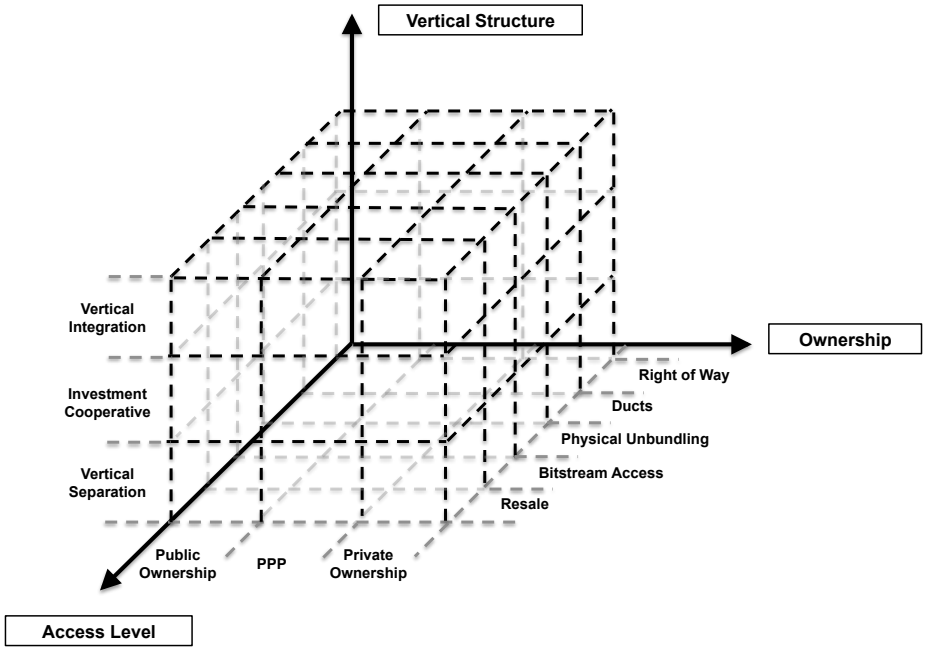

Figure 1: OA classification framework: vertical structure (impact on downstream market), ownership (goal of organization), and access level (quality differentiation) .

Based on these three dimensions bilateral access relationship can be characterized, but also more complex ventures (as, e.g., proposed by Forzati et al., 2010) can be illustrated by displaying the distinct and potentially heterogeneous individual relationships. Note, however, that access relationships are primarily defined by the vertical structure and the ownership, whereas the access level defines the spectrum of this particular relationship. Therefore, it is sufficient to consider the dimensions of vertical structure and ownership to distinguish four general settings of potential OA applications.

1. **Vertically integrated network and services providers** that are typically represented by national incumbents or regional operators of NGAN. In this context, an obligation to provide non-discriminatory access may be seen as an alternative instrument to cost-based price regulation. Further discussions have evolved around the question whether OA could be realized as a voluntary concept.
2. **Vertically separated, profit-maximizing network operators** including organizations that were established by vertical separation of formerly integrated operators (e.g., Openreach in the UK) and cross-industry entry of companies that are active in other markets such as energy utilities (e.g., RWE Germany). OA is envisioned to stimulate wholesale agreements by means of transparency and standardization resulting as a consequence of the non-discrimination condition.
3. **Cooperative undertakings by private-sector organizations** including risk- and network-sharing contracts as well as agreements on geographically complementary investments. Here, OA may serve as a regulatory tool to govern ex-ante access to the cooperative or ex-post access to the network.
4. **Public-sector participation** including local and nation-wide initiatives, state aid, public outsourcing, and public-private joint-ventures where the physical network is designed, built and maintained by the public entity while private firms operate the active network facilities and provide services. In this context OA is usually seen as an instrument to minimize the distortion of competition by state activity and is in general stipulated as a mandatory obligation.

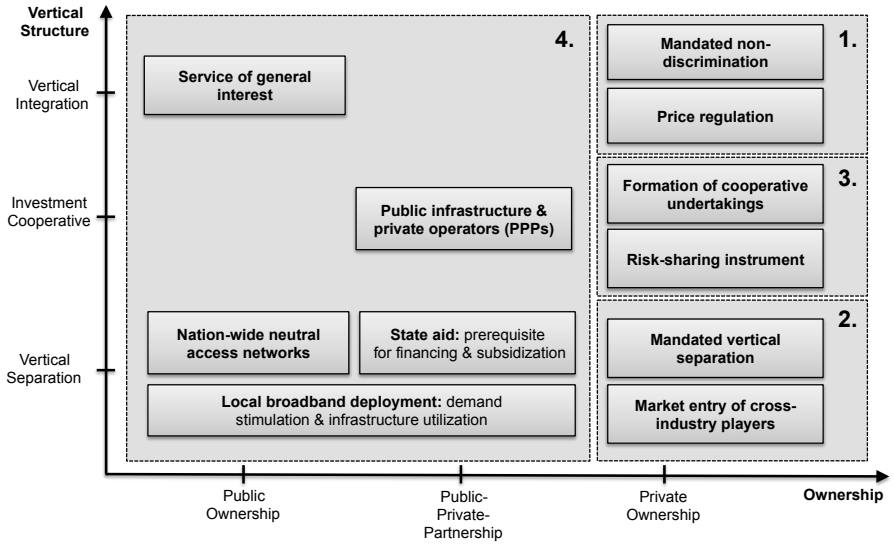

Figure 2: Classification of OA application scenarios.

3. Literature Survey

Based on the preceding classification, each of the identified OA applications is assessed from an economic perspective. To this end, implications for each of the respective forms of vertical structure and ownership are derived by surveying the extant economic literature. A particular emphasis is put on the presentation of the prevailing effects that have been identified by scholars as determinants of static and dynamic efficiency. In addition, regulatory and legal aspects that follow from particular characteristics of the access provider are noted. More precisely, the following list comprises the set of efficiency measures and determinants that are used throughout the assessment:

- *Static efficiency* is measured by social welfare and constituted by allocative and productive efficiency. Relevant determinants include the presence of transaction costs, economies of scale and scope, price and non-price discrimination, foreclosure, intensity of competition, and externalities.

- *Dynamic efficiency* encompasses technological progress and innovation, i.e., improvements in productive efficiency, which can be measured by social welfare over time (Kolasky & Dick, 2003; Viscusi et al., 2005). The literature on telecommunications has employed several proxies in order to quantify dynamic efficiency, such as the magnitude of investments, coverage, innovation, or the extent of infrastructure-based competition. In vertically related industries these outcomes are affected by the degree of coordination between upstream and downstream segment, and by the prevailing investment incentives of the incumbent as well as potential entrants.

- *Regulatory and legal requirements* describe the necessary degree of information and monitoring capability, accountability, task complexity and effectiveness.

3.1. Scenarios 1 and 2: Vertical Integration and Separation of the Access Provider

Liberalization in the telecommunications sector was driven by the perception that telephony service and long-distance networks could potentially be served by multiple competing firms. In contrast, the access network was still seen as a natural monopoly by the consensus opinion. Accordingly, questions concerning vertical separation have mostly been analyzed by assuming a monopolistic supplier that serves an oligopolistic or competitive downstream market. Addressing doubts about the natural monopoly assumption due to new access technologies (mobile, fixed-wireless), the recent literature on investment and regulation (see, e.g., Vareda, 2011) and on price discrimination (Inderst & Valletti, 2009) has extended the conventional model by allowing for potential replication of the upstream resource through market entry.

In general, the literature can further be distinguished according to whether the upstream firm possesses freedom in setting wholesale prices or if prices are set by the regulator. Particularly, the impact of price regulation on investment incentives has been thoroughly analyzed by a recent strand of literature. The results and remaining research questions of this literature are covered in a survey by Cambini & Jiang (2009), and therefore, they are not included in this overview. Further summaries that deal with specific aspects of the vertical structure in the telecommunications industry can be found in Tropina et al. (2010), Janssen & Mendys-Kamphorst (2008), Gonçalves & Nascimento (2010), and Yoo (2002).

Riordan (2008) presents a summary of the major theories explaining benefits and weaknesses of vertical integration in terms of static efficiency. It is shown that the perception about vertical integration as a beneficial or worrying practice has changed repeatedly since the 1950s according to the predominant theory at a particular epoche. Major insights have been obtained by the structure-conduct-performance theory dealing with vertical foreclosure and leverage of market power, the Chicago School stipulating the theories of single monopoly profit and elimination of price markups (Spengler, 1950), Transaction Cost Economics developing the theory of incomplete contracts (Whinston, 2003), and Post-Chicago Economics by pointing out to incentives on restoring monopoly power (Rey & Tirole, 2007b).

The general question what actually determines firms' boundaries and the degree of vertical integration is adressed in the first part of an extensive review by Lafontaine & Slade (2007). The authors present the most prominent theories along with prototypical analytical models and investigate whether derived predictions are supported by empirical findings. First, there is strong empirical support for the hypotheses derived from Transaction Cost Economics with regard to backward-integration. High asset specificity, transaction complexity and uncertainty are identified as drivers of integration between suppliers and manufacturers. Second, moral-hazard arguments established by agency theory seem to explain forward-integration between manufacturers and retailers very well, with the exception of the empirically observed negative relationship between downstream risk and vertical integration. The second part of the survey summarizes the observations made by the empirical literature which has studied the effects of vertical integration on firms' performance and on consumer surplus. The obtained conclusions are included separately hereafter in order to relate the empirical findings to the respective underlying theoretical concept.

The Single Monopoly Profit Theorem (SMPT). The theorem stipulates that an upstream monopolist will generally not inefficiently leverage its market power to complementary or downstream markets since it can generate the monopoly profit only once. Due to the incentive to maximize output of the complementary downstream products, the monopolist will decide to integrate forward only in the case if the downstream market is inefficient. However, this conclusion is subject to a number of exceptions as presented by Farrell & Weiser (2003) and builds on the following assumptions. First, the monopolist must have the ability to make enforceable multilateral commitments as shown by the theory of *restoring monopoly power* (Rey & Tirole, 2007b). Second, the monopolist must posses sufficient freedom to set wholesale charges in order to extract the monopoly rent. This is prohibited by most regulatory regimes that implement price regulation on a cost basis. In fact, it is the goal of regulated industries to prevent the monopoly profit in the first place. Moreover, the SMPT fails if the upstream monopoly is under threat itself by potential "two-level entry" and may be protected by foreclosing the downstream market.

Restoring Monopoly Power. Rey & Tirole (2007b) show that the ability by a monopolistic supplier to fully extract the monopoly profit breaks down if the wholesale firm is unable to commit to multilateral contracts. The monopolist has an incentive to offer a lower marginal access price to at least one downstream firm while taking a higher fixed premium. The downstream firm will accept the deal if the competitive advantage of the lower input price outweighs the additional fixed cost. Since downstream competitors

anticipate this incentive to discriminate, the supplier is unable to set the monopoly price in the first place. The network infrastructure, therefore, exhibits characteristics of a durable good (Coase, 1972). The commitment problem can be resolved and monopoly power can be restored by the supplier entering the downstream market through an own subsidiary. Alternatively, the separated monopolist may circumvent the commitment problem by negotiating an exclusive agreement with one of the downstream firms. Paradoxically, monopoly power may also be restored by regulatory activity. Rey & Tirole (2007b) show that a non-discrimination criterion (other than a most-favored-customer clause) will prohibit the supplier from providing preferential treatment to a downstream firm and bind the supplier to the uniform (monopolistic) access charge.

Raising Rivals' Costs (RRC). Critics of vertical integration have frequently raised the concern that a monopolistic supplier that is active in the upstream and downstream market has an incentive to distort downstream competition by raising rivals' costs. An assessment of this anti-competitive behavior has first been conducted by the seminal work of Salop & Scheffman (1983, 1987) and was followed by extensive analysis of RRC in the context of specific characteristics of network industries. In general, the integrated firm is able to raise costs either directly via the access charge (price discrimination) or through sabotage in the process of providing the input good (non-price discrimination). The former approach differs from the latter by the additional direct income effect for the upstream firm due to a higher wholesale price. In both cases the integrated firm may benefit from a competitive advantage in the downstream market derived from lower marginal costs. At the same time, decreasing market shares of independent retailers will lead to a diminished wholesale profit. Therefore, the decision to raise rivals' costs is always associated with a trade-off between upstream and downstream profits. In general, the empirical evidence with respect to observed foreclosure and RRC behavior according to Lafontaine & Slade (2007) is mixed, but there are several studies that uncover evidence of foreclosure in the case of industries characterized by natural monopolies, most notably in Cable TV. However, several studies point to the fact that efficiency gains due to vertical integration may outweigh the costs of foreclosure and could therefore benefit consumers through lower prices.

Price Discrimination. Assessing the incentives and welfare implications of price discrimination in the case of a regulated upstream market, Vickers (1995) shows that the integrated firm has an anti-competitive incentive to favor its subsidiary. Since entry in the downstream market is assumed to be costly in terms of duplication costs, it is concluded that price discrimination may also have a positive effect on total welfare by reducing inefficient entry. Likewise, Reitzes & Woroch (2009) find that the integrated input monopolist will engage in price discrimination against downstream rivals. However, the integrated monopolist may also set an input price above marginal cost to its downstream affiliate.

For an unregulated industry, the ability to discriminate in wholesale prices leads to contrary results depending on whether upstream firm faces the threat of demand-side substitution. DeGraba (1990) shows that under the assumption of an unconstrained monopolist, the more efficient downstream firm is optimally charged higher input prices. However, with respect to dynamic efficiency a ban of price discrimination increases investment incentives of retail firms. When introducing the possibility for demand-side

substitution these results are reversed (Inderst & Valletti, 2009). In particular, more efficient firms receive a discount compared to their less efficient competitors. Thereby, price discrimination hurts consumers in the short-run, but improves investment incentives, thus creating long-run benefits.

Non-price Discrimination. The literature on sabotage distinguishes between cost raising strategies that increase rivals' per-unit costs on top of the wholesale rental charge, and degradation of quality that lowers the demand of downstream competitors (Brito et al., 2012). Under a linear demand structure cost-raising and demand-reducing sabotage are indistinguishable (Reitzes & Woroch, 2009). Examples of non-price discrimination include poor quality of interconnection, delay in processing orders, creation of incompatibility, bundling of complements (Economides, 1998), or preferential treatment of affiliated content (Brito et al., 2012).

Incentives for sabotage emerge only in the presence of binding input price regulation (Beard et al., 2001; Reitzes & Woroch, 2009) and in the case that downstream firms can reap profits, i.e., that the downstream market is not perfectly competitive (Mandy, 2000). If prices are regulated, the input monopolist has to weigh higher downstream profits against lost upstream earnings when deciding whether to engage in non-price discrimination. While raising rivals' cost will lead to an increase in downstream prices and higher output by the integrated affiliate, the reduced market share of independents will reduce the demand for input (Economides, 1998). The theoretical literature has shown that while in most cases the integrated firm has an incentive to discriminate, there are exceptions in particular settings.

The results of the many theoretical models developed by scholars differ according to some key modelling decisions and assumptions about the market structure. The incentive to discriminate is altered by the downstream market structure (degree of product differentiation, costs of sabotage to the perpetrator, presence of scale economies, relative efficiency of competitors, competition intensity), characteristics of the upstream segment (upstream margin, potential upstream competition), and the model of the integrated firm (separated or common profit maximization) (Mandy, 2000). Some key results are highlighted in the following.

Economides (1998) stipulates that the sum of the three described income effects incurred by non-price discrimination is generally positive, and that the monopolist raises costs until competitors are forced out of business. According to this model, the result remains unaffected by a cost advantage or disadvantage of the monopolist's subsidiary compared to independent downstream firms.

Mandy (2000) concludes that the integrated monopolist abstains from sabotage if a) the downstream market is competitive (low degree of double marginalization), b) there is a sufficient upstream profit margin, and c) the monopolist's subsidiary is substantially less efficient compared to its competitors. Referring to the latter aspect, Weisman & Kang (2001) highlight that the incentive to discriminate is most pronounced in the situation where integration is highly efficient. Thus, the regulator is presented with the challenge to choose between productive and allocative efficiency. Symmetric considerations hold for the upstream market: If the monopolist would be required to decrease its market share, wholesale revenues decrease and the incentive to discriminate is raised (Weisman, 1995).

In the case that the upstream monopolist integrates forward and represents a new

entrant into the downstream market, Sibley & Weisman (1998) stipulate that for initially low market shares, the integrated firm has no incentive to raise rivals' costs. Analyzing the impact of downstream competition, Mandy & Sappington (2007) confirm the stated results for cost raising strategies in quantity-setting (Cournot) and price-setting (Betrand) competition, as well as cost raising sabotage in quantity-setting competition, but find opposing results for quality reducing behavior in price-setting competition.

Brito et al. (2012) analyze quality degradation in the presence of product differentiation. The authors show that the integrated firm has an incentive to discriminate, if the competitor provides an inferior product compared to its own subsidiary and the upstream margin is sufficiently low. They further show that a disparity in quality and low access prices may also lead to discrimination in the separation case, since the upstream firm benefits from a larger market share of firms that produce superior quality products.

With regard to regulated upstream prices, the integrated firm has an unambiguous incentive to discriminate if the access charge is set equal to marginal costs of providing the input (Sibley & Weisman, 1998; Kondaurova & Weisman, 2003; Reitzes & Woroch, 2009). Obviously, the monopolist will engage in sabotage since there are no opportunity costs in terms of lost wholesale profits. Only in the case of price competition this result may be reversed (Mandy & Sappington, 2007).

Reitzes & Woroch (2009) highlight the fact that pricing parity in the form of cost-based regulation incentivizes the upstream firm to provide excessive quality to its integrated affiliate, allowing it to charge higher access fees to its downstream competitors while degrading their input quality.

Double Marginalization. A well known beneficial effect of integration in terms of consumer and total welfare is the elimination of markups that may exist in a vertically separated industry. Except for the case of a perfectly competitive downstream market, double marginalization leads to the contraction of output and higher retail prices if price discrimination is difficult. In contrast, if the upstream monopolist is able to discriminate, e.g., by two-part tariffs, no double marginalization occurs, but at the costs of full monopoly profits. Under integration, i.e., common ownership, the subsidiary will consider the actual upstream production costs instead of the access price as marginal costs (Brito et al., 2012). Thus, double marginalization is also prevented in the case of linear tariffs (Riordan, 2008).

Economies of Scale and Scope. Proponents of vertical integration point out that separation prohibits the exploitation of substantial economies of scale and scope. In fact, empirical analyses in adjacent network industries have obtained mixed results. While other utility industries may have rather different technological characteristics and the magnitude of efficiencies may depend on the historical development of the sector, they share the necessity of high sunk upfront investment costs in the upstream market that have to be geared to the needs of the downstream services. In a conceptual comparison of the vertical structure in infrastructure sectors Pittman (2003) discusses the respective magnitude of vertical economies, but concludes that rapid technological change in the telecommunications sector complicates the formulation of a universal hypothesis about the extent of these efficiencies. Thus, in the light of the following ambivalent empirical results obtained for other infrastructure industries, one should abstain from a per se hypothesis that vertical economies are exceedingly high in general. Kwoka (2002), finds

evidence for economies of scope in the US electricity sector. In particular, economies of coordination between generation and distribution are identified as the main drivers of integration. These findings are in accordance with the early work of Kaserman & Mayo (1991) and similar results were replicated for the Spanish electricity market (Jara-Dıaz et al., 2004). However, it is further shown by Kwoka (2002) that there are potential instruments besides integration to achieve effective coordination. In particular, holding companies above a certain size can adequately substitute the coordination function of the integrated firm. In contrast to these studies, Nemoto & Goto (2004) find almost no economies of vertical integration for a set of Japanese utilities, while Garcia et al. (2007) show that no significant technological integration economies can be observed in a sample of the US water industry. Lafontaine & Slade (2007) report on the results of four studies that have investigated the effect of mandated separation in the gasoline refining and sales industry. They find an unambiguous negative impact on consumer surplus through higher costs and prices. Based on a conceptual analysis, De Bijl (2005) argues that separated operators face higher financing costs due to a lower scale compared to the integration scenario. Sidak & Crandall (2002) stipulate that mandated separation will create arbitrary and artificial boundaries that lead to inherently inefficient organizations. Furthermore, they refer to the indivisibility of intangible assets such as customer loyalty and goodwill. Additional costs are induced when separation is imposed on an initially integrated firm. Functional as well as ownership separation require costly structural reorganizations and the redesign of business processes (Cave, 2006b).

Dynamic incentives. Several scholars have argued that a lack of coordination has a negative impact on the efficiency of investments (De Bijl, 2005; Sidak & Crandall, 2002; Tropina et al., 2010). In a more differentiated analysis, Iossa & Stroffolini (2012) show that integration is particularly beneficial when little demand information is available, infrastructure cost is low, or investment is highly risky. Moreover, Crandall et al. (2010) has stated that separation creates a hold-up problem due to the inability to specify complete contracts. In contrast, Cadman (2010) argues that the hold-up problem is resolved by a sufficiently competitive downstream market.

Farrell & Katz (2000) have shown that integrated firms may have an incentive to engage in an "investment squeeze", forcing downstream competitors to engage in excessive investments. In fact, investment incentives in the downstream market may be strengthened by vertical separation. Since firms expect less discriminatory behavior in this case, perceived uncertainty is reduced and relationship-specific investment may be increased (Cadman, 2010).

With respect to the incentive to duplicate infrastructure, the consensus indicates that separation will diminish the incentives for future entry in the upstream market (De Bijl, 2005; Tropina et al., 2010). To some degree, this can be seen as the consequence of mitigated incentives for anti-competitive behavior by the upstream monopolist.

Regulatory and Legal Aspects. The literature has described several advantages of vertical separation from a regulatory perspective. The break-up into two separate organizations increases transparency, therefore making it significantly easier to oversee the behavior of the upstream monopolist (Cadman, 2010; Pittman, 2003). Moreover, the separation of business activities prevents distortion of competition through cross-subsidization. Even

in the case of vertical integration, the ability to impose separation alone can be an effective instrument to motivate the monopolist to adapt its behavior to regulatory rules (De Bijl, 2005). On the other hand, the decision to impose separation may be approached with caution. Due to the high costs of separation, the process is considered to be irreversible (Teppayayon & Bohlin, 2010). Especially in the case of high uncertainty about the outcome of separation, regulators should therefore abstain from mandated separation.

Implications. Static efficiency effects in integrated telecommunications industries have been thoroughly examined by the economic literature. Integrated operators are shown to benefit from economies of scale and scope as well as low information costs between the retail and wholesale division. The inherent incentive to price-discriminate has traditionally been countered with regulating wholesale prices, which in turn raises the issue of non-price discrimination, e.g., by raising rivals costs through sabotage. At the same time the implementation of regulatory control is faced with imperfect information.

OA, in the narrow sense, may represent an opportunity to take a first step towards deregulation by abstaining from price regulation. Non-discrimination obligations may facilitate regulatory monitoring by equivalence of input conditions or more easily obtained benchmarks for margin squeeze tests. Moreover, imposing OA in the case of an integrated access provider can potentially increase the transparency of wholesale offers and prices, therefore lowering transaction costs for wholesale agreements and entry barriers to service-based competition. However, further research is needed in order to decide whether OA can contain opportunistic behavior by the integrated operator.

Ensuring OA by imposing separation of upstream from downstream activities represents an effective instrument to counter non-price discrimination by removing the underlying incentives to discriminate against particular downstream firms and by simplifying regulatory oversight. However, the regulator has to be aware that these gains come at the costs of double marginalization, increased transaction costs, substantial separation costs, and diseconomies of scale.

The literature on dynamic efficiency points to ambivalent effects with respect to upstream investment incentives. Further research is expected in this area in order to clarify and quantify particular investment incentives. For instance, the coordination of investments by internalizing incentives of the downstream market is generally stated as a strong argument in favor of integration. However, this proposition may have to be reevaluated in the context of NGAN. Due to a layered architecture founded on the universal IP standard and the perception that fiber technology will not present an innovation bottleneck soon, the negative impact on innovation may not be that substantial in the short term.

3.2. Scenario 3: Co-Investment

Bourreau et al. (2012) present a brief summary of the advantages and disadvantages of co-investment. Accordingly, cost-sharing and risk-sharing rules have the potential to increase NGAN coverage and enhance consumer surplus. They point out that the frequently mentioned benefits of cost sharing are directly associated with sharing the subsequent revenues. Therefore, the business case of the particular investment project does not improve, unless the co-investment approach leads to more product differentiation in the downstream market, subsequently inducing a demand expansion effect.

Description	Int.	Sep.	Description & References
Static efficiency			
Double Marginalization	(+)	(–)	The subsidiary of an integrated firm considers the actual marginal costs of upstream production (Riordan, 2008; Brito et al., 2012).
Restoring monopoly power	(–)	(0/–)	Through integration the upstream monopolist can overcome its commitment problem. (Rey & Tirole, 2007b).
Price discrimination	(0/–)	(0/–)	In the absence of regulation, integrated firms may have incentives to engage in a price squeeze (Vickers, 1995; Farrell & Katz, 2000; Lafontaine & Slade, 2007). Under separation this anticompetitive incentive is eliminated, however, an uncontested upstream monopolist will charge more efficient firms a higher price. (DeGraba, 1990; Inderst & Valletti, 2009).
Non-price discrimination	(0/–)	(0)	In the case of price-regulation, the integrated operator is likely to distort downstream competition, but particular exceptions exist (inter alia: Economides (1998); Mandy (2000); Brito et al. (2012)).
Economies of scale	(0/+)	(–)	Larger scale decreases financing costs (De Bijl, 2005).
Economies of scope	(0/+)	(–)	Empirical evidence of scope advantages in the electricity industry (Kwoka, 2002; Jara-Dıaz et al., 2004). Contrary results in the case of Japanes utilities (Nemoto & Goto, 2004) and the water industry (Garcia et al., 2007).
Separation costs	(0)	(–)	Redesign of business processes (Cave, 2006b). Artificial boundaries lead to inefficient organizations (Sidak & Crandall, 2002).
Dynamic efficiency			
Coordination of investments	(+)	(0/–)	A lack of coordination may lead to inefficient investment (De Bijl, 2005; Sidak & Crandall, 2002)
Hold-up problem	(+)	(0/–)	Separation and incomplete contracts lead to opportunistic ex-post behavior delaying investments (Crandall et al., 2010). Resolved by a sufficiently competitive downstream market (Cadman, 2010).
Investment squeeze	(–)	(0)	Integrated firms may force downstream competitors to engage in excessive innovation (Farrell & Katz, 2000).
Upstream investment incentives	(+/–)	(–)	Ambivalent effects under integration (Cambini & Jiang, 2009). Reduced incentives for infrastructure-based competition in the case of separation (Tropina et al., 2010; De Bijl, 2005).
Downstream investment incentives	(–)	(+)	Trust induced by separation decreases perceived uncertainty (Cadman, 2010).
Regulation			
Transparency	(–)	(+)	Separation facilitates regulatory oversight (Cadman, 2010; Pittman, 2003; Economides, 1998) and prevents cross-subsidization (De Bijl, 2005).
Coercion	(0)	(+)	The regulator's ability to impose separation can be used as coercive instrument (De Bijl, 2005).
Irreversibility	(0)	(–)	The decision to separate can not be reversed ex-post, while effects may be uncertain ex-ante (Teppayayon & Bohlin, 2010).

Table 1: Summary - Vertical Integration & Separation.

Note: The signs (+), (0), and (–) qualitatively indicate the consensus of the surveyed literature on whether the issue has a positive, neutral, or negative impact, respectively, on the efficiency goals or the regulatory and legal requirements. For instance, the first row indicates that static efficiency is increased (decreased) due to double marginalization under integration (separation). (+/–) points to contradictory theories or evidence while (0/+) or (0/–) represent intermediate measures. This notation applies equally to the subsequent tables.

Nitsche & Wiethaus (2011) characterize risk-sharing as an alternative to regulatory instruments such as cost-based price-regulation (LRIC), fully distributed costs regulation, and regulatory holidays. In the case that there is no access regulation or risk-sharing agreement, no access to the downstream market is provided to the entrant ex-post. Risk-sharing is found to induce the strongest degree of competition compared to all other regulatory regimes and to attain a higher level of investment than the LRIC approach.

Rey & Tirole (2007a) discuss different rules that govern the access to cooperative undertakings for future entrants. In particular, they compare the models of non-discriminatory and fully discriminatory cooperatives. While the former allows later members to join an existent cooperative and use the established infrastructure by paying a cost-based access charge, the latter charges an entry fee in addition to the access charge. It is shown that investment is discouraged by an "open access" policy since future entry will marginalize profits to zero. In contrast, investment is encouraged by a "closed access" model, but at the same time, excessive restriction of access leads to a suboptimal outcome from a welfare standpoint. Therefore, Rey & Tirole (2007a) conclude that the access model involves the essential characteristics of the trade-off between static and dynamic efficiency (Gayle & Weisman, 2007). In order to improve social welfare, the authors suggest to either constrain the market power of closed cooperatives or to give open cooperatives an instrument to protect their investment partially.

Krämer & Vogelsang (2013) investigate collusive behavior in cost-sharing undertakings in an experimental setup. The authors find that co-investment affects retail prices by two contrary effects with a similar magnitude. On the one hand, co-investment increases prices by facilitating tacit collusion in downstream markets. On the other hand, reduced investment costs due to co-investment are passed on to consumers. Moreover, the communication between firms, a necessary prerequisite to co-investment, is found to have a positive impact on investment.

Inderst & Peitz (2012) show that ex-ante access contracts reduce the incentive to duplicate infrastructure, but increase the area that is covered by at least one network compared to investment under ex-post contracts. At the same time, they show that reduced duplication allows the access provider to engage in price discrimination against independent downstream firms under the general assumption that aggregate demand of the market is price-dependent. Consumers are therefore harmed by potentially higher downstream prices, but may benefit from ex-ante contracts making investment profitable in the first place. The authors also mention that ex-ante contracts will naturally mitigate the hold-up problem, since the ex-ante commitment prohibits ex-post haggling by the access seeker.

Bourreau et al. (2013) agree that ex-ante cooperative agreements can potentially increase coverage, but qualify these results subject to particular conditions. The authors show that the results hold only in the presence of a demand-expansion effect, high cost savings from joint investment or a combination of both. While the former may be induced by high service differentiation the latter is especially pronounced in the case of high uncertainty. Under mandated access regulation, investment incentives are reduced since the agreement to an ex-ante contract is now presented with a forgone option in the future. As in the case of unilateral investment, coverage decreases with lower access prices. On the contrary, under a voluntary access regime, coverage is increased at the cost of a less competitive downstream market.

	Effect	Description & References
Static efficiency		
Cost reduction	(+)	Instrument to lower financing costs, lower up-front costs per operator but joint production may exhibit diseconomies of scale (Bourreau et al., 2013).
Collusion	(–)	Experimental evidence of tacit price collusion (Krämer & Vogelsang, 2013).
Downstream Competition	(+/–)	Multiple firms in downstream market while avoiding duplication and regulation, ex-ante contracts can be used to dampen competition (Inderst & Peitz, 2012).
Dynamic efficiency		
Uncertainty	(+)	Spreading overall risk facilitates investment (Bourreau et al., 2013).
Investment incentives	(+/0)	Strong incentives for closed cooperatives, weak incentives for open cooperatives (Rey & Tirole, 2007a). Ex-ante contracts increase coverage and decrease duplication (Inderst & Peitz, 2012). Coverage only increases if there exists a demand expansion effect (Bourreau et al., 2013).

Table 2: Summary - Co-investment.

Implications. In summary, the literature indicates that the cooperative undertakings face a similar trade-off between static and dynamic efficiency with regard to access as in the case of unilateral investment. The introduction of a temporal dimension, however, may present opportunities to balance this trade-off. The regulator may prescribe (open) access ex-ante, i.e., before the investment, but not ex-post. The results obtained by Nitsche & Wiethaus (2011) point towards this direction, but need further assessment and robustness tests in more general settings (Inderst & Peitz, 2012). In particular, this raises the question about adequate parameters to balance this trade-off in the context of co-investment. For instance, what would be the necessary number of co-investment participants to secure downstream competition while abstaining from access regulation? This would also provide a valuable contribution to a more general issue currently debated in European mobile telecommunications markets: What is the minimum number of market participants that is necessary to establish a competitive market?

The context of cooperation opens the analysis to a broader behavioral evaluation. The results obtained by Krämer & Vogelsang (2013) point to several effects that are neglected by theoretical models. This includes especially the analysis of tacit and implicit collusion during the investment phase and the setting of downstream prices. Identifying the behavioral cause of particular effects may also present new approaches to support regulatory practice. For example, the significant impact of communication itself suggests that improving coordination of investments besides the formation of joint undertakings may already increase dynamic efficiency. Going further, behavioral approaches may not only be suited to identify these effects, but facilitate the design of instruments to govern the interactions.

3.3. Scenario 4: Public-Sector Participation

In order to provide a brief introduction into the vast literature on the general role of public-ownership, this sections commences with a reference to an overview of the fundamental theories within and a summary of several empirical surveys on the observed effects of public ownership. Thereupon, two more specific issues that have been related to OA and the deployment of NGAN networks are reviewed, namely the activities of municipalities and the formation of PPPs.

Summarizing the fundamental insights of the economic literature on private and state ownership, Shleifer (1998) concludes that private ownership should be the preferred option whenever innovation or cost efficiency represent major criteria. The static perspective and the exclusive concern about prices of state ownership deteriorate dynamic incentives and endanger social welfare in the long-run. Instead, government contracting and regulation are qualified as suitable instruments to ensure public goals that avoid an excessive role of the state sector. Moreover, Shleifer (1998) refers to the results presented by the public choice theory which highlight the adverse incentives for government and administration officials under state ownership.

Megginson & Netter (2001) survey the empirical literature on privatization and the relative performance of privately owned firms compared to state-owned enterprises (SOEs). Based on studies from numerous countries, which employ different methodological approaches, the authors are able to offer a number of general and robust conclusions. The empirical literature largely confirms that "privately owned firms are more efficient and more profitable than otherwise comparable state-owned firms" (Megginson & Netter, 2001, p.380). Furthermore, the consensus is that privatization leads to an improved operating and financial performance of former SOEs. Particularly, output, efficiency, profitability and capital investment spending increases in non-transition economies, while leverage significantly decreases.

Dewenter & Malatesta (2001) contribute to the empirical evidence that state-owned firms are significantly less profitable than privately owned firms. The dataset is based on Fortune magazine's list of the 500 largest firms worldwide in the timespan from 1975 to 1995. 147 of the 1369 firm-years sample are for govenment-owned firms, which are mainly located in Europe. Interestingly, in a survey of privatization procedures no evidence is found that the actual transfer of ownership leads to an increase in profitability. In fact, profitability is primarily increased prior to privatization, while afterwards no significant increase can be observed. This points to a structural transformation of the organization, conducted in advent of privatization, as the actual source of improved profitability.

Examining the privatization of national telecommunication companies, Bortolotti et al. (2002) provide specific empirical evidence for the telecommunications sector based on a global sample of 31 firms in 25 countries. The data set includes full and partial privatizations through public share offerings from 1981 and 1998. In line with the results of the general empirical literature on privatization, significant improvements of financial and operating performance are found. Efficiency gains are explained by better incentives and productivity, while significant cost reductions are also the dominant reason for increased profitability. Again, these improvements cannot solely be attributed to ownership change in most cases, but are also related to accompanying regulatory changes.

In an empirical study of US municipal utilities, Gillett et al. (2006) investigate the determinants that induce these utilities to expand their operations into telecommunications services. The ability to exploit economies of scope stemming from the provision

of internal communications services, and the location in markets with limited existing competition are found to be significant variables that lead a municipal electric to enter the telecommunications market. In contrast, rules that impede municipal entry are found to be effective in reducing municipal activity. The finding that rural areas are less likely to be served by a municipal utility is linked to substantial backhaul costs as a constraining factor. Due to the ambiguous impact of demographic variables, Gillett et al. (2006) conclude that the motivation of municipal utilities differs from private organizations. In particular, municipal supply may be motivated by the economic development of financially less attractive areas. Next to their empirical results, the authors stipulate several arguments in favor of a municipal approach: Utilities are depicted as early adopters that can accelerate the growth of NGA networks and may represent a superior governing mechanism compared to regulation of a private network operator, if infrastructure-based competition is infeasible.

Ford (2007) presents empirical support for the hypothesis that public investment in communications networks stimulates entry of private telecommunications firms, as opposed to crowding out private activity. The survey is based on a set of municipalities in the state of Florida, USA, of which a subset provides electricity and in some cases communications services. Private activity is measured by the number of competitive local exchange carriers (CLEC) that are active in the particular market. While the presence of public supply (electricity only) is associated with a lower number of private communications firms, the provision of communications services by the municipality increases the activity in the communications sector above the levels of cities that abstain from self-supply and municipals that provide electricity.

Using a comprehensive dataset that covers the US market from 1998 to 2002, Hauge et al. (2008) investigate market characteristics that may promote entry by municipal telecommunications providers relative to the motivation that may induce entry by CLECs. Based on their empirical analysis, the authors reject the hypothesis that municipal providers base their entry decision solely on expected profits. Interestingly, this is contrary to what the authors find with respect to CLECs. While CLECs are more likely to be located in urban areas with higher income and higher revenue possibility, municipal providers tend to serve complementary areas with higher cost structures and characteristics that predict lower demand. On the other hand, the results indicate a positive, but insignificant relationship between CLEC market participation and the presence of a municipal provider. Hence, the crowding out hypothesis, that the presence of a municipal provider impedes entry by a CLEC, cannot be rejected. In conclusion, the authors imply that municipalities do not represent a significant competitive threat to CLECs and do not impede private market entry.

Troulos & Maglaris (2011), in a qualitative survey of local broadband strategies in Europe, highlight the ability of municipal initiatives to stimulate demand for NGAN. The deployment of Metropolitan Area Networks connecting public institutions, implementation of e-Government services, price subsidization, and strengthened civil participation are presented as public instruments to boost network rollout. The role of municipal broadband as a complementary provider of basic infrastructure in rural areas and as a stimulator of private investments is emphasized. In line with Gillett et al. (2006), utilities which can exploit economies of scope are shown to be a major driver for the decision to provide municipal communications services. Supplementary, European-wide subsidies are seen as a public instrument to resolve the fragmentation and heterogene-

ity created by municipal approaches. Moreover, accompanying state aid regulation may introduce neutrality as the central principle for supply of access network. On the other hand, the authors mention the discouraging effect of state-owned network infrastructure on duplication incentives, crowding out private investment at the physical infrastructure level.

In a meta-analysis, Hodge & Greve (2007) review the effectiveness of PPPs, in particular, long-term infrastructure contracts with a focus on Europe. The analysis is preceded by a criticism of the extant literature, which highlights the lack of an actual evaluation of PPPs and calls for more empirical analysis which objectively quantifies costs and gains of such collaborations. Previous studies provide contradictory evidence on the performance of PPPs, raising doubts whether promised benefits of PPPs can actually be delivered in practice. Moreover, the results suggest that sector-specific variables have a substantial impact on the performance results. This gives rise to concerns about the accountability in PPPs, due to limited transparency, complexity of the negotiated deals and restricted public participation. In addition, administrative and political decision makers are incentivized by short-term gains, while long term contracts associated with infrastructure projects limit the future flexibility to rectify mistakes or to adapt to a changing environment. With regard to these issues, the authors highlight the importance of different organizational structures and the allocation of responsibility. The cross-country analysis indicates that PPPs in the UK and the Netherlands are implemented as top-down approaches, while undertakings in the North European countries and Germany are organized in a more decentralized way.

Gómez-Barroso & Feijóo (2010) summarize the historical and current debate about the respective roles of the public and the private sector in the telecommunications domain in their conceptual classification of recent contributions to the debate on private-public interplay. The authors state that public activity in the telecommunications industry is supported, although not demanded by the consensus of modern economic schools, due to the presence of market failures. The hypothesis that markets are in any case superior with regard to static efficiency is rejected, and instead, a pragmatic logic (Linder & Rosenau, 2000) is endorsed: PPPs should be considered whenever requirements differ from obviously private or public responsibilities. At the same time, the authors are cautious about the performance of PPPs, referring to the results by Rosenau (2000) that PPPs display weaknesses in the long-run and by Yescombe (2011) that PPPs introduce additional complexity.

Developing a theoretical model of incomplete contracts, Hart (2003) draws the conclusion that PPPs should be preferred over individual outsourcing contracts, whenever it is difficult to specify the quality of the infrastructure, but easy to specify the quality of the services. Since a PPP internalizes the operational expenditures, it engages in higher productive investment, reducing these costs, but also in excessive unproductive investment. In the opposite case, when infrastructure quality is easily specified, public outsourcing yields superior results, since it avoids unproductive investment. In conclusion, Hart (2003) emphasizes the role of contracting costs and criticizes the general perception that the private sector represents a cheaper source of financing than the state.

Based on a conceptual analysis, Given (2010) studies the reinvigorated role of the public sector and the impact of PPPs in the Australian and New Zealand telecommunications sectors. He finds that the proposed PPPs in telecommunications are not motivated by conventional reasons such as private financing and expertise, but rather by the willing-

ness to assert the pursuit of the public interest. Thus, the drastic steps of separation and nationalization are consequences of the concession that regulation as well as functional separation have proven to be insufficient instruments in ensuring public goals.

Implications. Participation of the public sector in its various forms can boost coverage and speed of network deployment. However, well-known concerns about cost efficiency, complexity and imperfect information should restrict the scope of public activity. Local initiatives and bottom-up approaches are likely to reduce these mentioned concerns. Moreover, municipal activity is capable of stimulating demand and extending the scope of viable investment cases due to the consideration of societal spill-over effects.

Besides the role as a financing facilitator, the public entity is likely to achieve its highest potential at the civil infrastructure level. Since civil infrastructure costs represent the largest share of total costs (Hoernig et al., 2012), exploiting economies of scope by providing ducts can reduce deployment costs significantly.

Mandated OA, as stipulated in the European State Aid Guidelines, can help to keep distortion of competition through the crowding-out effect at a minimum. In the context of state-owned access networks, the Australian case will give an indication whether OA can represent an effective alternative to regulation by ensuring the public interest while promoting efficient service-based competition on a neutral basis. However, while direct public control may facilitate the implementation of non-discriminatory access, the literature raises concerns about the adverse incentives of public decision makers and a lack of transparency and accountability in collaborations between state and private organizations.

4. Policy Guidelines

Up to now the discussion was concerned with the specific effects of a single OA application. Based on these results, this section addresses how the presented applications relate to each other. The preceding survey of the economic literature has shown that decision makers face multiple trade-offs when deciding for a particular regulatory regime. Therefore, in the context of NGANs, regulators are required to implicitly or explicitly weigh conflicting goals. Figure 3 illustrates the decision process proposed to assist regulators in choosing the most appropriate policy instrument, given their primary objective, observed market conditions, and their experience from previously implemented approaches. Rectangles represent the different regulatory scenarios and diamonds represent the key questions that policy makers must evaluate in order to determine the next steps and measures in the regulatory decision process. In this vein, the proposed policy guideline allows for an assessment of the transition between regulatory regimes when objects are not satisfactorily fulfilled, new problems or technological advancements arise, or the relative order of goals is reevaluated.

In order to make transparent where the identified trade-offs are discussed in the literature, references to representative articles are indicated at the respective decision branches. Moreover, it is highlighted whether these articles are overviews or whether they are based on conceptual, theoretical, or empirical analysis. Since the guideline is derived mainly from the findings within the economic literature, its scope is necessarily

	Effect	Description & References
Static efficiency		
Economies of scope	(+)	Utilities that provide internal communications infrastructure are more likely to expand their services (Gillett et al., 2006).
Economies of scale	(–)	Municipal approaches are unlikely to serve rural areas due to backhaul costs (Gillett et al., 2006).
Cost efficiency	(–)	Private ownership is superior in containing costs (Shleifer, 1998). State-owned firms are found to be significantly less profitable (Megginson & Netter, 2001; Bortolotti et al., 2002).
Dynamic efficiency		
Stimulation of demand	(+)	Municipal initiatives can stimulate demand (Gómez-Barroso & Feijóo, 2010).
Crowding-out effect	(+/–)	Municipal utilities substitutes private market entry (Gillett et al., 2006). Number of CLECs increases if a municipal provides communications services (Ford, 2007). Municipal providers serve complementary areas relative to CLECs (Hauge et al., 2008).
Quickness of deployment	(+/0)	Public utilities may serve as early adopters (Troulos & Maglaris, 2011).
Viability of investment	(+)	Public investors take into account spill-over effects to adjacent industries (Troulos & Maglaris, 2011).
Hold-up problem	(+)	Anticipation of the long-term socio-economic benefits (Troulos & Maglaris, 2011).
Innovation	(–)	State ownership neglects dynamic incentives (Shleifer, 1998).
Regulation		
Neutrality	(+)	State aid rules as a regulatory instrument to mandate non-discrimination (Troulos et al., 2010; Troulos & Maglaris, 2011).
Accountability	(–)	Limited transparency and public participation (Hodge & Greve, 2007).
Public interest	(+/–)	State ownership as an instrument to ensure public goals representing an alternative to regulation (Given, 2010). Adverse incentives of government and administrative officials (Shleifer, 1998).
Complexity	(–)	PPPs "add a substantial layer of extra complexity" (Yescombe, 2011, p.26).

Table 3: Summary - Public-sector participation.

incomplete and policy advice has to take into account complementary legal and technical considerations. Nevertheless, a visual representation and a predefined structure of the decision process, as laid out in the following, may also facilitate the interdisciplinary discourse between stakeholders.

The starting point of the proposed policy guideline is the regulatory status quo, which may either be constituted by an existing regulatory framework that is potentially to be replaced or complemented, or by an entirely unregulated industry where new rules are implemented based on a greenfield approach. Given a status quo, an evaluation of whether the existing legal and regulatory framework contributes to desireable sector performance is required in the first place. Policy makers will only be willing to make changes if there is potential room for improvement. The ensuing question of what can and what needs to be done is the underlying question that is addressed by the guideline. In any case, it needs to be verified whether (given the status quo) regulatory intervention is (still) justified at all. This is generally not the case if facility-based competition (FBC) is deemed feasible in the relevant time horizon. This would also imply that the essential facility doctrine does not hold (Renda, 2010), or in the case of Europe, that the three-criteria-test will fail. In these cases, deregulation has been suggested to be the optimal choice rather than continued regulation (Cave, 2006a; Vogelsang, 2013).

Given the need for regulation, policy makers must now select their primary objective. This may either be to promote competition (on existing network infrastructure) or to promote investment into new network infrastructure. Although some scholars argue that dynamic and static efficiency goals can be reconciled (Klumpp & Su, 2010), a growing strand of the literature has pointed towards a definite trade-off between these objectives (Bauer & Bohlin, 2008; Briglauer et al., 2013; Guthrie, 2006). The indication of slowly expanding NGANs in Europe seems to support the existence of an efficiency trade-off. Thus, policy makers must inevitably rank either competition or investment as being more important, while of course, trying to achieve the other as good as possible under this constraint. In this vein, this branch offers also a historical perspective. On the one hand, the political and academic debate of the last two decades was centered around the question of how to introduce and sustain a competitive downstream market on the basis of existing networks (Armstrong et al., 1996; Laffont & Tirole, 2001; Armstrong, 2002). On the other hand, more recently the need to promote investments in new NGAN infrastructure is considered to be the main regulatory challenge and, e.g., in the context of vectoring (see Bundesnetzagentur, 2013), several regulatory authorities have chosen investment over competition as their primary objective.

If competition is the primary objective, the introduction of service-based competition (SBC) based on *price regulation* is proposed as the first regulatory scenario that should be considered. The policy guideline implies that, in each regulatory scenario, policy makers must continuously evaluate whether the observed or expected market conditions still warrant to continue the current regulatory approach. In the case of price regulation, such evaluation loops are proposed with respect to investment incentives and competition. According to the Ladder of Investment principle (Cave & Vogelsang, 2003; Cave, 2006a), appropriate price regulation may incentivize entrants to invest into new infrastructures themselves. If this occurs, FBC may become feasible after all and regulation can be lifted. In reverse, even under price regulation, the incumbent may have a sufficiently large incentive to invest (Klumpp & Su, 2010), which would then overcome the efficiency trade-off. In this case, there is, of course, no reason to deviate from price regulation.

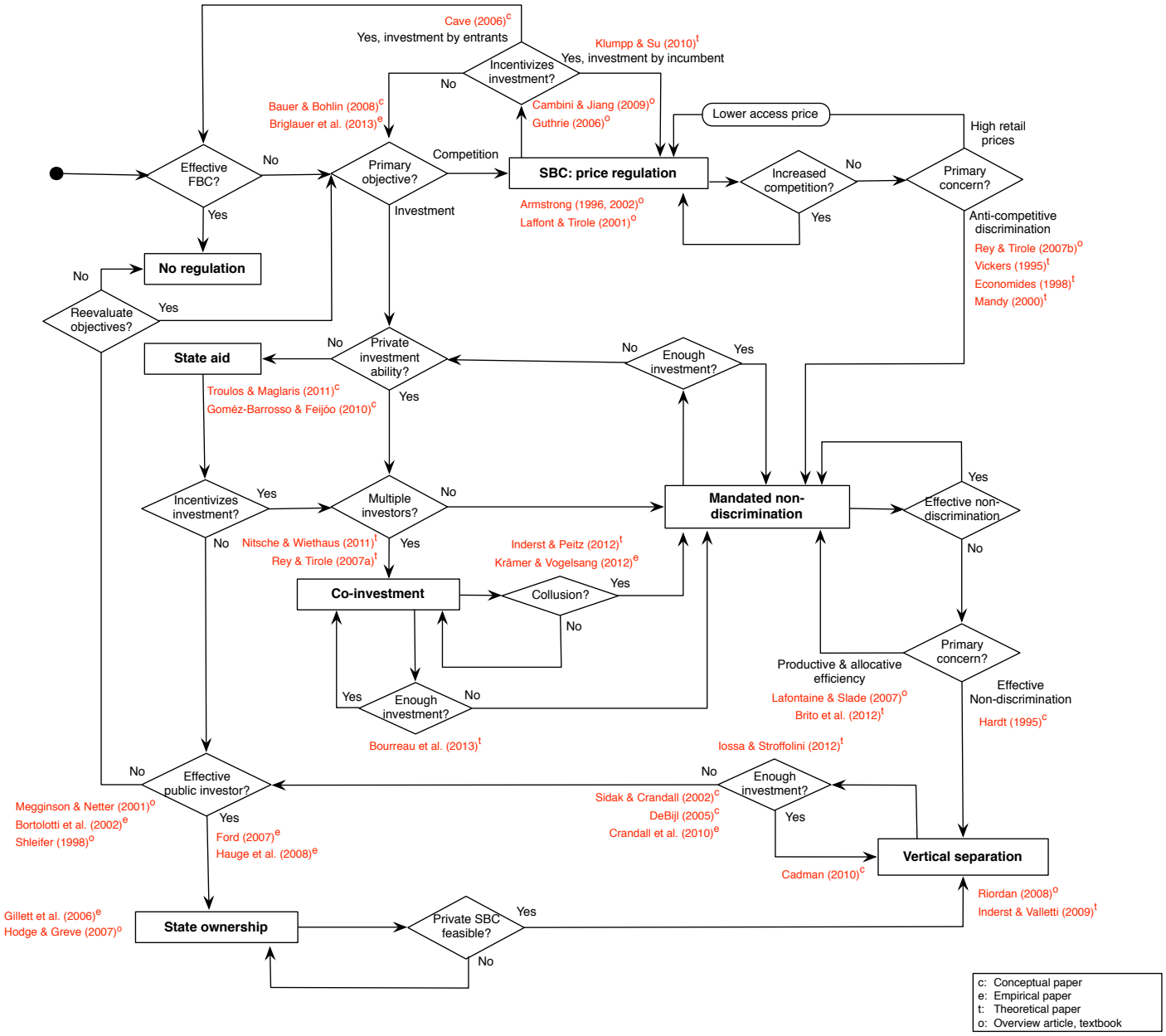

Figure 3: Recommended policy guideline for OA regulation of NGANs.

Similarly, if sufficient competition is achieved, there is no reason to change the functioning regulatory framework. If this is not the case, and the regulatory objective is primarily to reduce retail prices, then price regulation should be reevaluated after the access price was lowered. Otherwise, if competition is weak because of anti-competitive (non-price) discrimination, then *mandated non-discrimination* should be considered as an alternative regulatory scenario.

If, however, investment is considered the primary objective, the regulator is next faced with the question whether the private sector is in principle able to provide the necessary investments on its own or whether public-sector involvement is required. Private investment incentives may be fostered by allowing for cooperative approaches if multiple market participants are able and willing to make partial investments. In the case of high uncertainty, *co-investment* may strengthen investment incentives due to enhanced financing conditions and improved utilization of facilities by infrastructure sharing (Bourreau et al., 2013). With regard to competition, co-investment may be, on the one hand, an instrument to allow for multiple competitors in the retail market even in the absence of actual FBC or access regulation. On the other hand, regulators should exercise particular caution with regard to collusive behavior in the case of co-investment as cooperative undertakings provide additional instruments to coordinate behavior among market participants (Krämer & Vogelsang, 2013). In the case of experienced or highly probable collusion among a closed group of partners, *mandated non-discrimination* that allows for OA to the cooperative undertaking may be applied as an additional criterion. However, regulators need to be aware that these conditions, again, have a direct effect on the incentives to form such an undertaking in the first place (Rey & Tirole, 2007a). If co-investment is not a suitable option due to a lack of multiple investors or due to insufficient investments, *mandated non-discrimination* as a stand-alone institution may represent a regulatory alternative to conventional price regulation.

Mandated non-discrimination comprises regulatory rules that are especially concerned with providing equal conditions for access seekers relative to subsidiaries of vertically integrated operators. However, instead of prescribing a uniform (cost-based) access price, as in the case of price regulation, these rules give operators increased freedom when setting their wholesale prices. The European Commission's ex-ante margin-squeeze rule (European Commission, 2013a) can be seen as one possible implementation of this principle. While this approach is sometimes proposed as a suitable approach to balance the efficiency trade-off, there is little evidence on the impact of such rules with regard to investments and hence, further theoretical as well as empirical analysis of the actual implementations is required. Due to the increased pricing freedom of access providers in this scenario, regulators need to be particularly cautious about operators' incentives and abilities to discriminate against downstream competitors.

If regulators are primarily concerned with issues of anticompetitive discrimination and less intrusive regulatory rules prove to be ineffective, *vertical separation* may represent a last resort to eliminate the underlying incentives of anti-competitive discrimination. In any case, the decision to force a vertical break-up needs to weigh the expected competitive benefits against the potential losses in productive efficiency (Lafontaine & Slade, 2007) and allocative efficiency (Brito et al., 2012) as well as the affected investment incentives (i.a., Cadman, 2010; Crandall et al., 2010; De Bijl, 2005). If vertical separation is still considered the best regulatory option, the question whether the upstream infrastructure should be provided and operated by a private or public entity, should be guided by an

assessment of the investment incentives of private organizations and by the productive efficiency of public investors regarding the specific input good.

In general, public-sector participation should be considered as a substitute to private activity only when there is no or insufficient private investment. In the case where state ownership allows for the exploitation of efficiencies at specific access levels, public activity at these stages may benefit private activity at higher layers (Ford, 2007), thus representing an exception to the aforementioned general rule. Among the options for public intervention, *state aid* represents the less intrusive and thus the primary option, when investment is the regulator's primary objective and private investments are not expected. In this case, state aid allows for increased spending and greater public control, while maintaining market-driven coordination of activities and complementary resources. If state aid is insufficient to provide necessary investment incentives, *state ownership* provides a more drastic alternative to increase financing capabilities and gives public representatives full control of deployment and operations. However, well-known concerns about low efficiency and financial performance of public investors in general (Megginson & Netter, 2001), and the success of privatization in accordance with liberalization in telecommunications in particular (Bortolotti et al., 2002), should make decision makers skeptical whether the need for higher investments justifies a far-reaching conclusion as full public control. When opting for state ownership, efficiency issues may be mitigated by limiting public activity to the infrastructure level, enabling service-based competition by private businesses on top.

In contrast to state ownership, *no regulation* represents the other extreme on the spectrum of public intervention. Particularly in the case where investment is considered the primary public objective (and competition is deemed considerably less important), it may be the only alternative solution to public investment, if the latter is considered infeffective. By guaranteeing expected rents above the competitive level, investment incentives may be increased compared to competitive scenarios, obviously at the cost of a loss in static efficiency. According to these implications, the guideline explicitly denotes whether the regulator is willing to reconsider its goals or whether it is willing to take such radical measures to stimulate investment.

Of course, at each node, the decision process is not binary in reality, as suggested by Figure 3. For example, private investment ability and incentives are likely to differ across geographical areas depending on household density. Thus, state aid may be made available for rural areas, but not for urban areas. If there still remain uncovered areas, public ownership on a municipal level represents a further alternative (Hauge et al., 2008). Nevertheless, it is often useful to think in dichotomous categories, as depicted in the guideline, in order to realize the inherent trade-offs. Hence, each regulatory scenario is reached on the basis of some prerequisites and shall be sustained only if this is warranted by the continuous reevaluation of known issues and expected outcomes. Otherwise more heavy-handed regulatory scenarios may be considered. Thereby vertical separation and state ownership are seen as the last resort of regulation. In reverse, if market conditions change, regulators may evaluate the currently implemented regulatory scenario anew, possibly beginning from the starting point of the proposed policy guideline. Of course, this does not imply that intermediate regulatory scenarios must actually be implemented. The proposed decision process shall rather be understood as guiding policy makers to ask the right questions in the right order. Overall, the proposed approach thereby implements a "carrots and sticks" paradigm, equipping the regulator with more punitive measures if

market participants do not comply with the current set of rules, and offering the ability to lift obligations on the other hand if former obstacles are removed.

The policy guideline also illustrates the numerous reasons that can motivate a mandatory non-discrimination regime, like it is currently pursued by the European Commission (European Commission, 2013a). However, to date there exists only very limited experience on the expected consequences of this regime. In fact, there is no consensus on what regulatory measures are required to ensure non-discrimination in practice. While a margin squeeze test could serve as an instrument to counter price discrimination, non-price discrimination is more difficult to monitor (Hardt, 1995). Vertical separation has been discussed as an effective instrument to counter discriminatory incentives, but at the same time raises severe adverse effects on dynamic incentives as well as productive and allocative efficiency.

With regard to the role of the public sector at the supply side, the policy guideline implies that governments should adhere to the principle of subsidiarity. Only when investment is identified as an urgent and absolute primary need that cannot be provided by the private sector, public ownership on a large scale should be considered as a viable option. In such a case, vertical separation should restrict public activity to the infrastructure level, allowing for private activity on higher stages of the value chain. The case of Australia has demonstrated that such a regulatory scenario is a real option. Dissatisfaction with the performance and anti-competitive behavior of integrated network operators have led the Australian government to take over full control of the access network infrastructure and to provide connectivity at the last mile as a public service (Given, 2010). Representing less invasive instruments, state aid, PPPs, and municipal activity can serve as transitory and complementary instruments that should be implemented if they are likely to incentivize further private activity. On the other hand, the public sector has the general ability to stimulate network deployment by demand-side measures (Belloc et al., 2012).

5. Concluding remarks

The investment challenge in the advent of NGAN has introduced a variety of new business and organizational models as well as regulatory governance mechanisms. Within the last ten years the role of the public sector in telecommunications has again taken a turn, increasing its activity through municipal initiatives, PPPs and the deployment of state-owned network infrastructure. In the context of these developments, OA was suggested by regulators, scholars and industry stakeholders alike as a means to balance the inherent trade-off between static and dynamic efficiency. However, mutually contradictory interpretations, implementations in different contexts, and a lack of an explicit definition have prevented a common understanding of the precise meaning of OA, which in turn may have precluded the rise of such regulation.

By proposing an integrative definition and a structural framework to classify OA application scenarios, this article contributes to a common understanding and a differentiated view on the particular OA concepts. In particular, a survey of the extant economic literature highlighted that public-sector participation can potentially stimulate network investment and foster private activity. In contrast, concerns about cost efficiency and accountability should limit state activity to lower access levels where economies of scope are most significant. In this context, OA regulation can be implemented to minimize

competitive distortion on higher access levels. Co-investment may represent an additional instrument to strengthen investment incentives in cases of high uncertainty. In this context, OA governing ex-ante access to cooperative approaches may equip regulators with a new instrument to balance static and dynamic efficiency. In the case of vertical integration, OA may provide an alternative to price regulation. In this vein, economies of scope and scale may be exploited while anti-competitive behavior can be contained. At the same time, incentives of non-price discrimination and the effectiveness of a margin squeeze test have to be assessed by the regulator through empirical analysis. Vertical separation is likely to reduce non-price discrimination, but comes at the costs of structural reorganization and is expected to reduce incentives for facility-based competition.

At last, possible extensions and limitations of the herein proposed conceptual framework and policy guideline shall be pointed out. First, it must be noted that the presented literature survey and decision framework are necessarily incomplete as they are focused on regulatory instruments that fall under the proposed definition of OA. For example, the current outline does not include geographically segmented regulation or regulatory holidays, which, similar to state aid, co-investment and mandated non-discrimination, represent additional deviations from traditional access regulation that could foster investment in NGANs. However, it can be argued that these policy instruments are rather complementary to the considered regulatory scenarios. Hence, it should be possible to include them in the proposed policy guideline. Yet, research on the interaction between these instruments and the different OA scenarios is scant, particular with respect to geographic segmented regulation. Thus, future research is required before such an extension can be proposed comprehensively. Moreover, NRAs need to complement the presented analysis, which is based on economic arguments, by considering legal and technical issues that have not been discussed in this article.

Second, the proposed policy guideline highlights that there generally exists a trade-off between static and dynamic efficiency. However, it is worth mentioning that this trade-off is not necessarily linear. For instance, empirical findings by Aghion et al. (2005) suggest that the relationship between competition and innovation is characterized by inverted-U shape, i.e., innovation is the greatest for intermediate levels of competition. On the other hand, the general validity of this relationship is questioned by other studies (see, e.g., Sacco & Schmutzler, 2011).

Third, for the sake of clarity, the previous discussion was based on only two of the three identified dimensions of the OA framework. Evidently, each OA scenario can be subdivided again with respect to the level at which access is provided. Generally, access to lower network layers (representing high rungs of the ladder of investment concept), allow for a higher degree of quality differentiation and innovation by entrants, since this enables them to exert more physical control over their resources. Consequently, the access level also has an immediate impact on investment incentives and the scope of non-price discrimination, for example, which may then influence the evaluation at different nodes of the proposed policy guideline. Currently a set of different technologies and architectures are implemented in order to realize NGAN, establishing a heterogeneous landscape at the physical access level. However, at the same time, NGANs implement IP as the uniform interface at the network layer. This enables widespread availability of bitstream access, which provides logical unbundling of data flows on the identical physical connection. Since standardization of access products across technologies may play a large

role in platform competition comprising telephony networks, cable networks and mobile solutions, bitstream access could significantly decrease transaction and integration costs. Furthermore, given the tremendous increase in transmission capacity that can be achieved by NGANs, there is reason to believe that bitstream access provides a sufficient access level for vital competition and quality differentiation.

Fourth, the discussion of the proposed OA framework was exemplified on the basis that the monopolistic bottleneck, to which access shall be warranted, is constituted by the network layer. However, considering the whole telecommunications value chain, additional bottlenecks may exist further downstream. These may then not be under the control of the incumbents, but rather be controlled by so-called over-the-top content providers. In particular, such bottlenecks can be constituted by platforms (e.g., app stores or social networks). In this context, is is noted that the proposed framework may also be applied to characterize (open) access relationships at the application layer, using the same basic dimensions (ownership, vertical structure, access level), but, of course, with different characteristics of each dimension. For instance, in the case of platforms, the access level may be differentiated according to features of the application programming interface (API) that is provided. Nevertheless, mandating access at higher levels of the telecommunications value chain is obviously only warranted in case there is a significant market failure, e.g., due to inefficient pricing and a lack of replicability. On the one hand, two-sided platforms have an inherent incentive to price efficiently (cf. Rochet & Tirole, 2006) which implies that market failures are unlikely to occur. On the other hand, network effects may constitute substantial entry barriers that limit replicability. Thus, the case for mandating access at the application layer must be closely scrutinized.

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